PROPATH

A PROGRAM PACKAGE FOR THERMOPHYSICAL PROPERTIES OF FLUIDS VERSION 12.1

PROPATH GROUP

PROPATH Group

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PROPATH: A PROGRAM PACKAGE FOR THERMOPHYSICAL PROPERTIES OF FLUIDS, VERSION 12.1by PROPATH GROUP

Preface to Version12.1

Since the first release of PROPATH in 1984 as version 1.1, PROPATH has gained an increasing number of users all over the world, and has made a good deal of contribution, we believe, to research and education in science and technology and R&D activities in industries. This is our secret pleasure and humble pride.

A new W-PROPATH, a subset of PROPATH on Internet web page, has been developed. Users may execute single shot program of P-PROPATH on Internet web page by this new facility. Furthermore a new water program by IAPWS Industrial Formulation 1997 has been added to P-PROPATH subset.

All the members of PROPATH wish that the new version will find new users and that users' creative suggestions and criticism foster further development of PROPATH.

Takehiro ITO
Representing the PROPATH group
June, 2001

Preface to Version 7.1

PROPATH group released PROPATH computer PROgram PAckage on the THermophysical properties of fluids to non-profit organizations in 1984, and it has been revised once a year since then. It has been welcomed by many computer systems all over the world, and, as of the 1989 version of version 6.1, it is in use at a total of 23 domestic and 17 overseas organizations.

The release of a computer software like PROPATH ought not to be limited to non-profit organizations but should also be made available to science and technology-oriented organizations. The members of the group have received this complaint repeatedly from people in the industry. However, though they wish to release it to any interested individuals or organizations, some parts of it have not been allowed to be released due to copyright infringement considerations. But, recently many people have helped the members of the PROPATH GROUP succeed in removing that problem and to them the members are deeply appreciative. Now PROPATH may be obtained by any persons or organization.

The members also understand that formulations of the thermophysical properties which PROPATH is based on are the valuable resource of mankind, and they offer their highest esteem to those people who have been and are involved in the preparations of these equations. PROPATH provides people engaging in research, development, design and education with a powerful calculation environment. Thus it can enhance the potential value of original formulations of the thermophysical properties. The PROPATH objective is to remove the muscle work of evaluating equations from the creative activities of scientists and technologists.

The PROPATH group members wish that all suggestions from its creative users encourage the growth of it.

Takehiro ITO
Representing the PROPATH group
August, 1990

Notice

PROPATH users are requested to observe the following items.

1. Liability
PROPATH GROUP shall have no liability or responsibility to users or any other persons with respect to any liability, loss or damage caused or alleged to be caused directly or indirectly by the use of PROPATH. However the group asks those who have found any irregularities about PROPATH to inform the group of them by corresponding with the person representing the group†. This will help the group refine PROPATH.

2. Copyright and Others
PROPATH GROUP requests users or any other concerned persons (1) to observe the copyright law, and (2) never transfer a copy of the software to third parties, free or charged.

3. Version
Version number will be designated as version $m.n$ (m,n=integer, ≥ 1). (i) n is increased by one when some modifications or corrections have been made without any improvement in the function of PROPATH, and (ii) m is increased by one when any improvement in its function has been made. n is always reset to unity when m increases. The group reserves the right to revise PROPATH without notice.

4. Quotation
PROPATH, if necessary, shall be quoted as "PROPATH Group, PROPATH : A Program Package for Thermophysical Properties, version *m.n, month, year*".

5. Information through internet
Information on PROPATH is available through internet from the web

`http://gibbs.mech.kyushu-u.ac.jp/propath/`.

Latest users manual in the form of PostScript or PDF file can be downloaded from above site.

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Contents

I General Descriptions

1. Subsets of PROPATH

Seven subsets of PROPATH listed below are available.

Table I–1–1 Subsets of PROPATH

name of subset	function	Part
P-PROPATH	Pure substances and mixtures with fixed composition	II
A-PROPATH	Moist Air	III
M-PROPATH	Binary mixtures	IV
F-PROPATH	Binary mixtures by general equations	V
I-PROPATH	Ideal gases and ideal gas mixtures	VI
E-PROPATH	Facilities to make PROPATH function reference from MS-Excel	VII
W-PROPATH	Single Shot P-PROPATH on Internet home page	VIII

2. Language and Structure of PROGRAMs

2.1 Language

All PROPATH SUBPROGRAM except E-PROPATH is written in FORTRAN77 and use is made of neither extended facilities provided only in the special versions of FORTRAN77 compiler nor of utilities prepared for any specific computer system.

In preparing E-PROPATH(Part VII), extended facilities of Compaq Visual Fortran version 5.0A and Microsoft VBA Language have been used to build LIBRARY FILEs and to define MS-Excel functions. Reference to PROPATH SUBPROGRAMs from E-PROPATH is limited to PROPATH FUCTION SUBPROGRAMs in Part II and III at this moment.

2.2 Structure of PROGRAM and Precision of Variable (Number of Digits)

Every PROPATH SUBPROGRAM for thermophysical properties or constants is a FORTRAN FUNCTION SUBPROGRAM or SUBROUTINE SUBPROGRAM. The ARGUMENTs to these FUNCTIONs or SUBROUTINEs are SINGLE PRECISION REAL, SINGLE PRECISION INTEGER or CHARACTER, and the value of the FUNCTIONs is also SINGLE PRECISION REAL or CHARACTER.

The value of FUNCTION in E-PROPATH is limited to SINGLE PRECISION REAL.

3. Temperature Scale

The temperature scale used for each formulation of thermophysical property is shown at the proper place. See 2.1.1 of Part II, for example.

Functions for conversion between 'International practical temperature scale 1968(IPTS-1968)' and 'International temperature scale 1990(ITS-1990)' are available and they are included in the libraries for all substances.

Table I-3-1 Functions for temperature scale conversion

Name of Function	Function and Argument	Range of Argument
T90(T68)	T90: Temperature by ITS-1990 [K], [°C] T68: Temperature by IPTS-1968 [K], [°C]	$73.15 \leq$ T68 ≤ 1033.15 [K] $1337.15 \leq$ T68 ≤ 3273.15 [K] $-200 \leq$ T68 ≤ 630 [°C] $1064 \leq$ T68 ≤ 3000 [°C]
T68(T90)	T68: Temperature by IPTS-1968 [K], [°C] T90: Temperature by ITS-1990 [K], [°C]	$73.156 \leq$ T90 ≤ 902.841 [K] $1337.2 \leq$ T90 ≤ 3271.65 [K] $-199.994 \leq$ T90 ≤ 629.691 [°C] $1064.05 \leq$ T90 ≤ 2998.5 [°C]

4. PROGRAM EXECUTION

This chapter is of concerned only to Part II through VI.

4.1 EXECUTION of User's PROGRAM UNIT

When a user wishes to run his/her PROGRAM UNIT CALLing PROPATH SUBPROGRAM(s), he/she shall link his/her OBJECT FILEs with PROPATH FUNCTION SUBPROGRAM(s) or PROPATH SUBROUTINE SUBPROGRAM(s) registered as library. An example of these procedures is shown in 7.3(for UNIX) and 8.1(for MS-DOS and Windows).

4.2 Application PROGRAMs and their Execution

Single shot programs that evaluate all SUBPROGRAMs and LIST are available as executable PROGRAMs. User can get values of various thermophysical properties at any thermodynamic state through these PROGRAMs. The EXECUTION procedure on MS-DOS or Windows is described in 8.2. LIST of sample EXECUTIONs are shown in part II through V.

5. Environment for PROPATH

Since the PROPATH programs in Part II through VI are coded by FORTRAN 77 and partly by C language, they are independent of operating systems. User can install it to any computers if only compilers of both FORTRAN 77 and C language are available.

However, E-PROPATH(Part VII) is dependent upon operating systems, and runs only under the enviroment shown below.

Table I-5-1 Environment for PROPATH

Computer	IBM/PC–AT (and Compatible) or NEC 9800 Series
Operating System	Microsoft Windows 95/98/Me and WindowsNT 3.51 or later
Version of Excel	Microsoft Excel 97 or later

6. List of Files

Table I-6-1 List of Supplied FILES.

List of uncompressed files

```
A-PROPATH       M-PROPATH       NOTE            makefiles       tools
F-PROPATH       Makefile.linux  P-PROPATH       mkmsc.bat
I-PROPATH       Makefile.uxp    history.sh      mkvcc.bat

src/A-PROPATH:
jmaig.f      jmaigss.f    jmarf.f      jmarfss.f    maigss.out
jmaig.for    jmaigss.for  jmarf.for    jmarfss.for

src/F-PROPATH:
Makefile.gnu  bwr           csd           pr

src/F-PROPATH/bwr:
MkDosSrc.pl    bwrm14.c       bwrm8.c        makefile.vcc   sample2.for
ModFromDos.pl  bwrm15.c       bwrm97.c       mklib.bat      test.f
README.jpn     bwrm2.c        bwrm98.f       mkmsclib.bat   test.for
bwrm.h         bwrm3.c        bwrm98.for     mkvcclib.bat   test0.f
bwrm1.c        bwrm4.c        bwrm99.c       propath.h      test0.for
bwrm11.c       bwrm5.c        ctest.c        sample1.f      test2.f
bwrm12.c       bwrm6.c        lib.lst        sample1.for    test2.for
bwrm13.c       bwrm7.c        makefile.msc   sample2.f      unix

src/F-PROPATH/bwr/unix:
Makefile      bwrm15.c      bwrm97.c      sample1.f     test0.f
Makefile.gnu  bwrm2.c       bwrm98.f      sample1.for   test0.for
bwrm.h        bwrm3.c       bwrm98.for    sample2       test2
bwrm1.c       bwrm4.c       bwrm99.c      sample2.f     test2.f
bwrm11.c      bwrm5.c       ctest         sample2.for   test2.for
bwrm12.c      bwrm6.c       ctest.c       test
bwrm13.c      bwrm7.c       propath.h     test.f
bwrm14.c      bwrm8.c       sample1       test.for

src/F-PROPATH/csd:
CSDMX-SS.DAT  jcsdmx.f      jcsdmx.for    jcsdmxs.f     jcsdmxs.for

src/F-PROPATH/pr:
PRMX-SS.DAT  jprmx.f      jprmx.for    jprmxss.f    jprmxss.for

src/I-PROPATH:
Makefile.gnu   jIproidg.for   jiprolib.f     jipropair.for  jipropkck.f
history.sh     jIprojnf.f     jiprolib.for   jipropcho.f    jipropkck.for
jIproidg.f     jIprojnf.for   jipropair.f    jipropcho.for

src/M-PROPATH:
AWMX-SS.DAT   jawmx.f       jawmxss.f
Makefile.gnu  jawmx.for     jawmxss.for

src/P-PROPATH:
Makefile.gnu   jco.for        jic4h10.for   jr114.for    jr152a.for
jair.f         jco2.f         jkr.f         jr115.f      jr21.f
jair.for       jco2.for       jkr.for       jr115.for    jr21.for
jarg.f         jd2o.f         jn2.f         jr12.f       jr22.f
jarg.for       jd2o.for       jn2.for       jr12.for     jr22.for
jc2h4.f        jf2.f          jnc4h10.f     jr123.f      jr23.f
jc2h4.for      jf2.for        jnc4h10.for   jr123.for    jr23.for
jc2h6.f        jh2.f          jne.f         jr12b1.f     jr500.f
jc2h6.for      jh2.for        jne.for       jr12b1.for   jr500.for
jc3h6.f        jh2o.f         jnh3.f        jr13.f       jr502.f
jc3h6.for      jh2o.for       jnh3.for      jr13.for     jr502.for
```

```
jc3h8.f        jh2oi90.f    jo2.f          jr134a.f    jr503.f
jc3h8.for      jh2oi90.for  jo2.for        jr134a.for  jr503.for
jch4.f         jhe4.f       jpuress.f      jr13b1.f    jrc318.f
jch4.for       jhe4.for     jpuress.for    jr13b1.for  jrc318.for
jch42.f        jhe4i90.f    jr11.f         jr14.f      jsf6.f
jch42.for      jhe4i90.for  jr11.for       jr14.for    jsf6.for
jcl2.f         jhgk.f       jr113.f        jr142b.f    jxe.f
jcl2.for       jhgk.for     jr113.for      jr142b.for  jxe.for
jco.f          jic4h10.f    jr114.f        jr152a.f

src/makefiles:
Makefile.gnu.A-PROPATH      Makefile.gnu.F-PROPATH.pr
Makefile.gnu.F-PROPATH.csd  mklink.sh

src/tools:
For2f.pl        clean.sh        mkMakefiles.pl
```

Table I-6-2 List of Single Shot Program and Library FILES for PartII through VI (UNIX).

Name of Subset	Name of Substance	Single Shot Program	Library FILE
P-PROPATH	Helium 4(IUPAC-IPTS 1968)	`he4-ss`	`libjhe4.a`
	Helium 4(NIST-ITS 1990)	`he4i90ss`	`libjhe4i90.a`
	Neon	`ne-ss`	`libjne.a`
	Argon	`arg-ss`	`libjarg.a`
	Krypton	`kr-ss`	`libjkr.a`
	Xenon	`xe-ss`	`libjxe.a`
	n-Hydrogen	`h2-ss`	`libjh2.a`
	Fluorine	`f2-ss`	`libjf2.a`
	Chlorine	`cl2-ss`	`libjcl2.a`
	Nitrogen	`n2-ss`	`libjn2.a`
	Oxygen	`o2-ss`	`libjo2.a`
	Air	`air-ss`	`libjair.a`
	Carbon Monoxide	`co-ss`	`libjco.a`
	Carbon Dioxide	`co2-ss`	`libjco2.a`
	Water(IFC 1967-IPTS1968)	`h2o-ss`	`libjh2o.a`
	Water(IFC 1967-ITS1990)	`h2oi90-ss`	`libjh2oi90.a`
	Water(IAPS 1984)	`hgk-ss`	`libjhgk.a`
	Heavy Water	`d2o-ss`	`libjd2o.a`
	Ammonia	`nh3-ss`	`libjnh3.a`
	Sulfur Hexafluoride	`sf6-ss`	`libjsf6.a`
	Methane(IUPAC)	`ch4-ss`	`libjch4.a`
	Methane(Friend, Ely and Ingham)	`ch42--ss`	`libjch42.a`
	Ethylene	`c2h4-ss`	`libjc2h4.a`
	Ethane	`c2h6-ss`	`libjc2h6.a`
	Propylene	`c3h6-ss`	`libjc3h6.a`
	Propane	`c3h8-ss`	`libjc3h8.a`
	n-Butane	`nc4h10-ss`	`libjnc4h10.a`
	i-Butane	`ic4h10-ss`	`libjic4h10.a`
	FC-14(R14)	`r14-ss`	`libjr14.a`
	FC-C318(RC318)	`rc318-ss`	`libjrc318.a`
	CFC-11(R11)	`r11-ss`	`libjr11.a`
	CFC-12(R12)	`r12-ss`	`libjr12.a`
	CFC-13(R13)	`r13-ss`	`libjr13.a`
	CFC-113(R113)	`r113-ss`	`libjr113.a`
	CFC-114(R114)	`r114-ss`	`libjr114.a`
	CFC-115(R115)	`r115-ss`	`libjr115.a`
	CFC-152a(R152a)	`r152a-ss`	`libjr152a.a`
	HCFC-21(R21)	`r21-ss`	`libjr21.a`
	HCFC-22(R22)	`r22-ss`	`libjr22.a`
	HCFC-123(R123)	`r123-ss`	`libjr123.a`
	HCFC-142b(R142b)	`r142b-ss`	`libjr142b.a`
	HFC-23(R23)	`r23-ss`	`libjr23.a`
	HFC-134a(R134a)	`r134a-ss`	`libjr134a.a`
	Halon 1211(R12B1)	`r12b1-ss`	`libjr12b.a`
	Halon 1301(R13B1)	`r13b1-ss`	`libjr13b.a`
	Refrigerant 500	`r500-ss`	`libjr500.a`
	Refrigerant 502	`r502-ss`	`libjr502.a`
	Refrigerant 503	`r503-ss`	`libjr503.a`

Table I-6-2 List of Files(cont'd)

Name of Subset	Name of Substance	Single Shot Program	Library FILE
A-PROPATH	Moist Air (Ideal Gas)	maig-ss	libjmaig.a
	Moist Air (Real Fluid)	marf-ss	libjmarf.a
M-PROPATH	Mixture with Ammonia and Water (Ibrahim and Klein)	awmx-ss	libjawmx.a
	Mixture with Ammonia and Water (Tiller-Roth and Friend)	awmx2-ss	libjawmx2.a
F-PROPATH	Binary Mixtures by General Equations		
	Peng-Robinson Equation	prmx-ss PRMX-SS.DAT	libjprmx.a
	CSD Equation	csdmx-ss CSDMX-ss.DAT	libjcsdmx.a
	BWR Equation	----	libjbwr.a
I-PROPATH	Ideal Gases and Ideal Gas Mixtures	ipropair ipropcho ipropidg ipropjnf ipropkck	libjiprolib.a

Table I-6-3 List of Single Shot Program and Library FILES
for Part II through VI (MS-DOS, Windows95/98 and WindowsNT).

Name of Subset	Name of Substance	Single Shot Program	Library FILE
P-PROPATH	Helium 4(IUPAC-IPTS 1968)	HE4–SS.EXE	JHE4.LIB
	Helium 4(NIST-ITS 1990)	HE4I90SS.EXE	JHE4I90.LIB
	Neon	NE–SS.EXE	JNE.LIB
	Argon	ARG–SS.EXE	JARG.LIB
	Krypton	KR–SS.EXE	JKR.LIB
	Xenon	XE–SS.EXE	JXE.LIB
	n-Hydrogen	H2–SS.EXE	JH2.LIB
	Fluorine	F2–SS.EXE	JF2.LIB
	Chlorine	CL2–SS.EXE	JCL2.LIB
	Nitrogen	N2–SS.EXE	JN2.LIB
	Oxygen	O2–SS.EXE	JO2.LIB
	Air	AIR–SS.EXE	JAIR.LIB
	Carbon Monoxide	CO–SS.EXE	JCO.LIB
	Carbon Dioxide	CO2–SS.EXE	JCO2.LIB
	Water(IFC 1967-IPTS1968)	H2O–SS.EXE	JH2O.LIB
	Water(IFC 1967-ITS1990)	H2OI90SS.EXE	JH2OI90.LIB
	Water(IAPS 1984)	HGK–SS.EXE	JHGK.LIB
	Heavy Water	D2O–SS.EXE	JD2O.LIB
	Ammonia	NH3–SS.EXE	JNH3.LIB
	Sulfur Hexafluoride	SF6–SS.EXE	JSF6.LIB
	Methane(IUPAC)	CH4–SS.EXE	JCH4.LIB
	Methane(Friend, Ely and Ingham)	CH42–SS.EXE	JCH42.LIB
	Ethylene	C2H4–SS.EXE	JC2H4.LIB
	Ethane	C2H6–SS.EXE	JC2H6.LIB
	Propylene	C3H6–SS.EXE	JC3H6.LIB
	Propane	C3H8–SS.EXE	JC3H8.LIB
	n-Butane	NC4H10SS.EXE	JNC4H10.LIB
	i-Butane	IC4H10SS.EXE	JIC4H10.LIB
	FC-14(R14)	R14–SS.EXE	JR14.LIB
	FC-C318(RC318)	RC318–SS.EXE	JRC318.LIB
	CFC-11(R11)	R11–SS.EXE	JR11.LIB
	CFC-12(R12)	R12–SS.EXE	JR12.LIB
	CFC-13(R13)	R13–SS.EXE	JR13.LIB
	CFC-113(R113)	R113–SS.EXE	JR113.LIB
	CFC-114(R114)	R114–SS.EXE	JR114.LIB
	CFC-115(R115)	R115–SS.EXE	JR115.LIB
	CFC-152a(R152a)	R152A–SS.EXE	JR152A.LIB
	HCFC-21(R21)	R21–SS.EXE	JR21.LIB
	HCFC-22(R22)	R22–SS.EXE	JR22.LIB
	HCFC-123(R123)	R123–SS.EXE	JR123.LIB
	HCFC-142b(R142b)	R142B–SS.EXE	JR142B.LIB
	HFC-23(R23)	R23–SS.EXE	JR23.LIB
	HFC-134a(R134a)	R134A–SS.EXE	JR134A.LIB
	Halon 1211(R12B1)	R12B1–SS.EXE	JR12B.LIB
	Halon 1301(R13B1)	R13B1–SS.EXE	JR13B.LIB
	Refrigerant 500	R500–SS.EXE	JR500.LIB
	Refrigerant 502	R502–SS.EXE	JR502.LIB
	Refrigerant 503	R503–SS.EXE	JR503.LIB

Table I-6-3 List of Files(cont'd)

Name of Subset	Name of Substance	Single Shot Program	Library FILE
A-PROPATH	Moist Air (Ideal Gas)	MAIG–SS.EXE	JMAIG.LIB
	Moist Air (Real Fluid)	MARF–SS.EXE	JMARF.LIB
M-PROPATH	Mixture with Ammonia and Water (Ibrahim and Klein)	AWMX–SS.EXE	JAWMX.LIB
	Mixture with Ammonia and Water (Tillner-Roth and Friend)	AWMX2–SS.EXE	JAWMX2.LIB
F-PROPATH	Binary Mixtures by General Equations		
	Peng-Robinson Equation	PRMX–SS.EXE PRMX-SS.DAT	JPRMX.LIB
	CSD Equation	CSDMX–SS.EXE CSDMX-SS.DAT	JCSDMX.LIB
	BWR Equation	—	JBWR.LIB
I-PROPATH	Ideal Gases and Ideal Gas Mixtures	IPROPAIR.EXE IPROPCHO.EXE IPROPIDG.EXE IPROPJNF.EXE IPROPKCK.EXE	JIPROLIB.LIB

Table I-6-4 List of Import FILEs and library FILEs for E-PROPATH(Part VII)

Name of Subset	Name of Substance	Import FILE	Library FILE
P-PROPATH	Helium 4(IUPAC-IPTS 1968)	JHE4.BAS	JHE4.DLL
	Helium 4(NIST-ITS1990)	JHE4I90.BAS	JHE4I90.DLL
	Neon	JNE.BAS	JNE.DLL
	Argon	JARG.BAS	JARG.DLL
	Krypton	JKR.BAS	JKR.DLL
	Xenon	JXE.BAS	JXE.DLL
	n-Hydrogen	JH2.BAS	JH2.DLL
	Chlorine	JCL2.BAS	JCL2.DLL
	Nitrogen	JN2.BAS	JN2.DLL
	Oxygen	JO2.BAS	JO2.DLL
	Air	JAIR.BAS	JAIR.DLL
	Fluorine	JF2.BAS	JF2.DLL
	Carbon Monoxide	JCO.BAS	JCO.DLL
	Carbon Dioxide	JCO2.BAS	JCO2.DLL
	Water(IFC 1967-IPTS1968)	JH2O.BAS	JH2O.DLL
	Water(IFC 1967-ITS1990)	JH2OI90.BAS	JH2OI90.DLL
	Water(IAPS 1984)	JHGK.BAS	JHGK.DLL
	Heavy Water	JD2O.BAS	JD2O.DLL
	Ammonia	JNH3.BAS	JNH3.DLL
	Sulfur Hexafluoride	JSF6.BAS	JSF6.DLL
	Methane(IUPAC Table)	JCH4.BAS	JCH4.DLL
	Methane(Friend, Ely and Ingham)	JCH42.BAS	JCH42.DLL
	Ethylene	JC2H4.BAS	JC2H4.DLL
	Ethane	JC2H6.BAS	JC2H6.DLL
	Propylene	JC3H6.BAS	JC3H6.DLL
	Propane	JC3H8.BAS	JC3H8.DLL
	n-Butane	JNC4H10.BAS	JNC4H10.DLL
	i-Butane	JIC4H10.BAS	JIC4H10.DLL
	FC-14(R14)	JR14.BAS	JR14.DLL
	FC-C318(RC318)	JRC318.BAS	JRC318.DLL
	CFC-11(R11)	JR11.BAS	JR11.DLL
	CFC-12(R12)	JR12.BAS	JR12.DLL
	CFC-13(R13)	JR13.BAS	JR13.DLL
	CFC-113(R113)	JR113.BAS	JR113.DLL
	CFC-114(R114)	JR114.BAS	JR114.DLL
	CFC-115(R115)	JR115.BAS	JR115.DLL
	CFC-152a(R152a)	JR152A.BAS	JR152A.DLL
	HCFC-21(R21)	JR21.BAS	JR21.DLL
	HCFC-22(R22)	JR22.BAS	JR22.DLL
	HCFC-123(R123)	JR123.BAS	JR123.DLL
	HCFC-142b(R142b)	JR142B.BAS	JR142B.DLL
	HCFC-23(R23)	JR23.BAS	JR23.DLL
	HCFC-134a(R134a)	JR134A.BAS	JR134A.DLL
	Halon 1201(R12B1)	JR12B1.BAS	JR12B1.DLL
	Halon 1301(R13B1)	JR13B1.BAS	JR13B1.DLL
	Refrigerant 500	JR500.BAS	JR500.DLL
	Refrigerant 502	JR502.BAS	JR502.DLL
	Refrigerant 503	JR503.BAS	JR503.DLL
A-PROPATH	Moist Air (Ideal Gas)	JMAIG.BAS	JMAIG.DLL
	Moist Air (Real Fluid)	JMARF.BAS	JMARF.DLL

7. Procedures to Register PROPATH SUBPROGRAM(s) as Libraries and How to Link User's PROGRAM UNIT with the Library at the EXECUTION in UNIX Operatind System

This section is of concerned only to Part II through VI.

Any element of PROPATH SUBPROGRAM should be installed in a computer system as a library in the form of archive file to be offered for public use. However it cannot be registered as an automatic CALL library, because the NAMEs of SUBPROGRAMs are common between some subsets of PROPATH. Therefore a user should specify the library of which he/she wants to get thermophysical properties at the EXECUTION. The procedures for installation to make a library and the procedure to specify it at the EXECUTION for FUJITSU main frame computer with UXP operating system are described below:

(1) How to extract compressed source files

The source programs of PROPATH are supplied as compressed files of `pXXsrc.tar.gz`(XX is number of version). The `gzip` and `tar` programs are made use to extract these files.

```
gzip -c -d pXXsrc.tar.gz | tar xvfp -
```

The subdirectories of `A-PROPATH, F-PROPATH, I-PROPATH, M-PROPATH` and `P-PROPATH` are created under the subdirectory `src`, and the source programs are extracted into these subdirectories.

(2) Procedure for making libraries and single shot programs

There is a makefile named `Makefile.uxp` in the subdirectory `src`. With this makefile and `make` command, compilation and linking process will be done as follows.

```
make -f Makefile.uxp
```

The target directory where the PROPATH libraries and single shot programs are installed is specified in the `Makefile.uxp` as follows.

```
BINDIR=/usr/local/lib/propath/bin
LIBDIR=/usr/local/lib/propath/bin
```

(3) How to specify the library at the EXECUTION

Nitrogen library `libjn2.a` is assumed to be located in the directory `/usr/local/lib/propath/bin`. To link the library with user's PROGRAM UNIT `main.f`, the user execute the following command.

```
frt main.f -L/usr/local/lib/propath/bin -llibjn2
```

8. How to Link User's PROGRAM UNIT with the Library and How to EXECUTE the Single Shot Programs in MS-DOS or Windows

This section is of concerned only to Part II through VI.

(1) How to build the Library from the source file

A user must complie the source file to make the object file before building the Library. For example, if he/she wishes to build the Library of helium 4, he/she complies the source file `JHE4.F` using `FL` command or `FL32` command.

- 16bit MS-FORTRAN

```
C:>FL /c JHE4.F
```

- 32bit MS-FOTRAN(Fortran PowerStation version 4.0 or later)

```
C:>FL32 /c JHE4.F
```

If the compilation of the source file has been completed successfully, the object file `JHE4.OBJ` is created at the current directory. A user can build the Library from the object file using `LIB` command.

```
C:>LIB JHE4.OBJ
```

The Library `JHE4.LIB` is created.

(2) How to Link User's PROGRAM UNIT with the Library

A user may use `LINK` command to link user-defined object file with Library.

- 16bit MS-FORTRAN

```
C:>LINK ***.OBJ,,,JHE4.LIB+LLIBFOR7.LIB
```

- 32bit MS-FOTRAN(Fortran PowerStation version 4.0 or later)

```
C:>LINK ***.OBJ JHE4.LIB
```

where

`LINK:`	Linker of MS-FORTRAN
`***.OBJ:`	User's object file (compiled using `FL` or `FL32` command)
`LLIBFOR7.LIB:`	Standard Library of 16 bit MS-FORTRAN (Large-memory Model and Math Coprocessor)

(3) How to EXECUTE the Single Shot Programs

Simply execute one of EXECUTABLE PROGRAMs which have file extension of EXE. For example, entering

```
C:>HE4-SS.EXE
```

is all you do when you wish to execute the helium 4 Single Shot Program.

9. FUNCTION REFERENCE from MS-C

This chapter is of concerned only to PartII through VI.

When the PROPATH libraries are created by MS-FORTRAN compiler, a user can refer these FUNCTIONs from MS-C which is a product of the same company. FUNCTION REFERENCE from MS-C may be advantageous if one would like to get a graphic output on display or plotter. Here the procedure of mixed language programing is introduced.

List 1 is an example of the MS-C PROGRAM. This PROGRAM calculates some thermodynamic properties in the saturated region for temperatures inputted from the standard input device. The line degignated by (1) defines external REFERENCE of FORTRAN SUBROUTINE `KPAMES` descrived in 1.1 in Part II. Making use of this SUBROUTINE is recommended because it is complicated to specify the value of the COMMON VALIABLES `KPA` and `MESS` from MS-C. The lines designated by (2) are the definitions of PROPATH FUNCTIONs to be referred from MS-C. The meaning of these PROPATH FUNCTIONs are described in FUNCTION Tables of each substance. The line (3) sets the values of `KPA` and `MESS`. In this case, the units of pressure and temperature are [Pa] and [C], respectively. The lines (4) call PROPATH FUNCTIONs.

Now the following procedures show how to compile and link List 1 program with PROPATH library and to create EXECUTABLE PROGRAM.

Compiling by MS-C compiler:

```
A>CL/AL /c SAT_TBL.C
```

where
`CL:` MS-C compiler
`SAT_TBL.C:` Source File of List 1

Linking with the PROPATH library:

```
A>LINK /NOE SAT_TBL.OBJ,,,JH2O.LIB+LLIBFOR7.LIB+LLIBC7.LIB
```

where
`LINK:` Linker of MS-C
`SAT_TBL.OBJ:` OBJECT FILE of List 1
`JH2O.LIB:` Library of water FUNCTION SUBPROGRAMs
`LLIBFOR7.LIB:` Standard Library of MS-FORTRAN (Large-memory Model and Math Coprocessor)
`LLIBC7.LIB:` Standard Library of MS-C (Large-memory Model and Math Coprocessor)
Finally, the EXECUTABLE PROGRAM `SAT_TBL.EXE` is to be created.

List 1

```
/* <<<< SAT_TBL.C >>>>
Thermodynamic Properties in Saturated Region
coding history: 01/07/91 Ver.1.00
06/10/96 Ver.1.10 */
#include <dos.h>
#include <stdio.h>
#include <conio.h>
#include <string.h>

#define NL fprintf(stdout,"\n")

extern void fortran
```

```
kpames  (long far *, long far *);  /* ----------(1) */
extern float fortran pst    (float *); /* ---+          */
extern float fortran vtd    (float *); /*    |          */
extern float fortran vtdd   (float *); /*    |          */
extern float fortran htd    (float *); /*    |          */
extern float fortran htdd   (float *); /*    +------(2) */
extern float fortran alht   (float *); /*    |          */
extern float fortran std    (float *); /*    |          */
extern float fortran stdd   (float *); /*    |          */
extern float fortran cptd   (float *); /*    |          */
extern float fortran cptdd  (float *); /* ---+          */

void main()
{
float ps,t[100],tt,vd,vdd,hd,hdd,lh,sd,sdd,cpd,cpdd,
kiro=1.0e+003, mega=1.0e+006;
long kpa=3,mess=0;  /* P[Pa], T[C], no messages */

kpames(&kpa,&mess); /* --------------------------(3) */
    NL;
while (1){
printf("\ninput T[C] (T<0: quit)=");
scanf("%e",&tt);
if(tt<0.0) exit();
/* PROPATH functions for saturated region */
ps=pst(&tt)/mega;           /* ---+          */
vd=vtd(&tt);                /*    |          */
vdd=vtdd(&tt);              /*    |          */
hd=htd(&tt)/kiro;           /*    |          */
hdd=htdd(&tt)/kiro;         /*    +------(4) */
lh=alht(&tt)/kiro;          /*    |          */
sd=std(&tt)/kiro;           /*    |          */
sdd=stdd(&tt)/kiro;         /*    |          */
cpd=cptd(&tt)/kiro;         /*    |          */
cpdd=cptdd(&tt)/kiro;       /* ---+          */

printf("T=%10.3f[C]\t\t\t",tt);
printf("P=%10.4f[MPa]\n",ps);
printf("v'=%12.4e[m^3/kg]\t\t",vd);
printf("V\"=%12.4e[m^3/kg]\n",vdd);
printf("h'=%10.3f[kJ/kg]\t\t",hd);
printf("h\"=%10.3f[kJ/kg]\t",hdd);
printf("r=%10.3f[kJ/kg]\n",lh);
printf("s'=%10.3f[kJ/(kg*K)]\t",sd);
printf("s\"=%10.3f[kJ/(kg*K)]\n",sdd);
printf("cp'=%10.3f[kJ/(kg*K)]\t",cpd);
printf("cp\"=%10.3f[kJ/(kg*K)]\n",cpdd);
}
}
```

10. Addition and Alteration in Version 12.1

10.1 New Subset of PROPATH

W-PROPATH has been added on.

10.2 New Substances or Formulations

Water (IAPWS Industrial Formulation 1997-ITS 1990) has been added to P-PROPATH.

10.3 Newly Introduced PROPATH FUNCTIONs

The following new FUNCTIONs have been added to P-PROPATH. However, these FUNCTIONs are implemented only in above new water library at this moment.

AKPD, AKPDD, AKTD, AKTDD, CVPD, CVTD, EPSPD, EPSPDD, EPSTD, EPSTDD,
GAMPD, GAMTD, WPD, WPDD, WTD, WTDD, TPH2, TPS2

Last two FUNCTIONs have the common arguments and return value with conventional TPH and TPS. The new FUNCTIONs are based on the direct formulations newly developed, whereas the conventiolnal FUNCTIONs perform iterative calculations.

11. Definition of Some Thermodynamic Properties

The isentropic exponent, Joule-Thomson coefficient, volmetric coefficient of expansion, isentropic compressibility, isothermal compressibility, pressure coefficient, pseudo boiling point and velocity of sound are defined as follows:

Table I–11–1 Definition of Some Thermodynamic Properties

No.	Name of Function	Thermodynamic property	Definition
82	AKPT	isentropic exponent, κ	$\kappa = -\frac{v}{p}\left(\frac{\partial p}{\partial v}\right)_s = -\frac{c_p}{c_v}\frac{v}{p}\left(\frac{\partial p}{\partial v}\right)_T = -\frac{c_p}{c_v}\frac{v}{p}\left(\frac{\partial^2 f}{\partial v^2}\right)_T$ where f denotes specific helmholtz free energy.
94	AJTPT	Joule-Thomson coefficient, μ	$\mu = \left(\frac{\partial T}{\partial p}\right)_h = \frac{T\left(\frac{\partial v}{\partial T}\right)_p - v}{c_v}$
92	BPPT	volmetric coefficient of expansion, β_p	$\beta_p = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$
90	BSPT	isentropic compressibility, β_s	$\beta_s = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_s = -\frac{1}{v\left(\frac{\partial p}{\partial v}\right)_s} = \sqrt{v/w^2}$
91	BTPT	isothermal compressibility, β_T	$\beta_T = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T = \frac{c_p}{c_v}\beta_s$
93	BVPT	pressure coefficient, β_v	$\beta_v = \frac{1}{p}\left(\frac{\partial p}{\partial T}\right)_v$
98	TPSEUP	pseudo boiling point, T_m	The temperature which satisfies the following equation. $\left(\frac{\partial c_p}{\partial T}\right)_p = 0$
83	WPT	velocity of sound, w	$w = \sqrt{-v^2\left(\frac{\partial p}{\partial v}\right)_s} = \sqrt{v/{\beta_s}^2}$

12. Bridgman's Table

Most of the first partial derivatives of thermodynamic properties are evaluated by looking up the Bridgman's table. The table yields derivatives symbolized as $(\partial * /\partial **)_{***}$, where "*", "**" and "***" are any one from the following 8 properties.

$$p, T, v, s, u, h, f, g$$

$(\partial * /\partial **)_{***}$ reduces to unity when "*"="**", and is meaningless when "*"="***" or "**"="***" holds. Thus the number of interesting derivatives is ${}_8p_3 = 8 \times 7 \times 6$=336. The first derivatives constructed from the table contains some of the 8 properties listed above and

isobaric specific heat:	$c_p = (\partial h/\partial T)_p = T(\partial s/\partial T)_p$
volumetric coefficient of expansion:	$\beta_p = (1/v)(\partial v/\partial T)_p$
isothermal compressibility:	$\beta_T = -(1/v)(\partial v/\partial p)_T$

$(\partial * /\partial **)_{***}$ is found as the ratio of two entries like $(\partial *)_{**}$ and $(\partial **)_{***}$ from the table by the following rule.

$$\left(\frac{\partial *}{\partial **}\right)_{***} = \frac{(\partial *)_{***}}{(\partial **)_{***}}$$

The table is constructed by only 28 lines of formula for 336 different derivatives evaluated. Though the number of different $(\partial *)_{**}$ is ${}_8p_2 = 8 \times 7$=56, the pair of $(\partial *)_{**}$ and $-(\partial **)_{*}$ is listed in the same line.

[example] Joule-Thomson coefficient $(\partial T/\partial p)_h$ is found from $(\partial T)_h$ and $(\partial p)_h$ in the table as follows.

$$\mu = \left(\frac{\partial T}{\partial p}\right)_h = \frac{(\partial T)_h}{(\partial p)_h} = \frac{-(-v + \beta_p T v)}{-c_p} = \frac{v(\beta_p T - 1)}{c_p}$$

Isochoric specific heat $(\partial u/\partial T)_v$ is evaluated from $(\partial u)_v$ and $(\partial T)_v$ in the table as follows.

$$c_v = \left(\frac{\partial u}{\partial T}\right)_v = \frac{(\partial u)_v}{(\partial T)_v} = \frac{T{\beta_p}^2 v^2 - \beta_T v c_p}{-\beta_T v} = c_p - ({\beta_p}^2 v/\beta_T)T$$

Tbale I-12-1 Bridgman's table

$[p]$	$(\partial T)_p = -(\partial p)_T = 1$ $(\partial v)_p = -(\partial p)_v = \beta_p v$ $(\partial s)_p = -(\partial p)_s = c_p/T$ $(\partial u)_p = -(\partial p)_u = c_p - \beta_p pv$ $(\partial h)_p = -(\partial p)_h = c_p$ $(\partial f)_p = -(\partial p)_f = -s - \beta_p pv$ $(\partial g)_p = -(\partial p)_g = -s$
$[T]$	$(\partial v)_T = -(\partial T)_v = \beta_T v$ $(\partial s)_T = -(\partial T)_s = \beta_p v$ $(\partial u)_T = -(\partial T)_u = \beta_p Tv - \beta_T pv$ $(\partial h)_T = -(\partial T)_h = -v + \beta_p Tv$ $(\partial f)_T = -(\partial T)_f = -\beta_T pv$ $(\partial g)_T = -(\partial T)_g = -v$
$[v]$	$(\partial s)_v = -(\partial v)_s = {\beta_p}^2 v^2 - \beta_T v c_p/T$ $(\partial u)_v = -(\partial v)_u = T{\beta_p}^2 v^2 - \beta_T v c_p$ $(\partial h)_v = -(\partial v)_h = T{\beta_p}^2 v^2 - \beta_p v^2 - \beta_T v c_p$ $(\partial f)_v = -(\partial v)_f = \beta_T vs$ $(\partial g)_v = -(\partial v)_g = \beta_T vs - \beta_p v^2$
$[s]$	$(\partial u)_s = -(\partial s)_u = {\beta_p}^2 v^2 p - \beta_T v c_p/T$ $(\partial h)_s = -(\partial s)_h = -v c_p/T$ $(\partial f)_s = -(\partial s)_f = \beta_p vs + {\beta_p}^2 v^2 p - \beta_T v c_p p/T$ $(\partial g)_s = -(\partial s)_g = \beta_p vs - v c_p/T$
$[u]$	$(\partial h)_u = -(\partial u)_h = p\beta_p v^2 - \beta_T v c_p p - v c_p - pT{\beta_p}^2 v^2$ $(\partial f)_u = -(\partial u)_f = sT\beta_p v - \beta_T v c_p p - \beta_T vsp + pT{\beta_p}^2 v^2$ $(\partial g)_u = -(\partial u)_g = \beta_p v^2 p + \beta_p vsT - v c_p - \beta_T vsp$
$[h]$	$(\partial f)_h = -(\partial h)_f = (s - v\beta_p p)(v - v\beta_p T) - \beta_T v c_p p$ $(\partial g)_h = -(\partial h)_g = \beta_p vsT - v(s - c_p)$
$[f]$	$(\partial g)_f = -(\partial f)_g = \beta_T vsp - vs - \beta_p v^2 p$

$[p]$, for example, in the table means that the entries in that box is $(\partial *)_p$ or $-(\partial p)_*$.

II P-PROPATH:
Pure Substances and Mixtures with Fixed Composition

1. General Features

1.1 FUNCTION SUBPROGRAM REFERENCE

Every P-PROPATH user has to make an initialization process by one of the following two procedures.

1.1.1 Initialization by COMMON VARIABLEs

Every user's PROGRAM UNIT which is going to CALL the P-PROPATH FUNCTION SUBPROGRAM should include the following one LINE before the first EXECUTABLE STATEMENT.

```
COMMON/UNIT/KPA, MESS
```

KPA and MESS are reserved as INTEGER VARIABLEs. Furthermore, the following two LINEs must be placed in the user's PROGRAM UNIT before the first FUNCTION CALL appears.

KPA= M
MESS= N

where both M and N are INTEGERs selected by a user.

KPA specifies the units of pressure and temperature for P-PROPATH FUNCTIONs and their ARGUMENTs. Descriptions on the system of units will be found in 1.3 and the relation between the value of M and the units is shown there. When a user wishes to use other units in his/her PROGRAM UNIT later, he/she is supposed to do the same at that place.

MESS specifies whether the message to the erroneous FUNCTION REFERENCE is to be printed out to the standard listing device or not. P-PROPATH does not return any messages when $N = 0$, while it does when $N \neq 0$.

1.1.2 Initialization by SUBROUTINE SUBPROGRAM KPAMES

The alternative method to set the values for KPA and MESS is to make use of SUBROUTINE SUBPROGRAM KPAMES as the following.

```
CALL KPAMES(KPA,MESS)
```

1.2 Operations to Manage Erroneous FUNCTION REFERENCE

A predetermined sequence of operations will occur to process the erroneous FUNCTION REFERENCE when an improper FUNCTION REFERENCE has been done. Erroneous FUNCTION REFERENCEs are grouped into 3 levels, with the ascending severity of the user's mistake. (A user has committed a more serious mistake when he/she gets a level 2 ERROR than when a level 1 ERROR occurs)

1.2.1 Level 1 ERROR (Convergence Failure)

The method of iteration, which is built into some of the P-PROPATH FUNCTION SUBPROGRAMs to solve an implicit equation, may not work in some cases where a user has specified an ARGUMENT of FUNCTION very close to the saturation line or the critical point. A level 1 ERROR means P-PROPATH has stopped performing the iteration after the preset maximum number of iteration. Then the P-PROPATH FUNCTION SUBPROGRAM returns him/her an unexpected FUNCTION value and an ERROR message, though the user is not responsible for this type of ERROR,. A level 1 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+10
output to the standard listing device:
`**** NO CONVERGENCE AT (`*`NAME OF FUNCTION CALLED`*`) ****`

The PROPATH group is working hard to ensure that P-PROPATH FUNCTION SUBPROGRAM will not react with level 1 ERRORs because of poor programing technique. However when a user wants to get a value of a thermophysical property just on the saturation line or at the critical point and not at a point very close to it, he/she should try to CALL another FUNCTION for the states on the saturation line or at the critical point.

1.2.2 Level 2 ERROR (Invalid ARGUMENT(s))

A level 2 ERROR occurs when the ARGUMENT a user transferred to P-PROPATH FUNCTION has failed to drop in the proper range. A level 2 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+20
output to the standard listing device:
`**** OUT OF RANGE AT (`*`NAME OF FUNCTION`*`) FOR (`*`NAME OF SUBSTANCE`*`) WHEN`
`(`*`FIRST ARGUMENT`*`) AND (`*`SECOND ARGUMENT, if any`*`) ****`

FUNCTION tables provides the proper range of ARGUMENT(s) for each substance.

1.2.3 Level 3 ERROR (FUNCTION Unavailable)

A user encounters a level 3 ERROR when a P-PROPATH FUNCTION SUBPROGRAM is not available for the substance selected. A level 3 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+30
output to the standard listing device:
`**** FUNCTION (`*`NAME OF FUNCTION CALLED`*`) UNAVAILABLE FOR (`*`NAME OF`*
`SUBSTANCE``) ****`

Function table provides a list of FUNCTION SUBPROGRAMs available for each substance.

1.3 System of Units

All quantities, REAL ARGUMENTs and values of FUNCTION, are in the fundamental SI or in the coherent derived SI with two exceptions. Pressure can be in the unit of Pascal Pa or bar, and temperature in the unit of Kelvin K or degree Celsius °C. Users are allowed to make their own selection on these units by specifing a value to COMMON INTEGER VARIABLE `KPA`. The procedure to set a value to `KPA` is described in 1.1, and the relation between the value of `KPA` and the units of pressure and temperature is shown in the table below. The temperature is based on the International Practical Temperature Scale 1968, IPTS-1968 or International Temperature Scale, ITS-1990.

Table II-1-1 Units of Pressure and Temperature Specified by `KPA`

`KPA`	unit of pressure	unit of temperature
0	Pa	K
1	bar	°C
2	bar	K
3	Pa	°C
others	Pa	K

1.4 Reserved NAMEs

P–PROPATH uses a lot of NAMEs, listed below, for its own purpose. These are the NAMEs of FUNCTION SUBPROGRAMs to which a user can access directly, `KPA`, the first COMMON INTEGER VARIABLE, to specify the units of pressure and temperature, and `MESS`, the second COMMON INTEGER VARIABLE, to allow or suppress the listing of error messages. These are supposed to appear in the user's PROGRAM UNIT only when they assume their original meaning. A, B, C, $\cdots$ are the first LETTERs in the NAMEs listed in the same line.

NAMEs of FUNCTION SUBPROGRAMs:

A : AIPPT, AJTPT, AKPD, AKPDD, AKPT, AKTD, AKTDD, ALAPP, ALAPT,
: ALHP, ALHT, ALMPD, ALMPDD, ALMPT, ALMTD, ALMTDD, AMUPD, AMUPDD,
: AMUPT, AMUTD, AMUTDD
B : BPPT, BSPT, BTPT, BVPT
C : CPPD, CPPDD, CPPT, CPTD, CRP, CPTDD, CVPD, CVPDD, CVPT, CVTD, CVTDD
E : EPSPD, EPSPDD, EPSPT, EPSTD, EPSTDD
F : FC
G : GAMPD, GAMPDD, GAMPT, GAMTD, GAMTDD
H : HPD, HPDD, HPS, HPT, HPX, HTD, HTDD, HTX
I : IDENTF
P : PLDT, PMLT, PRPD, PRPDD, PRPT, PRTD, PRTDD, PST, PSTD, PSTDD
S : SIGP, SIGT, SPD, SPDD, SPT, SPX, STD, STDD, STX
T : T68, T90, TLDP, TMLP, TPH, TPH2, TPS, TPS2, TPSEUP, TPV, TRPL,
: TSBP, TSP, TSPD, TSPDD
U : UPD, UPDD, UPS, UPT, UPX, UTD, UTDD, UTX
V : VPD, VPDD, VPS, VPT, VPX, VTD, VTDD, VTX
W: WPD, WPDD, WPT, WTD, WTDD
X : XPH, XPS, XPU, XPV, XTH, XTS, XTU, XTV

NAMEs of COMMON INTEGER VARIABLEs:

K : KPA
M: MESS

1.5 Naming Convention of FUNCTION SUBPROGRAM

The NAMEs of FUNCTION SUBPROGRAM have been allocated in a regular pattern. This will help a user to remember them. The first one to six LETTERs stand for the kinds of the thermophysical properties. These are, in alphabetical order,

"AIP"	=ion product
"AJT"	=Joul-Thomson coefficient
"AK"	=isentropic exponent
"ALAP"	=Laplace coefficient
"ALH"	=latent heat of vaporization
"ALM"	=thermal conductivity
"AMU"	=coefficient of viscosity
"BP"	=volmetric coefficient of expansion
"BS"	=isentropic compressibility
"BT"	=isothermal compressibility
"BV"	=pressure coefficient
"CP"	=isobaric specific heat
"CRP"	=critical constants
"CV"	=isochoric specific heat
"EPS"	=static dielectric constant
"FC"	=fundamental constants
"GAM"	=ratio of specific heats
"H"	=specific enthalpy
"IDENTF"	=name of substance or version number
"PLD"	=pressure on λ line
"PML"	=pressure on melting line
"PR"	=Prandtl number
"PS"	=saturation pressure
"S"	=specific entropy
"SIG"	=surface tension
"T"	=temperature
"TLD"	=temperature on λ line
"TML"	=temperature on melting line
"TPSEU"	=pseudo boiling temperature
"TRPL"	=property at the triple point
"TS"	=saturation temperature
"U"	=specific internal energy
"V"	=specific volume
"W"	=velocity of sound
"X"	=dryness fraction of wet vapor

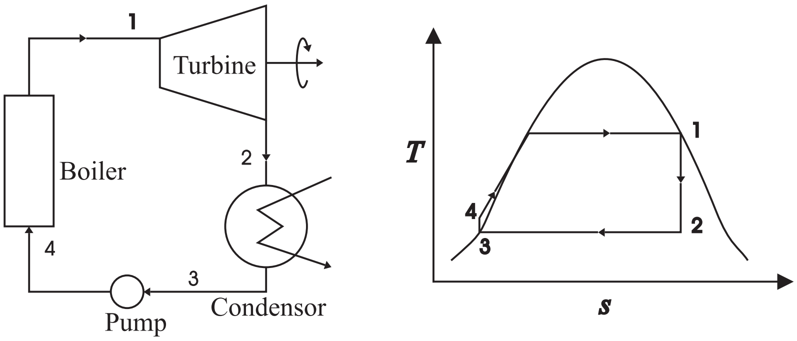
"A" at the top of the first 6 of these has been attached to avoid the DEFAULT IMPLIED TYPING characteristic of FORTRAN language.

After these one to six LETTERs mentioned above, there come the LETTER(s) reminding users of the partinent ARGUMENT(s). These are made of one or two LETTERs, and in the latter case the order of the two LETTERs coincides with the order of the ARGUMENTS which they stand for in the parentheses ( ) of FUNCTION symbol. They are "H"= specific enthalpy, "P"= pressure, "S"= specific entropy, "T"= temperature, "U"= specific internal energy, "V"= specific volume, and "X"= dryness fraction of wet vapor. However no LETTER follows after "CRP", "FC", "IDENTF" and "TRPL". In these four FUNCTION SUBPROGRAMs, they are argumented by a CHARACTER. For the case of "CRP" and "TRPL", one of 'H', 'P', 'S', 'T', and 'V' is the possible CHARACTER CONSTANT, and the value of the FUNCTION is specific enthalpy, pressure, specific entropy, temperature or specific volume in the same order. For "FC", either 'M' or 'R' is the possible, and the value of the FUNCTION is molecular weight or gas constant. Finally, for "IDENTF" one of 'C', 'S' or 'V' is possible, and the molecular formula, the name of substance or the version number of the package is provided as a CHARACTER value.

Lastly the NAME of FUNCTION SUBPROGRAM ends with "D" and "DD" standing for the saturated liquid and the dry saturated vapor, respectively. These conform to the Japanese and German conventions " ' " and " " " in the thermodynamic literature. In English literature, they are symbolized as " f " and " g ", respectively.

1.6 An Example of User's PROGRAM UNIT

[**Example**] A reversible Rankine cycle works between a higher pressure of 10 MPa and a lower pressure of 5 kPa (see figure). Find the cycle effectiveness, the thermal efficiency, the work ratio and the steam rate. Assume a reference temperature of 25°C.



Reversible Rankine Cycle

Sample Program

```
**************************************************
*                                                *
*     SAMPLE PROGRAM FOR /PROPATH/ USERS         *
*                                                *
*     EXAMPLE FROM       NISHIKAWA  AND  ITO,    *
*                        OHYOH NETSURIKIGAKU,    *
*                        CORONA  SHA,  TOKYO,    *
*                        1983                    *
*                                                *
**************************************************
*
***** EX.11.4 ON PAGE 306, CYCLE EFFICIENCY, WORK RATIO, *****
*****                AND STEAM RATE FOR RANKINE CYCLE   *****
*
      REAL*4 L,L0,LT0,LP0
      COMMON/UNIT/KPA, MESS
      KPA=1
      MESS=1
      P1=100.0
      P2=0.05
      T0=298.15
      H1=HPDD(P1)
      S1=SPDD(P1)
      H3=HPD(P2)
      R=ALHP(P2)
      S3=SPD(P2)
      X=XPS(P2,S1)
      H2=H3+X*R
      T4=TPS(P1,S3)
      H4=HPT(P1,T4)
      LT0=H1-H2
      LP0=H4-H3
      L0=LT0-LP0
      QB0=H1-H4
      L=L0/LT0
```

```
      ETA=L0/QB0
      G0=3600.0/L0*1000.
      GT0=3600.0/LT0*1000.
      PSI1=H1-T0*S1
      PSI4=H4-T0*S3
      ETAC=L0/(PSI1-PSI4)
      WRITE(6,*)'********* SAMPLE PROGRAM FOR /PROPATH/ USERS *********'
      WRITE(6,*)'   CYCLE EFFICIENCY                 ETA =',ETA
      WRITE(6,*)'   WORK RATIO                       L0  =',L
      WRITE(6,*)'   STEAM RATE PER NET POWER         G0  =',
     &     G0,' (KG/KWH)'
      WRITE(6,*)'   STEAM RATE PER TURBINE POWER     GT0 =',
     &    GT0,' (KG/KWH)'
      WRITE(6,*)'   CYCLE EFFECTIVENESS              EATC=',ETAC
      STOP
      END
```

Output

```
 ********* SAMPLE PROGRAM FOR /PROPATH/ USERS *********
    CYCLE EFFICIENCY                 ETA =0.38983846
    WORK RATIO                       L0  =0.99013019
    STEAM RATE PER NET POWER         G0  =3.5793953  (KG/KWH)
    STEAM RATE PER TURBINE POWER     GT0 =3.5440674  (KG/KWH)
    CYCLE EFFECTIVENESS              ETAC=0.96117246
```

1.7 Sample Output of Single Shot Program

```
+---------------------------------------------------------+
|  PROPATH Version 10.1                                   |
|  A Program Package for Thermophysical Properties of Fluids |
|                                                         |
|  Application Program: <Single Shot for Pure Substances>    |
|  Copyright PROPATH Group, Dec. 10, 1996                 |
+---------------------------------------------------------+
-- Hit RETURN Key ---




================================================================================
|          SS: An Application Program for PROPATH Providing                    |
|    Thermophysical Properties of WATER(IFC 1967) (H2O) VER.10.1               |
================================================================================
| No.       PROPATH Functions                     | No.   PROPATH Functions     |
================================================================================
|  1: TSP, VPD, VPDD, HPD, HPDD, SPD, SPDD       | 12: TPH, XPH                |
|     UPD, UPDD, ALHP                             | 13: HPS, TPS, UPS, VPS, XPS |
|  2: TSP, ALAPP, ALMPD, ALMPDD, AMUPD, AMUPDD   | 14: XPU                     |
|  3: CPPD, CPPDD, CVPDD, GAMPDD, PRPD, PRPDD    | 15: TPV, XPV                |
|     SIGP                                        | 16: HPX, SPX, UPX, VPX      |
|  4: TSP, TSPD, TSPDD, TLDP,TMLP, TPSEUP,TSBP   | 17: XTH                     |
|  5: PST, VTD, VTDD, HTD, HTDD, STD, STDD       | 18: XTS                     |
|     UTD, UTDD, ALHT                             | 19: XTU                     |
|  6: PST, ALAPT, ALMTD, ALMTDD, AMUTD, AMUTDD   | 20: XTV                     |
|  7: CPTD, CPTDD, CVTDD, GAMTDD, PRTD, PRTDD    | 21: HTX, STX, UTX, VTX      |
|     SIGT                                        | 22: CRP, FC, TRPL           |
|  8: PST, PSTD, PSTDD, PLDT, PMLT, PSBT         | 23: T90, T68                |
|  9: VPT, HPT, SPT, UPT                          |                             |
| 10: ALMPT, AMUPT, CPPT, CVPT, GAMPT, PRPT       |                             |
| 11: AKPT, AJTPT, AIPPT, BPPT, BSPT, BTPT        | 99: Change System of Unit   |
|     BVPT, EPSPT, WPT                            |  0: Quit                    |
================================================================================
Input No. : 1
===========================================
Calculation of TSP, VPD,  VPDD, HPD,  HPDD
               SPD, SPDD, UPD,  UPDD, ALHP
===========================================
Input P[Pa] ( P<0 : Quit ) ====> 1.01325E+05
       P=  1.013250E+05 [Pa]               TSP=  3.731499E+02 [K]
     VPD=  1.043708E-03 [m**3/kg]         VPDD=  1.673001E+00 [m**3/kg]
     HPD=  4.190644E+05 [J/kg]            HPDD=  2.676009E+06 [J/kg]
     SPD=  1.306870E+03 [J/(kg*K)]        SPDD=  7.355380E+03 [J/(kg*K)]
     UPD=  4.189586E+05 [J/kg]            UPDD=  2.506492E+06 [J/kg]
    ALHP=  2.256944E+06 [J/kg]

Input P[Pa] ( P<0 : Quit ) ====> -1
================================================================================
|          SS: An Application Program for PROPATH Providing                    |
|    Thermophysical Properties of WATER(IFC 1967) (H2O) VER.10.1               |
================================================================================
| No.       PROPATH Functions                     | No.   PROPATH Functions     |
================================================================================
|  1: TSP, VPD, VPDD, HPD, HPDD, SPD, SPDD       | 12: TPH, XPH                |
|     UPD, UPDD, ALHP                             | 13: HPS, TPS, UPS, VPS, XPS |
|  2: TSP, ALAPP, ALMPD, ALMPDD, AMUPD, AMUPDD   | 14: XPU                     |
|  3: CPPD, CPPDD, CVPDD, GAMPDD, PRPD, PRPDD    | 15: TPV, XPV                |
|     SIGP                                        | 16: HPX, SPX, UPX, VPX      |
|  4: TSP, TSPD, TSPDD, TLDP,TMLP, TPSEUP,TSBP   | 17: XTH                     |
|  5: PST, VTD, VTDD, HTD, HTDD, STD, STDD       | 18: XTS                     |
|     UTD, UTDD, ALHT                             | 19: XTU                     |
```

```
|  6: PST, ALAPT, ALMTD, ALMTDD, AMUTD, AMUTDD | 20: XTV                      |
|  7: CPTD, CPTDD, CVTDD, GAMTDD, PRTD, PRTDD  | 21: HTX, STX, UTX, VTX       |
|     SIGT                                     | 22: CRP, FC, TRPL            |
|  8: PST, PSTD, PSTDD, PLDT, PMLT, PSBT       | 23: T90, T68                 |
|  9: VPT, HPT, SPT, UPT                       |                              |
| 10: ALMPT, AMUPT, CPPT, CVPT, GAMPT, PRPT    |                              |
| 11: AKPT, AJTPT, AIPPT, BPPT, BSPT, BTPT     | 99: Change System of Unit    |
|     BVPT, EPSPT, WPT                         |  0: Quit                     |
==============================================================================
Input No. : 99
=========================================
No.     Unit                (Current)
=========================================
 1 ---> Pressure             [Pa]
 2 ---> Temperature          [K]
 3 ---> Energy               [J/kg]
        Entropy and Sp. Heat [J/(kg*K)]
 4 ---> Specific Volume      [m**3/kg]
 5 ---> Thermal Conductivity [W/(m*K)]
 6 ---> Viscosity            [Pa*s]
 7 ---> Surface Tension      [N/m]
 8 ---> Laplace Coefficient  [m]
 9 ---> Sonic Velocity       [m/s]
10 ---> Joul-Thomson Coef.   [K/Pa]
 0 ---> Return to the Function Menu
=========================================
Input No. : 1
==================
Unit for Pressure
==================
 1 ---> [Pa]
 2 ---> [kPa]
 3 ---> [MPa]
 4 ---> [bar]
 5 ---> [ata]
 6 ---> [atm]
 7 ---> [mmHg]
 8 ---> [lb/in**2]
 9 ---> [lb/ft**2]
==================
Input No. : 3
=========================================
No.     Unit                (Current)
=========================================
 1 ---> Pressure             [MPa]
 2 ---> Temperature          [K]
 3 ---> Energy               [J/kg]
        Entropy and Sp. Heat [J/(kg*K)]
 4 ---> Specific Volume      [m**3/kg]
 5 ---> Thermal Conductivity [W/(m*K)]
 6 ---> Viscosity            [Pa*s]
 7 ---> Surface Tension      [N/m]
 8 ---> Laplace Coefficient  [m]
 9 ---> Sonic Velocity       [m/s]
10 ---> Joul-Thomson Coef.   [K/Pa]
 0 ---> Return to the Function Menu
=========================================
Input No. : 2
====================
Unit for Temperature
====================
 1 ---> [K]
 2 ---> [C]
 3 ---> [F]
 4 ---> [R]
====================
Input No. : 2
=========================================
No.     Unit                (Current)
=========================================
 1 ---> Pressure             [MPa]
```

```
 2 ---> Temperature          [C]
 3 ---> Energy               [J/kg]
        Entropy and Sp. Heat [J/(kg*K)]
 4 ---> Specific Volume      [m**3/kg]
 5 ---> Thermal Conductivity [W/(m*K)]
 6 ---> Viscosity            [Pa*s]
 7 ---> Surface Tension      [N/m]
 8 ---> Laplace Coefficient  [m]
 9 ---> Sonic Velocity       [m/s]
10 ---> Joul-Thomson Coef.   [K/Pa]
 0 ---> Return to the Function Menu
========================================
Input No. : 0
===============================================================================
|          SS: An Application Program for PROPATH Providing                   |
|    Thermophysical Properties of WATER(IFC 1967) (H2O) VER.10.1              |
===============================================================================
| No.       PROPATH Functions                    | No.   PROPATH Functions     |
===============================================================================
|  1: TSP, VPD, VPDD, HPD, HPDD, SPD, SPDD       | 12: TPH, XPH              |
|     UPD, UPDD, ALHP                            | 13: HPS, TPS, UPS, VPS, XPS |
|  2: TSP, ALAPP, ALMPD, ALMPDD, AMUPD, AMUPDD | 14: XPU                     |
|  3: CPPD, CPPDD, CVPDD, GAMPDD, PRPD, PRPDD  | 15: TPV, XPV                |
|     SIGP                                       | 16: HPX, SPX, UPX, VPX    |
|  4: TSP, TSPD, TSPDD, TLDP,TMLP, TPSEUP,TSBP | 17: XTH                     |
|  5: PST, VTD, VTDD, HTD, HTDD, STD, STDD       | 18: XTS                   |
|     UTD, UTDD, ALHT                            | 19: XTU                   |
|  6: PST, ALAPT, ALMTD, ALMTDD, AMUTD, AMUTDD | 20: XTV                     |
|  7: CPTD, CPTDD, CVTDD, GAMTDD, PRTD, PRTDD  | 21: HTX, STX, UTX, VTX      |
|     SIGT                                       | 22: CRP, FC, TRPL         |
|  8: PST, PSTD, PSTDD, PLDT, PMLT, PSBT         | 23: T90, T68              |
|  9: VPT, HPT, SPT, UPT                         |                           |
| 10: ALMPT, AMUPT, CPPT, CVPT, GAMPT, PRPT      |                           |
| 11: AKPT, AJTPT, AIPPT, BPPT, BSPT, BTPT       | 99: Change System of Unit |
|     BVPT, EPSPT, WPT                           |  0: Quit                  |
===============================================================================
Input No. : 9
=================================
Calculation of VPT, HPT, SPT, UPT
=================================
Input P[MPa] and T[C] ( P<0 : Quit) : 20.0,450.0
       P=  2.000000E+01 [MPa]                T=  4.500000E+02 [C]
     VPT=  1.270676E-02 [m**3/kg]          HPT=  3.064273E+06 [J/kg]
     SPT=  5.908902E+03 [J/(kg*K)]         UPT=  2.810137E+06 [J/kg]

Input P[MPa] and T[C] ( P<0 : Quit) : -1,0
===============================================================================
|          SS: An Application Program for PROPATH Providing                   |
|    Thermophysical Properties of WATER(IFC 1967) (H2O) VER.10.1              |
===============================================================================
| No.       PROPATH Functions                    | No.   PROPATH Functions     |
===============================================================================
|  1: TSP, VPD, VPDD, HPD, HPDD, SPD, SPDD       | 12: TPH, XPH              |
|     UPD, UPDD, ALHP                            | 13: HPS, TPS, UPS, VPS, XPS |
|  2: TSP, ALAPP, ALMPD, ALMPDD, AMUPD, AMUPDD | 14: XPU                     |
|  3: CPPD, CPPDD, CVPDD, GAMPDD, PRPD, PRPDD  | 15: TPV, XPV                |
|     SIGP                                       | 16: HPX, SPX, UPX, VPX    |
|  4: TSP, TSPD, TSPDD, TLDP,TMLP, TPSEUP,TSBP | 17: XTH                     |
|  5: PST, VTD, VTDD, HTD, HTDD, STD, STDD       | 18: XTS                   |
|     UTD, UTDD, ALHT                            | 19: XTU                   |
|  6: PST, ALAPT, ALMTD, ALMTDD, AMUTD, AMUTDD | 20: XTV                     |
|  7: CPTD, CPTDD, CVTDD, GAMTDD, PRTD, PRTDD  | 21: HTX, STX, UTX, VTX      |
|     SIGT                                       | 22: CRP, FC, TRPL         |
|  8: PST, PSTD, PSTDD, PLDT, PMLT, PSBT         | 23: T90, T68              |
|  9: VPT, HPT, SPT, UPT                         |                           |
| 10: ALMPT, AMUPT, CPPT, CVPT, GAMPT, PRPT      |                           |
| 11: AKPT, AJTPT, AIPPT, BPPT, BSPT, BTPT       | 99: Change System of Unit |
|     BVPT, EPSPT, WPT                           |  0: Quit                  |
===============================================================================
Input No. : 22
============================
```

```
Calculation of CRP, FC, TRPL
============================
Critical Constants
       H=  2.107400E+06 [J/kg]                P=  2.212000E+01 [MPa]
       S=  4.442860E+03 [J/(kg*K)]            T=  3.741500E+02 [C]
       V=  3.170000E-03 [m**3/kg]
Fundamental Constants
       M=  1.801530E+01 [-]                   R=  4.615100E+02 [J/(kg*K)]
Triple Point
       P=  6.112000E-04 [MPa]                 T=  1.000977E-02 [C]
-- Hit RETURN Key to Function Menu---
==============================================================================
|          SS: An Application Program for PROPATH Providing                  |
|    Thermophysical Properties of WATER(IFC 1967) (H2O) VER.10.1              |
==============================================================================
| No.       PROPATH Functions                  | No.   PROPATH Functions     |
==============================================================================
|  1: TSP, VPD, VPDD, HPD, HPDD, SPD, SPDD     | 12: TPH, XPH                |
|     UPD, UPDD, ALHP                          | 13: HPS, TPS, UPS, VPS, XPS |
|  2: TSP, ALAPP, ALMPD, ALMPDD, AMUPD, AMUPDD | 14: XPU                     |
|  3: CPPD, CPPDD, CVPDD, GAMPDD, PRPD, PRPDD  | 15: TPV, XPV                |
|     SIGP                                     | 16: HPX, SPX, UPX, VPX      |
|  4: TSP, TSPD, TSPDD, TLDP,TMLP, TPSEUP,TSBP | 17: XTH                     |
|  5: PST, VTD, VTDD, HTD, HTDD, STD, STDD     | 18: XTS                     |
|     UTD, UTDD, ALHT                          | 19: XTU                     |
|  6: PST, ALAPT, ALMTD, ALMTDD, AMUTD, AMUTDD | 20: XTV                     |
|  7: CPTD, CPTDD, CVTDD, GAMTDD, PRTD, PRTDD  | 21: HTX, STX, UTX, VTX      |
|     SIGT                                     | 22: CRP, FC, TRPL           |
|  8: PST, PSTD, PSTDD, PLDT, PMLT, PSBT       | 23: T90, T68                |
|  9: VPT, HPT, SPT, UPT                       |                             |
| 10: ALMPT, AMUPT, CPPT, CVPT, GAMPT, PRPT    |                             |
| 11: AKPT, AJTPT, AIPPT, BPPT, BSPT, BTPT     | 99: Change System of Unit   |
|     BVPT, EPSPT, WPT                         |  0: Quit                    |
==============================================================================
Input No. : 0
***** See You Again ! *****
Stop - Program terminated.
```

2. Individual Sustance and Formulation

2.1 Helium 4(IUPAC-IPTS 1968)

Equations for thermodynamic properties have been cited from the IUPAC Table[1], and those for transport properties from McCarty et al.[2] and Hands et al.[3].

2.1.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.1.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Helium 4
Library File for UNIX:	libjhe4.a
Library File for DOS,Windows95/NT:	JHE4.LIB
Single Shot Program for UNIX:	he4-ss
Single Shot Program for DOS,Windows95/NT:	HE4–SS.EXE

2.1.3 Important Constants and Others

Molecular Formula:	He
Relative Molecular Mass:	4.0026
Gas Constant:	2077.2 J/(kg·K)

Critical Constants:

Critical Pressure:	0.22746×10^6Pa (2.2746 bar)
Critical Temperature:	5.2014 K (−267.9486°C)
Critical Specific Volume:	0.014360 m^3/kg

Triple Point:

Pressure:	5.040×10^3 Pa (0.05040 bar)
Temperature:	2.1773 K (−270.9727°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K)(ideal gas state) 126.039 J/(mol·K) and 6197 J/mol are assigned to the specific entropy and the specific enthalpy, respectively.

2.1.4 Formula

Equation of State:

Equation (14) in a function form of $P{=}P(\rho,T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature. However, n_{50}, n_{51}, n_{60}, n_{61}, n_{62}, n_{70}, n_{71}, n_{72} in table I in the same reference have been corrected as n_{60}, n_{61}, n_{62}, n_{70}, n_{71}, n_{72}, n_{50}, n_{51}, respectively.

Vapor Pressure:

Equation(7) in reference[1]. However 1.2774706525×10^2 in table J in the same reference have been corrected as 1.4127497598×10^2.

Properties at Vapor-Liquid Equilibrium:

Equations (7), (8) and (14) for specific volume, equation (7) and the equation given on page 39 for specific entropy, and equation (7) and the equation given on page 40 for specific enthalpy, and equations (7) and (23) for isobaric specific heat, respectively. All of these have been cited from reference[1].

Pressure and Temperature on λ-Line:

Equation (3) in reference [1]

Pressure and Temperature on Melting Line:
Equations (5) and (6) in reference [1]

Transport Properties:
Viscosity from reference[2] and thermal conductivity from reference[3]. Both are valid in the temperature range of T<173.15 °C(100 K).

References

[1] S.Angus and K.M.de Reuck, Helium International Thermodynamic Table of the Fluid State, IUPAC, (1977).
[2] R.D.McCarty, N.B.S. Technical Note 631, (Nov., 1972), p.9.
[3] B.A.Hands and V.D.Arp, Cryogenics, vol.21, (1981), p.697.

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] $TLDP(P) \le T \le 1400$ [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] $TMLP(P) \le T \le 1400$ [K] $0.0504 \le P < 30.13$ [bar] $TLDP(P) \le T \le 1126.85$ [°C] $30.13 \le P \le 700$ [bar] $TMLP(P) \le T \le 1126.85$ [°C] exclude the critical region shown in Fig.II-2-2
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] $TLDP(P) \le T \le 1400$ [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] $TMLP(P) \le T \le 1400$ [K] $0.0504 \le P < 30.13$ [bar] $TLDP(P) \le T \le 1126.85$ [°C] $30.13 \le P \le 700$ [bar] $TMLP(P) \le T \le 1126.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.218797\times10^6$ [Pa] $0.0504 \le P \le 2.18797$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$2.1773 \le T \le 5.15$ [K] $-270.9727 \le T \le -268$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] $0.0504 \le P \le 2.2746$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$2.1773 \le T \le 5.2014$ [K] $-270.9727 \le T \le -267.9486$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$46.99\times10^3 \le P \le 0.219\times10^6$ [Pa] $0.4699 \le P \le 2.19$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$46.99\times10^3 \le P \le 0.219\times10^6$ [Pa] $0.4699 \le P \le 2.19$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 10.397\times10^6$ [Pa] $3.5 \le T \le 300$ [K] $10.397\times10^6 \le P \le 70\times10^6$ [Pa] $TMLP(P) \le T \le 300$ [K] $0.0504 \le P < 103.97$ [bar] $-269.65 \le T \le 26.85$ [°C] $103.97 \le P \le 700$ [bar] $TMLP(P) \le T \le 26.85$ [°C] exclude the critical region shown in Fig.II-2-1
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$3.5 \le T \le 5.15$ [K] $-269.65 \le T \le -268$ [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$3.5 \le T \le 5.15$ [K] $-269.65 \le T \le -268$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$46.99\times10^3 \le P \le 0.22746\times10^6$ [Pa] $0.4699 \le P \le 2.2746$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$46.99\times10^3 \le P \le 0.22746\times10^6$ [Pa] $0.4699 \le P \le 2.2746$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 10.397\times10^6$ [Pa] $3.5 \le T \le 300$ [K] $10.397\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)$\le T \le 300$ [K] $0.0504 \le P < 103.97$ [bar] $-269.65 \le T \le 26.85$ [°C] $103.97 \le P \le 700$ [bar] TMLP(P)$\le T \le 26.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$3.5 \le T \le 5.2014$ [K] $-269.65 \le T \le -267.9486$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$3.5 \le T \le 5.2014$ [K] $-269.65 \le T \le -267.9486$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)$\le T \le 1400$ [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)$\le T \le 1400$ [K] $0.0504 \le P < 30.13$ [bar] TLDP(P)$\le T \le 1126.85$ [°C] $30.13 \le P \le 700$ [bar] TMLP(P)$\le T \le 1126.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)$\le T \le 1400$ [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)$\le T \le 1400$ [K] $0.0504 \le P < 30.13$ [bar] TLDP(P)$\le T \le 1126.85$ [°C] $30.13 \le P \le 700$ [bar] TMLP(P)$\le T \le 1126.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)$\le T \le 1400$ [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)$\le T \le 1400$ [K] $0.0504 \le P < 30.13$ [bar] TLDP(P)$\le T \le 1126.85$ [°C] $30.13 \le P \le 700$ [bar] TMLP(P)$\le T \le 1126.85$ [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.219\times10^6$ [Pa] 0.0504≤P≤2.19 [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.219\times10^6$ [Pa] 0.0504≤P≤2.19 [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C] exclude the critical region shown in Fig.II-2-2
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 6.7406×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 0.22746×10^6 [Pa], 2.2746 [bar] Pressure S: 'A'='S': 5.6988×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 5.2014 [K], −267.9486 [°C] Temperature V: 'A'='V': 0.014360 [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
7B	CVTD(T)		
78	CVTDD(P)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 4.0026 Relative Molecular Mass R: 'A'='R': 2077.2 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heat of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.219\times10^6$ [Pa] $0.0504\leq P\leq2.19$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heat [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C] exclude the critical region shown in Fig.II-2-2
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heat of Saturated Vapor [–] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'HE' Molecular Formula S: 'A'='S': 'HELIUM 4(IUPAC−IPTS 1968)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)	PLDT∗: Pressure on Lambda-line [Pa], [bar] T∗: Temperature [K], [°C]	1.7678≤T≤2.1773 [K] −271.3822≤T≤−270.9727 [°C]
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	1.7678≤T≤11.023 [K] −271.3822≤T≤−262.127 [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$46.99\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.4699≤P≤2.19 [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$46.99\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.4699≤P≤2.19 [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P\leq10.397\times10^6$ [Pa] 3.5≤T≤300 [K] $10.397\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤300 [K] 0.0504≤P≤103.97 [bar] −269.65≤T≤26.85 [°C] 103.97≤P≤700 [bar] TMLP(P)≤T≤26.85 [°C] exclude the critical region shown in Fig.II-2-1
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.218797\times10^6$ [Pa] 0.0504≤P≤2.18797 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C] 0≤X≤1.0 [–]
67	TLDP(P)	TLDP∗: Temperature on Lambda-line [K], [°C] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] 0.0504≤P<30.13 [bar]
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$3.013\times10^6 \le P \le 70\times10^6$ [Pa] 30.13≤P≤700 [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] HPT(P,TLDP(P))≤H≤ HPT(P,1400K) [J/kg] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,1400K) [J/kg] 0.0504≤P<30.13 [bar] HPT(P,TLDP(P))≤H≤ HPT(P,1126.85°C) [J/kg] 30.13≤P≤700 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,1126.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$0.228\times10^6 < P \le 50\times10^6$ [Pa] 2.28<P≤500 [bar]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] VPT(P,TLDP(P))≤V≤ VPT(P,1400K) [m^3/kg] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1400K) [m^3/kg] 0.0504≤P<30.13 [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1126.85°C) [m^3/kg] 30.13≤P≤700 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,1126.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 5.04×10^3 [Pa], 0.0504 [bar] Pressure T∗: 'A'='T': 2.1773 [K], −270.9727 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3 \le P < 3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3 \le P \le 0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$5.04 \times 10^3 \leq P \leq 0.22746 \times 10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$5.04 \times 10^3 \leq P \leq 0.22746 \times 10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04 \times 10^3 \leq P < 3.013 \times 10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013 \times 10^6 \leq P \leq 70 \times 10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $0.0504 \leq P < 30.13$ [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] $30.13 \leq P \leq 700$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04 \times 10^3 \leq P < 3.013 \times 10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013 \times 10^6 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤1400 [K] $0.0504 \leq P < 30.13$ [bar] TLDP(P)≤T≤1126.85 [°C] $30.13 \leq P \leq 700$ [bar] TMLP(P)≤T≤1126.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04 \times 10^3 \leq P \leq 0.22746 \times 10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04 \times 10^3 \leq P < 3.013 \times 10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013 \times 10^6 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤1400 [K] $0.0504 \leq P < 30.13$ [bar] TLDP(P)≤T≤1126.85 [°C] $30.13 \leq P \leq 700$ [bar] TMLP(P)≤T≤1126.85 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$5.04\times10^3 \leq P \leq 0.22746\times10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$5.04\times10^3 \leq P \leq 0.22746\times10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$5.04\times10^3 \leq P \leq 0.22746\times10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$5.04\times10^3 \leq P \leq 0.22746\times10^6$ [Pa] $0.0504 \leq P \leq 2.2746$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$2.1773 \leq T \leq 5.2014$ [K] $-270.9727 \leq T \leq -267.9486$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

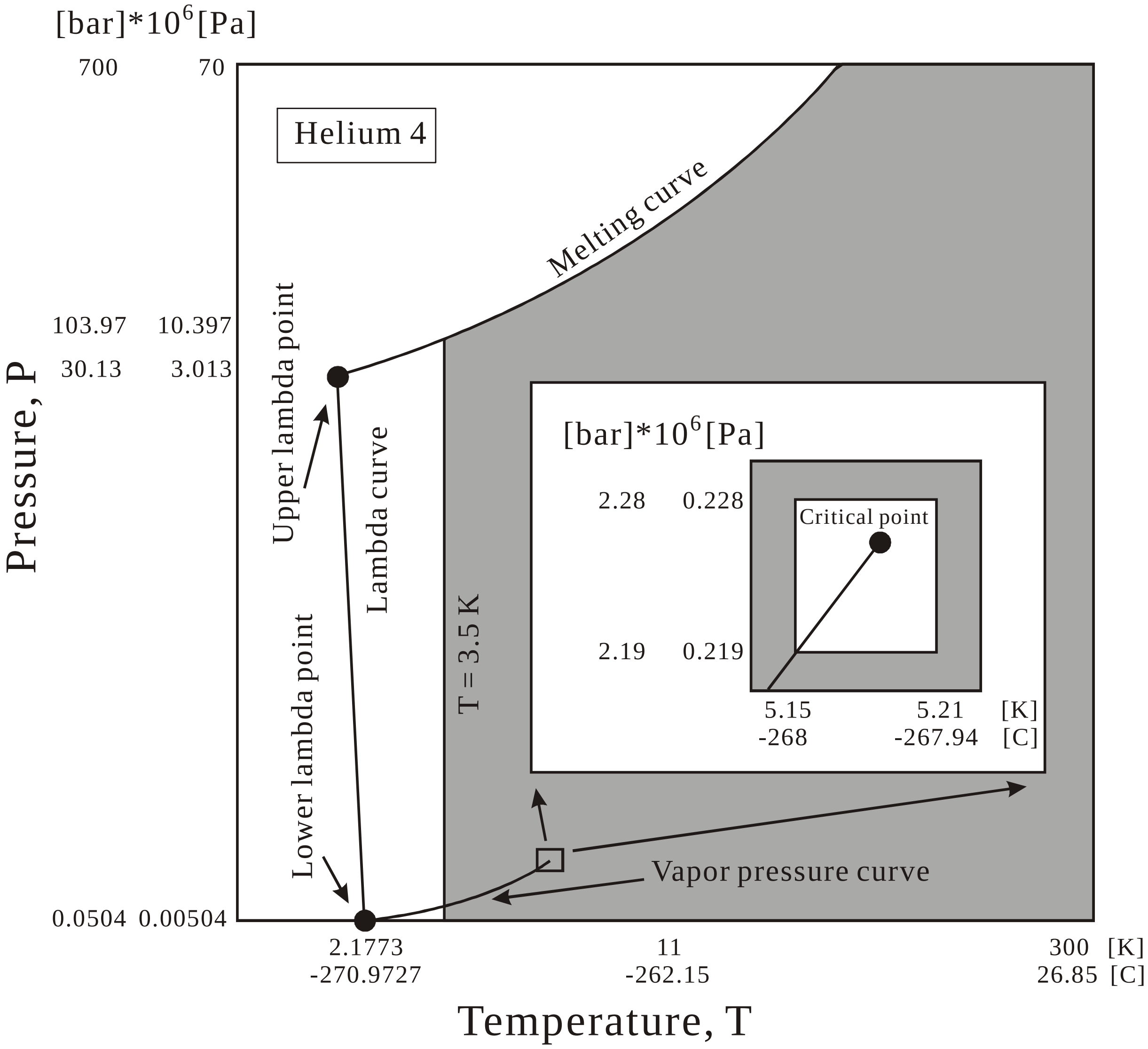


Fig.II–2.1–1 Range of Arguments(P,T) for ALMPT(P,T) and PRPT(P,T).

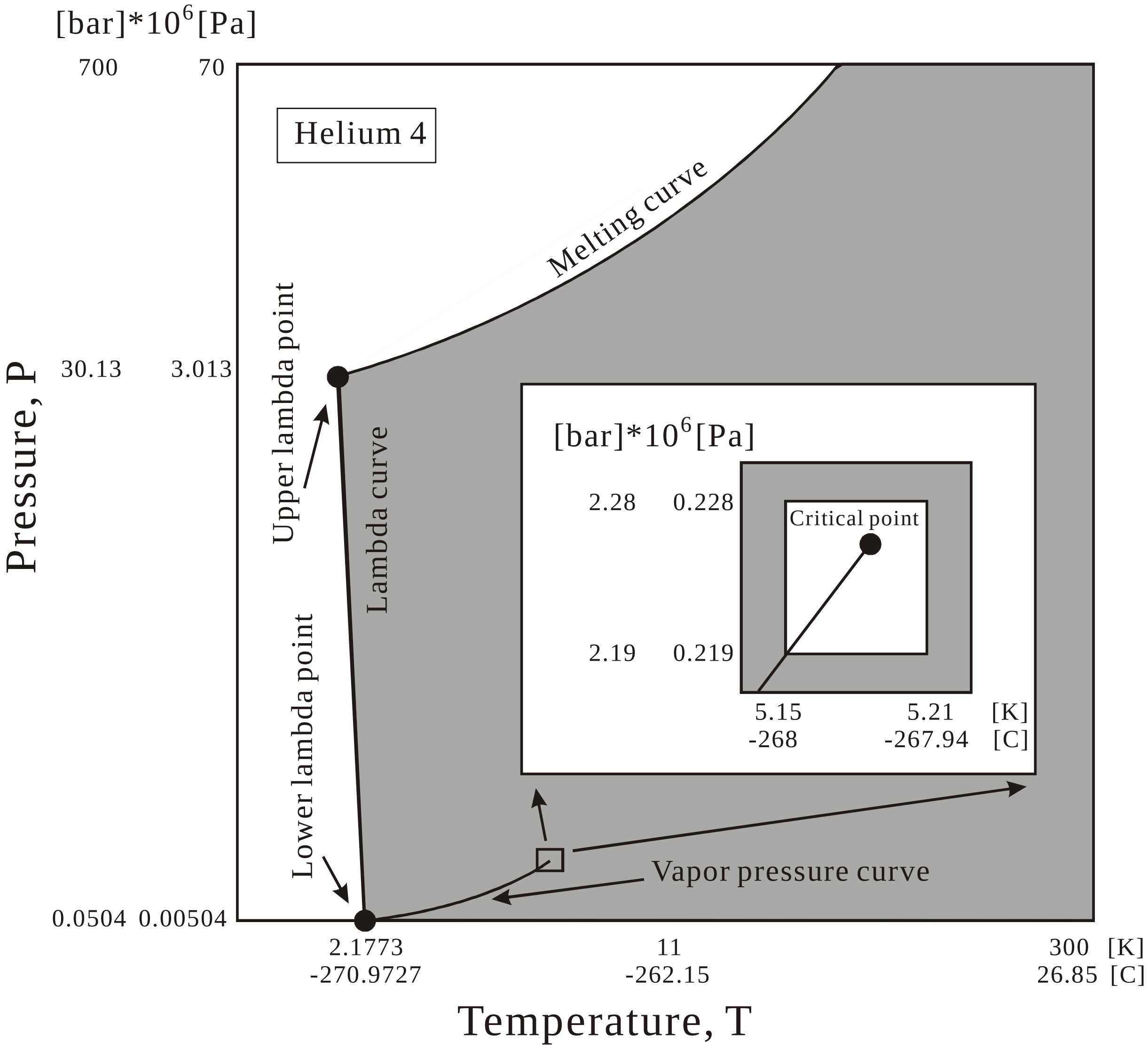


Fig.II–2.1–2 Range of Arguments(P,T) for AJTPT(P,T),CPPT(P,T) and GAMPT(P,T).

2.2 Helium 4(NIST-ITS 1990)

Equations for thermodynamic properties have been cited from reference [1] and [2].

2.2.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.2.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Helium 4
Library File for UNIX:	libjhe4i90.a
Library File for DOS,Windows95/NT:	JHE4I90.LIB
Single Shot Program for UNIX:	he4i90ss
Single Shot Program for DOS,Windows95/NT:	HE4I90SS.EXE

2.2.3 Important Constants and Others

Molecular Formula:	He
Relative Molecular Mass:	4.0026
Gas Constant:	2077.2 J/(kg·K)

Critical Constants:

Critical Pressure:	0.22746×10^6Pa (2.2746 bar)
Critical Temperature:	5.1953 K (-267.9547°C)
Critical Specific Volume:	0.014360 m^3/kg

Triple Point:

Pressure:	5.0418×10^3 Pa (0.05040 bar)
Temperature:	2.1768 K (-270.9732°C)

Reference State:

At temperature of 0.8K and density of 146.15 kg/m^3, 4.515 J/(kg·K) and -0.606 J/kg are assigned to the specific entropy and the specific Hermholtz free energy, respectively.

2.2.4 Formula

Equation of State:

Equation (7) in a function form of A=$A(v, T)$ in reference [1], and equation (3) in a form of $p(T, v)$ in reference [2]. Here A=specific Helmholtz free energy, v=specific volume , T=temperature and p=pressure.

Vapor Pressure:

Equation(2) in reference[3].

Pressure and Temperature on λ-Line:

Equation(3) in reference [4]

References

[1] V. D. Arp, J. Low Temp. Phys., vol.79, (1990), p.93
[2] R. D. McCarty and V. D. Arp, Adv. Cryogenic Eng., vol. 35, (1990), p.1465.
[3] M.Durieux and R.L.Rusby, Metrologia, vol.19, (1983), p.67
[4] H.A.Kierstead, Phys. Rev., vol.162, (1967), p.153

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \le P \le 2.5328\times10^6$ [Pa] $0.8 \le T \le 1500$ [K] $2.5328\times10^6 < P \le 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \le P \le 25.328$ [bar] $-272.35 \le T \le 1226.85$ [°C] $25.328 < P \le 1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \le P \le 2.5328\times10^6$ [Pa] $0.8 \le T \le 1500$ [K] $2.5328\times10^6 < P \le 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \le P \le 25.328$ [bar] $-272.35 \le T \le 1226.85$ [°C] $25.328 < P \le 1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$1.47515 \le P \le 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \le P \le 2.16454$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$0.8 \le T \le 5.13$ [K] $-272.35 \le T \le -268.02$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \le P \le 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \le P \le 2.16454$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$0.8 \le T \le 5.13$ [K] $-272.35 \le T \le -268.02$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$47.04\times10^3 < P \le 0.216454\times10^6$ [Pa] $0.4704 < P \le 2.16454$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$47.04\times10^3 < P \le 0.216454\times10^6$ [Pa] $0.4704 < P \le 2.16454$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \le P \le 10.485\times10^6$ [Pa] $3.5 < T \le 1500$ [K] $10.485\times10^6 < P \le 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \le P \le 104.85$ [bar] $-269.65 < T \le 1226.85$ [°C] $104.85 < P \le 1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$3.5 < T \le 5.13$ [K] $-269.65 < T \le -268.02$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$3.5 < T \le 5.13$ [K] $-269.65 < T \le -268.02$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$47.04\times10^3 < P \le 0.216454\times10^6$ [Pa] $0.4704 < P \le 2.16454$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$47.04\times10^3 < P \le 0.216454\times10^6$ [Pa] $0.4704 < P \le 2.16454$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418{\times}10^3{\le}P{\le}10.485{\times}10^6$ [Pa] $3.5{<}T{\le}1500$ [K] $10.485{\times}10^6{<}P{\le}100{\times}10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418{\times}10^{-3}{\le}P{\le}104.85$ [bar] $-269.65{<}T{\le}1226.85$ [°C] $104.85{<}P{\le}1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$3.5{<}T{\le}5.13$ [K] $-269.65{<}T{\le}-268.02$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$3.5{<}T{\le}5.13$ [K] $-269.65{<}T{\le}-268.02$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418{\times}10^3{\le}P{\le}2.5328{\times}10^6$ [Pa] $0.8{\le}T{\le}1500$ [K] $2.5328{\times}10^6{<}P{\le}100{\times}10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418{\times}10^{-3}{\le}P{\le}25.328$ [bar] $-272.35{\le}T{\le}1226.85$ [°C] $25.328{<}P{\le}1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418{\times}10^3{\le}P{\le}2.5328{\times}10^6$ [Pa] $0.8{\le}T{\le}1500$ [K] $2.5328{\times}10^6{<}P{\le}100{\times}10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418{\times}10^{-3}{\le}P{\le}25.328$ [bar] $-272.35{\le}T{\le}1226.85$ [°C] $25.328{<}P{\le}1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418{\times}10^3{\le}P{\le}2.5328{\times}10^6$ [Pa] $0.8{\le}T{\le}1500$ [K] $2.5328{\times}10^6{<}P{\le}100{\times}10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418{\times}10^{-3}{\le}P{\le}25.328$ [bar] $-272.35{\le}T{\le}1226.85$ [°C] $25.328{<}P{\le}1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418{\times}10^3{\le}P{\le}2.5328{\times}10^6$ [Pa] $0.8{\le}T{\le}1500$ [K] $2.5328{\times}10^6{<}P{\le}100{\times}10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418{\times}10^{-3}{\le}P{\le}25.328$ [bar] $-272.35{\le}T{\le}1226.85$ [°C] $25.328{<}P{\le}1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515{\le}P{\le}0.216454{\times}10^6$ [Pa] $14.7515{\times}10^{-6}{\le}P{\le}2.16454$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515{\le}P{\le}0.216454{\times}10^6$ [Pa] $14.7515{\times}10^{-6}{\le}P{\le}2.16454$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \le P \le 2.5328\times10^6$ [Pa] $0.8 \le T \le 1500$ [K] $2.5328\times10^6 < P \le 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \le P \le 25.328$ [bar] $-272.35 \le T \le 1226.85$ [°C] $25.328 < P \le 1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8 \le T \le 5.13$ [K] $-272.35 \le T \le -268.02$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8 \le T \le 5.13$ [K] $-272.35 \le T \le -268.02$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 21.948×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 0.22746×10^6 [Pa], 2.2746 [bar] Pressure S: 'A'='S': 5.7685×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 5.1953 [K], −267.9547 [°C] Temperature V: 'A'='V': 0.014360 [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515 \le P \le 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \le P \le 2.16454$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \le P \le 2.5328\times10^6$ [Pa] $0.8 \le T \le 1500$ [K] $2.5328\times10^6 < P \le 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \le P \le 25.328$ [bar] $-272.35 \le T \le 1226.85$ [°C] $25.328 < P \le 1000$ [bar] TMLP(P)≤T≤1226.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8 \le T \le 5.13$ [K] $-272.35 \le T \le -268.02$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 4.0026 Relative Molecular Mass R: 'A'='R': 2077.2 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heat of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$1.47515 \le P \le 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \le P \le 2.16454$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heat [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] $0.8 \leq T \leq 1500$ [K] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] TMLP(P)$\leq T \leq 1500$ [K] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] $-272.35 \leq T \leq 1226.85$ [°C] $25.328 < P \leq 1000$ [bar] TMLP(P)$\leq T \leq 1226.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heat of Saturated Vapor [–] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] SPT(P,0.8K)$\leq$S$\leq$ SPT(P,1500K) [J/(kg·K)] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] SPT(P,TMLP(P))$\leq$S$\leq$ SPT(P,1500K) [J/(kg·K)] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] SPT(P,−272.35°C)$\leq$S$\leq$ SPT(P,1226.85°C) [J/(kg·K)] $25.328 < P \leq 1000$ [bar] SPT(P,TMLP(P))$\leq$S$\leq$ SPT(P,1226.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] $0.8 \leq T \leq 1500$ [K] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] TMLP(P)$\leq T \leq 1500$ [K] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] $-272.35 \leq T \leq 1226.85$ [°C] $25.328 < P \leq 1000$ [bar] TMLP(P)$\leq T \leq 1226.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'HE' Molecular Formula S: 'A'='S': 'HELIUM 4(NIST-ITS 1990)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)	PLDT∗: Pressure on Lambda-line [Pa], [bar] T∗: Temperature [K], [°C]	$1.7673 \leq T \leq 2.1768$ [K] $-271.383 \leq T \leq -270.973$ [°C]
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 13.8943$ [K] $-272.35 \leq T \leq -259.256$ [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$47.04 \times 10^3 \leq P \leq 0.216454 \times 10^6$ [Pa] $0.4704 \leq P \leq 2.16454$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$47.04 \times 10^3 \leq P \leq 0.216454 \times 10^6$ [Pa] $0.4704 \leq P \leq 2.16454$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418 \times 10^3 \leq P \leq 10.485 \times 10^6$ [Pa] $3.5 < T \leq 1500$ [K] $10.485 \times 10^6 < P \leq 100 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 1500$ [K] $50.418 \times 10^{-3} \leq P \leq 104.85$ [bar] $-269.65 < T \leq 1226.85$ [°C] $104.85 < P \leq 1000$ [bar] TMLP(P)$\leq T \leq 1226.85$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$3.5 < T \leq 5.13$ [K] $-269.65 < T \leq -268.02$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$3.5 < T \leq 5.13$ [K] $-269.65 < T \leq -268.02$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.1953$ [K] $-272.35 \leq T \leq -267.9547$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418 \times 10^3 \leq P \leq 2.5328 \times 10^6$ [Pa] $0.8 \leq T \leq 1500$ [K] $2.5328 \times 10^6 < P \leq 100 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 1500$ [K] $50.418 \times 10^{-3} \leq P \leq 25.328$ [bar] $-272.35 \leq T \leq 1226.85$ [°C] $25.328 < P \leq 1000$ [bar] TMLP(P)$\leq T \leq 1226.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$0.8 \leq T \leq 5.13$ [K] $-272.35 \leq T \leq -268.02$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)	TLDP∗: Temperature on Lambda-line [K], [°C] P∗: Pressure [Pa], [bar]	$5.0418\times10^3 \leq P \leq 3.0134\times10^6$ [Pa] $50.418\times10^{-3} \leq P \leq 30.134$ [bar]
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$2.5328\times10^6 \leq P \leq 100\times10^6$ [Pa] $25.328 \leq P \leq 1000$ [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] HPT(P,0.8K)≤H≤ HPT(P,1500K) [J/kg] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,1500K) [J/kg] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] HPT(P,−272.35°C)≤H≤ HPT(P,1226.85°C) [J/kg] $25.328 < P \leq 1000$ [bar] HPT(P,TMLP(P))≤H≤ HPT(P,1226.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $25.328 < P \leq 1000$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$0.2275\times10^6 < P \leq 50\times10^6$ [Pa] $2.275 < P \leq 500$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] VPT(P,TLDP(P))≤V≤ VPT(P,1500K) [m^3/kg] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1500K) [m^3/kg] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1226.85°C) [m^3/kg] $25.328 < P \leq 1000$ [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1226.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 5.0418×10^3 [Pa], 50.418×10^{-3} [bar] Pressure T∗: 'A'='T': 2.1768 [K], −270.9732 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.22746\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.2746$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418 \times 10^3 \leq P \leq 2.5328 \times 10^6$ [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] $2.5328 \times 10^6 < P \leq 100 \times 10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] $50.418 \times 10^{-3} \leq P \leq 25.328$ [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 25.328<P≤1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418 \times 10^3 \leq P \leq 2.5328 \times 10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328 \times 10^6 < P \leq 100 \times 10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418 \times 10^{-3} \leq P \leq 25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.22746 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.2746$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.22746 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.2746$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 25.328<P≤1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515 \leq P \leq 0.22746\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.4746$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3 \leq P \leq 2.5328\times10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328\times10^6 < P \leq 100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3} \leq P \leq 25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.47515 \leq P \leq 0.216454\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.16454$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.47515 \leq P \leq 0.22746\times10^6$ [Pa] $14.7515\times10^{-6} \leq P \leq 2.2746$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.3 Neon

Equations for thermodynamic properties have been cited from the National Standard Reference Data Service of the USSR, A Series of Property Tables [1] and one for surface tension from Miller et al.[2].

2.3.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.3.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Neon
Library File for UNIX:	libjne.a
Library File for DOS,Windows95/NT:	JNE.LIB
Single Shot Program for UNIX:	ne-ss
Single Shot Program for DOS,Windows95/NT:	NE–SS.EXE

2.3.3 Important Constants and Others

Molecular Formula:	Ne
Relative Molecular Mass:	20.183
Gas Constant:	411.95 J/(kg·K)

Critical Constants:

Critical Pressure:	2.653×10^6Pa (26.53 bar)
Critical Temperature:	44.40 K (−228.75°C)
Critical Specific Volume:	2.069×10^{-3}m^3/kg

Triple Point:

Pressure:	0.04335×10^6Pa (0.4335 bar)
Temperature:	24.55 K (−248.6°C)

2.3.4 Formula

Equation of State:
Equations (2.44) and (3.33) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:
Equation (1.71) in reference [1].

Properties at Vapor-Liquid Equilibrium:
Equations (2.44) and (3.33) for specific volume, equations (3.27), (3.31), (3.32) and (3.33) for isobaric specific heat. All of these have been cited from reference [1].

Pressure and Temperature on Melting Line:
Equation (1.65) in reference [1].

Transport Properties:
Equations (4.25) and (6.13) in reference [1] for viscosity.

The Other Properties:

Equation (23-1) in reference [2] for surface tension.

References

[1] V.A.Rabinovich, A.A.Vasserman, V.I.Nedstup and L.S.Veksler, Thermophysical Properties of NEON, ARGON, KRYPTON AND XENON, National Standard Reference Data Service of the USSR: A Series of Property Tables, Vol.10, English-Language Edition, edited by T.B.Selover, Jr., (1987).

[2] J.W.Miller, Jr. and C.L.Yaws, Chem. Eng., 83–23, (1976), p.127.

Table II–2.3–1 Neon Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)		
5	ALHT(T)		
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$43.35\times10^3 \leq P \leq 2.653\times10^6$ [Pa] $0.4335 \leq P \leq 26.53$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$43.35\times10^3 \leq P \leq 2.653\times10^6$ [Pa] $0.4335 \leq P \leq 26.53$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$24.55 \leq T \leq 44.4$ [K] $-248.6 \leq T \leq -228.75$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$24.55 \leq T \leq 44.4$ [K] $-248.6 \leq T \leq -228.75$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$43.35\times10^3 \leq P < 1.6118\times10^6$ [Pa] $0.4335 \leq P < 16.118$ [bar]
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$24.55 \leq T < 40.673$ [K] $-248.6 \leq T < -232.477$ [°C]
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants P∗: 'A'='P': 2.653×10^6[Pa], 26.53 [bar] Pressure T∗: 'A'='T': 44.40 [K], −228.75 [°C] Temperature V: 'A'='V': 2.069×10^{-3} [m^3/kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		

Table II–2.3–1 Neon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 20.183 Relative Molecular Mass R: 'A'='R': 411.95 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)		
24	HPDD(P)		
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)		
27	HTD(T)		
28	HTDD(T)		
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'NE' Molecular Formula S: 'A'='S': 'NEON' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$24.55 \leq T \leq 38$ [K] $-248.6 \leq T \leq -235.15$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$24.55 \leq T \leq 44.4$ [K] $-248.6 \leq T \leq -228.75$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$43.35 \times 10^3 \leq P \leq 2.653 \times 10^6$ [Pa] $0.4335 \leq P \leq 26.53$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$24.55 \leq T \leq 44.4$ [K] $-248.6 \leq T \leq -228.75$ [°C]
33	SPD(P)		
34	SPDD(P)		
35	SPT(P,T)		
36	SPX(P,X)		
37	STD(T)		
38	STDD(T)		
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$43.35 \times 10^3 \leq P \leq 1.039 \times 10^8$ [Pa] $0.4335 \leq P \leq 1039$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		

Table II–2.3–1 Neon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.04335×10^6 [Pa], 0.4335 [bar] Pressure T∗: 'A'='T': 24.55 [K], −248.60 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$43.35\times10^3\leq P\leq2.653\times10^6$ [Pa] $0.4335\leq P\leq26.53$ [bar]
98	TPSEUP(P)		
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)		
43	UPDD(P)		
79	UPS(P,S)		
44	UPT(P,T)		
45	UPX(P,X)		
46	UTD(T)		
47	UTDD(T)		
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$43.35\times10^3\leq P\leq2.653\times10^6$ [Pa] $0.4335\leq P\leq26.53$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$43.35\times10^3\leq P\leq2.653\times10^6$ [Pa] $0.4335\leq P\leq26.53$ [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$24.55\leq T\leq44.4$ [K] $-248.6\leq T\leq-228.75$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$24.55\leq T\leq44.4$ [K] $-248.6\leq T\leq-228.75$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.4 Argon

Equations for thermodynamic properties have been cited from the IUPAC Table [1], one for surface tension from Miller et al.[2], and one for thermal conductivity from reference [3].

2.4.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.4.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Argon
Library File for UNIX:	libjarg.a
Library File for DOS,Windows95/NT:	JARG.LIB
Single Shot Program for UNIX:	arg-ss
Single Shot Program for DOS,Windows95/NT:	ARG–SS.EXE

2.4.3 Important Constants and Others

Molecular Formula:	Ar
Relative Molecular Mass:	39.948
Gas Constant:	208.13 J/(kg·K)

Critical Constants:

Critical Pressure:	4.998×10^{6}Pa (49.98 bar)
Critical Temperature:	150.86 K (−122.29°C)
Critical Specific Volume:	1.8667×10^{-3}m^3/kg

Triple Point:

Pressure:	0.06875×10^{6}Pa (0.6875 bar)
Temperature:	83.78 K (−189.37°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K)(gas), 154.735 J/(mol·K) and 6197 J/mol are assigned to the specific entropy and the specific enthalpy, respectively.

2.4.4 Formula

Equation of State:

Equation (7) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=Temperature.

Vapor Pressure:

Equation (5) in reference [1].

Properties on Bubble-Point Curve:

Equation (9) in reference [1].

Properties at Vapor-Liquid equilibrium:

saturated liquid: Equations (5) and (9) for specific volume, equations at page 7 for specific enthalpy and specific entropy, respectively.

saturated vapor: Equations (5) and (7) for specific volume, equation (7) and equations at page 7 for specific enthalpy and specific entropy, and equations (7) and (9) for isochoric specific heat and isobaric specific heat, respectively. However, the constant CO_3=-360.553×10^4 in eq.(9) has been corrected to CO_3=-360.553×10^7.

All of these have been cited from reference [1].

Transport Properties:
Thermal conductivity for saturated liquid from reference [3].

The Other Properties:
Surface tension from reference [2].

References

[1] International Thermodynamic Tables of the Fluid State, Argon, 1971, IUPAC, (1972).
[2] J.W.Miller Jr and C.L.Yaws, Chemical Engineering, vol.83, No. 23, (1976), p.127.
[3] Thermal conductivity, TPRC Data Series, vol.3, Plenum, (1970).

Table II–2.4–1 Argon Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 3.1675\times10^6$ [Pa] $0.6875 \leq P \leq 31.675$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 140$ [K] $-189.37 \leq T \leq -133.15$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3 \leq P \leq 100\times10^6$ [Pa] $83.78 \leq T \leq 1100$ [K] $0.1 \leq P \leq 1000$ [bar] $-189.37 \leq T \leq 826.85$ [°C] see Fig.II-2-1
19	CPTD(T)		
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 189.17×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.998×10^6 [Pa], 49.98 [bar] Pressure S: 'A'='S': 2.201×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 150.86 [K], −122.29 [°C] Temperature V: 'A'='V': 1.8667×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]

Table II–2–1 Argon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3\leq P\leq100\times10^6$ [Pa] $83.78\leq T\leq1100$ [K] $0.1\leq P\leq1000$ [bar] $-189.37\leq T\leq826.85$ [°C] see Fig.II-2-1
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$83.78\leq T\leq150.86$ [K] $-189.37\leq T\leq-122.29$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 39.948 Relative Molecular Mass R: 'A'='R': 208.13 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3\leq P\leq4.998\times10^6$ [Pa] $0.6875\leq P\leq49.98$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3\leq P\leq4.998\times10^6$ [Pa] $0.6875\leq P\leq49.98$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10.0\times10^3\leq P\leq100\times10^6$ [Pa] $0.1\leq P\leq1000$ [bar] see Fig.II-2-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3\leq P\leq100\times10^6$ [Pa] $83.78\leq T\leq1100$ [K] $0.1\leq P\leq1000$ [bar] $-189.37\leq T\leq826.85$ [°C] see Fig.II-2-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$68.75\times10^3\leq P\leq4.998\times10^6$ [Pa] $0.6875\leq P\leq49.98$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$83.78\leq T\leq150.86$ [K] $-189.37\leq T\leq-122.29$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$83.78\leq T\leq150.86$ [K] $-189.37\leq T\leq-122.29$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$83.78\leq T\leq150.86$ [K] $-189.37\leq T\leq-122.29$ [°C] $0\leq X\leq1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'AR' Molecular Formula S: 'A'='S': 'ARGON' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		

Table II–2.4–1 Argon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	83.78≤T≤150.86 [K] −189.37≤T≤−122.29 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \le P \le 4.998\times10^6$ [Pa] 0.6875≤P≤49.98 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	83.78≤T≤150.86 [K] −189.37≤T≤−122.29 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \le P \le 4.998\times10^6$ [Pa] 0.6875≤P≤49.98 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \le P \le 4.998\times10^6$ [Pa] 0.6875≤P≤49.98 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3 \le P \le 100\times10^6$ [Pa] 83.78≤T≤1100 [K] 0.1≤P≤1000 [bar] −189.37≤T≤826.85 [°C] see Fig.II-2-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$68.75\times10^3 \le P \le 4.998\times10^6$ [Pa] 0.6875≤P≤49.98 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	83.78≤T≤150.86 [K] −189.37≤T≤−122.29 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	83.78≤T≤150.86 [K] −189.37≤T≤−122.29 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	83.78≤T≤150.86 [K] −189.37≤T≤−122.29 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$10.0\times10^3 \le P \le 100\times10^6$ [Pa] 0.1≤P≤1000 [bar] see Fig.II-2-2 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10.0\times10^3 \le P \le 100\times10^6$ [Pa] 0.1≤P≤1000 [bar] see Fig.II-2-3 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$10.0\times10^3 \le P \le 100\times10^6$ [Pa] 0.1≤P≤1000 [bar] see Fig.II-2-4 for V
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗:'A'='P': 68.75×10^3 [Pa], 0.6875 [bar] Pressure T∗:'A'='T': 83.78 [K], −189.37 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \le P \le 4.998\times10^6$ [Pa] 0.6875≤P≤49.98 [bar]

Table II–2.4–1 Argon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
79	UPS(P,S)		
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3 \leq P \leq 100\times10^6$ [Pa] $83.78 \leq T \leq 1100$ [K] $0.1 \leq P \leq 1000$ [bar] $-189.37 \leq T \leq 826.85$ [°C] see Fig.II-2-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar]
80	VPS(P,S)		
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10.0\times10^3 \leq P \leq 100\times10^6$ [Pa] $83.78 \leq T \leq 1100$ [K] $0.1 \leq P \leq 1000$ [bar] $-189.37 \leq T \leq 826.85$ [°C] see Fig.II-2-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$68.75\times10^3 \leq P \leq 4.998\times10^6$ [Pa] $0.6875 \leq P \leq 49.98$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$83.78 \leq T \leq 150.86$ [K] $-189.37 \leq T \leq -122.29$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.4–1 Argon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$68.75{\times}10^3{\le}P{\le}4.998{\times}10^6$ [Pa] $0.6875{\le}P{\le}49.98$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$68.75{\times}10^3{\le}P{\le}4.998{\times}10^6$ [Pa] $0.6875{\le}P{\le}49.98$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$68.75{\times}10^3{\le}P{\le}4.998{\times}10^6$ [Pa] $0.6875{\le}P{\le}49.98$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$68.75{\times}10^3{\le}P{\le}4.998{\times}10^6$ [Pa] $0.6875{\le}P{\le}49.98$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$83.78{\le}T{\le}150.86$ [K] $-189.37{\le}T{\le}-122.29$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$83.78{\le}T{\le}150.86$ [K] $-189.37{\le}T{\le}-122.29$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$83.78{\le}T{\le}150.86$ [K] $-189.37{\le}T{\le}-122.29$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$83.78{\le}T{\le}150.86$ [K] $-189.37{\le}T{\le}-122.29$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

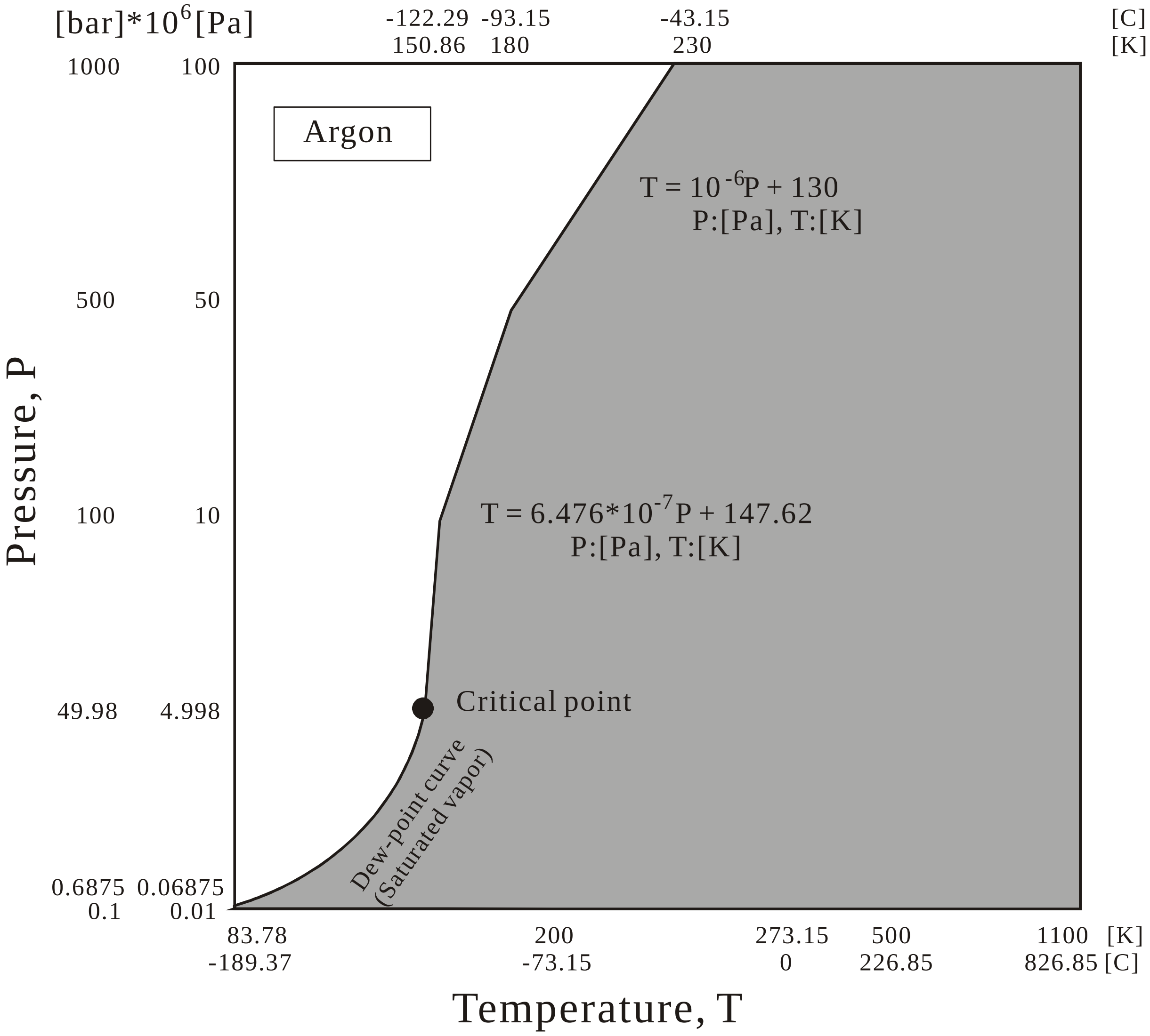


Fig.II–2.4–1 Range of Arguments(P,T) for CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T) and VPT(P,T).

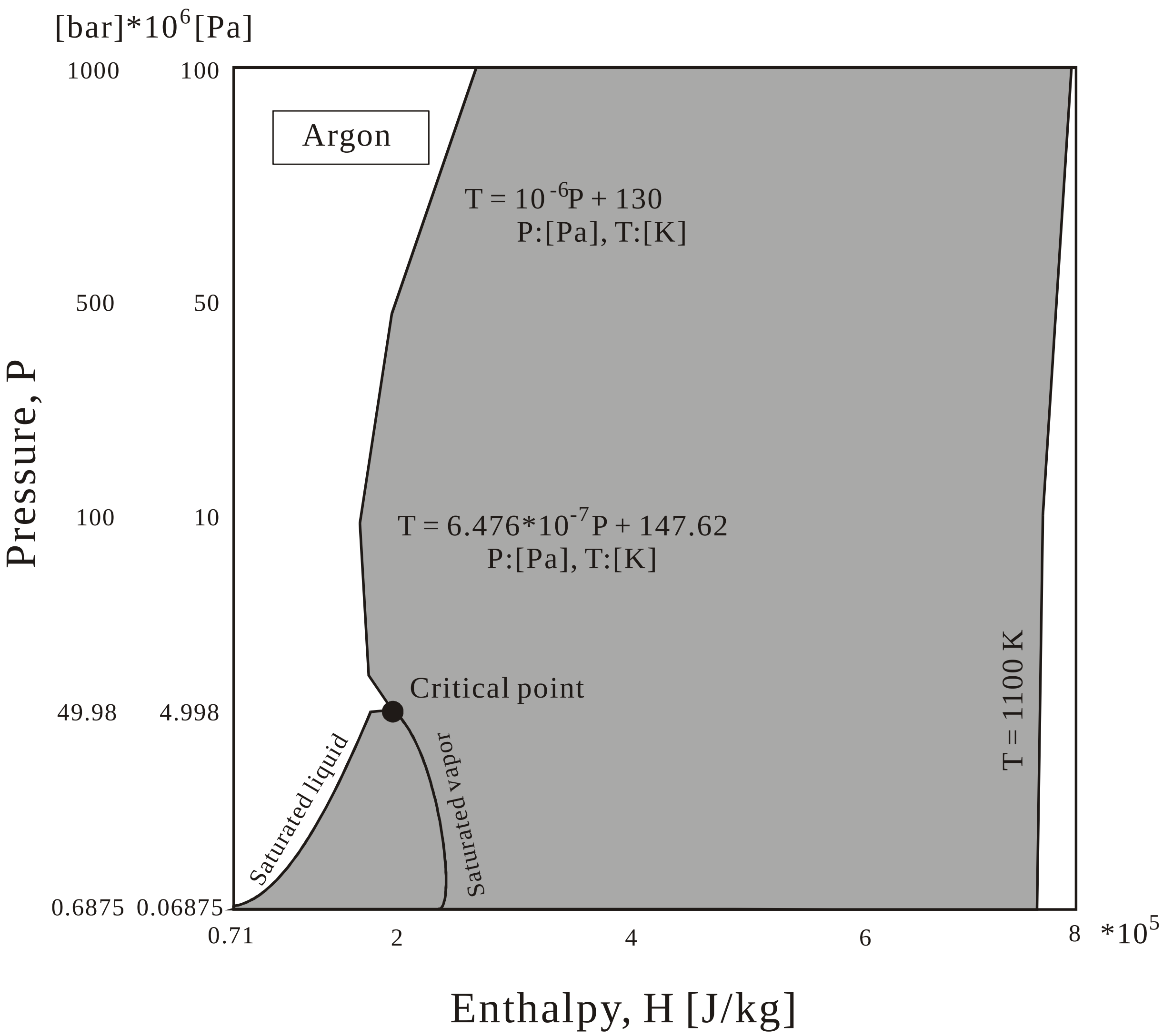


Fig.II–2.4–2 Range of Arguments(P,H) for TPH(P,H).

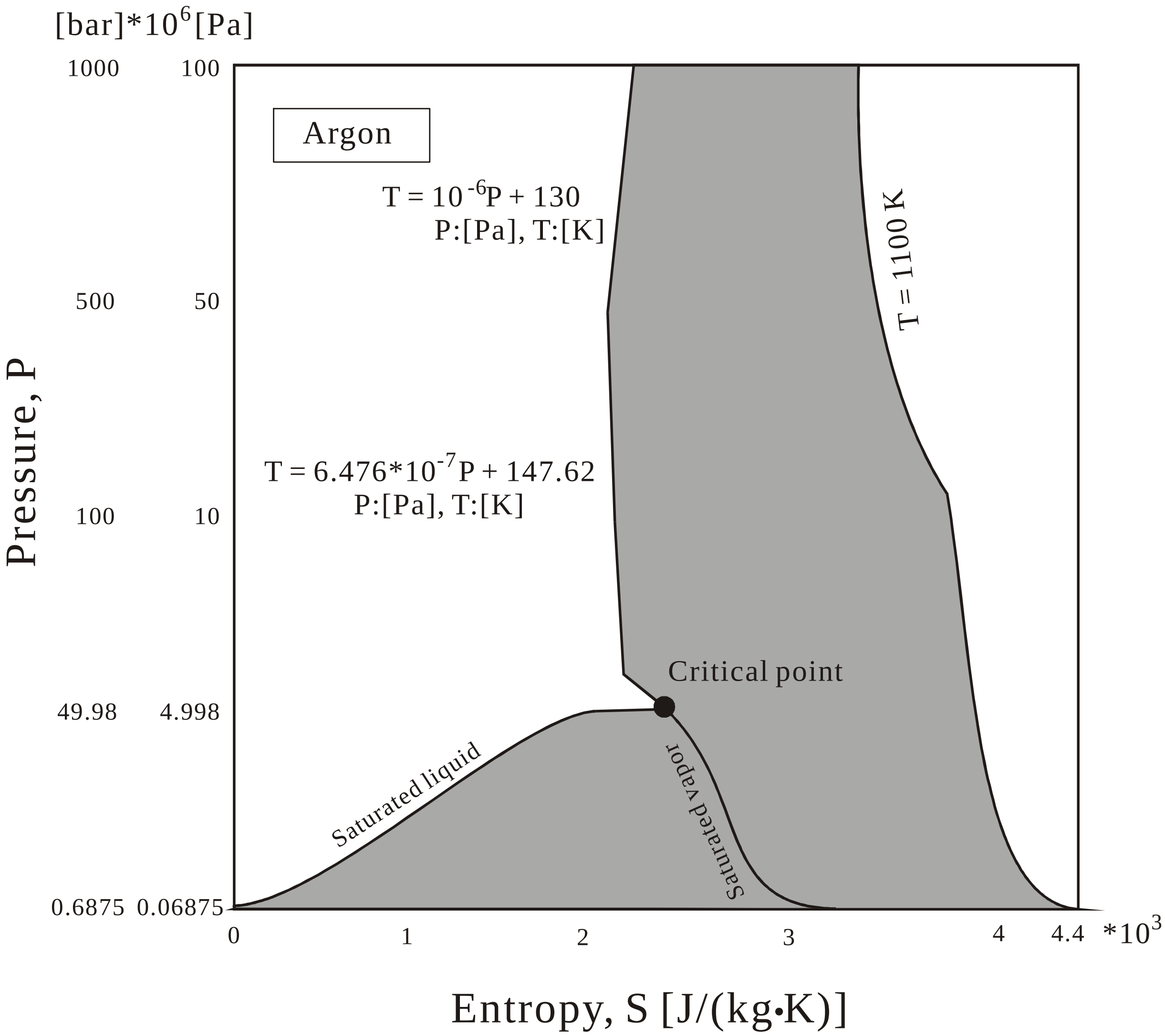


Fig.II–2.4–3 Range of Arguments(P,S) for HPS(P,S) and TPS(P,S).

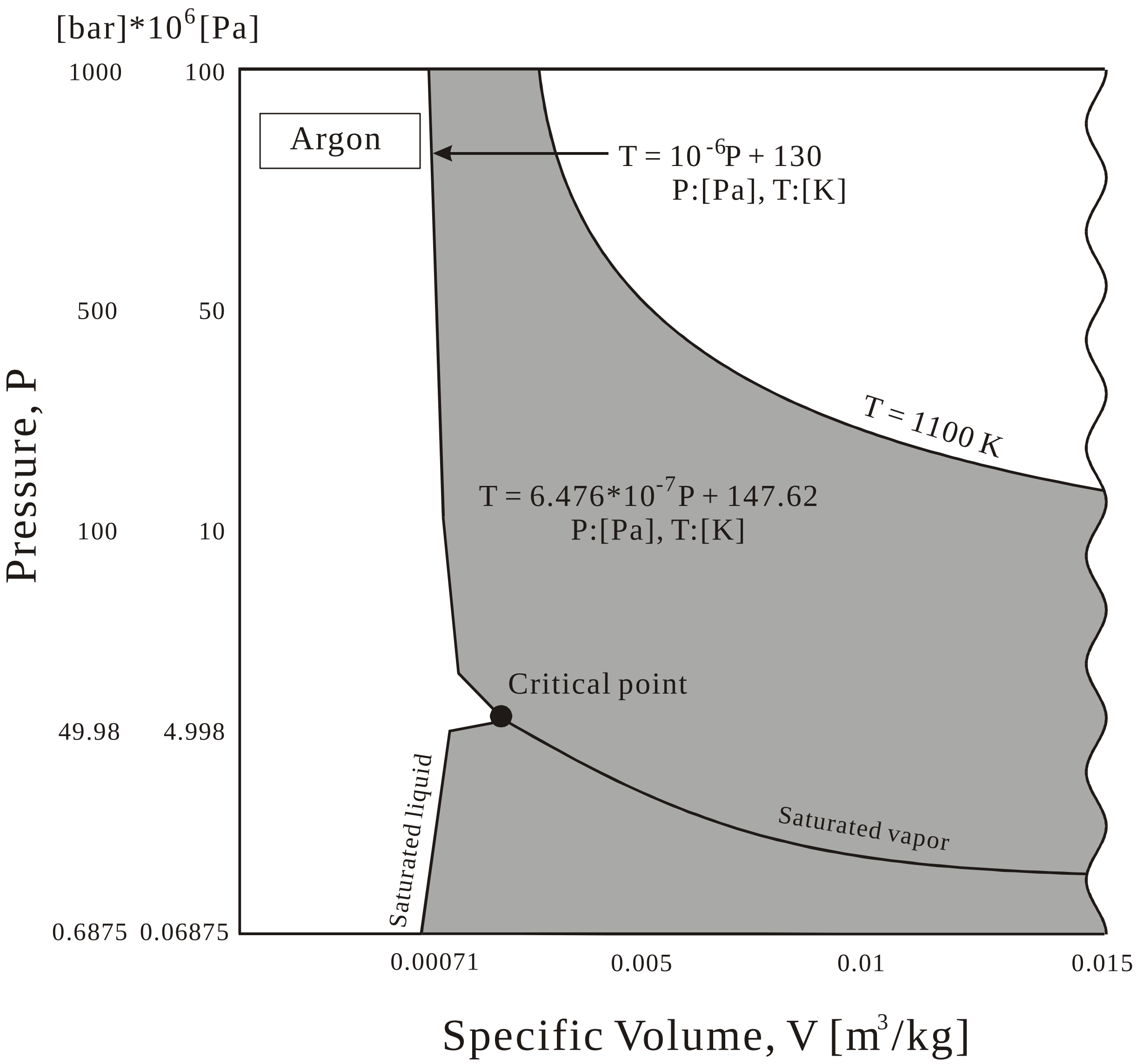


Fig.II–2.4–4 Range of Arguments(P,V) for TPV(P,V).

2.5 Krypton

Equations for thermodynamic properties have been cited from the National Standard Reference Data Service of the USSR, A Series of Property Tables [1].

2.5.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.5.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Krypton
Library File for UNIX:	libjkr.a
Library File for DOS,Windows95/NT:	JKR.LIB
Single Shot Program for UNIX:	kr-ss
Single Shot Program for DOS,Windows95/NT:	KR–SS.EXE

2.5.3 Important Constants and Others

Molecular Formula:	Kr
Relative Molecular Mass:	83.80
Gas Constant:	99.22 J/(kg·K)

Critical Constants:

Critical Pressure:	5.496×10^6Pa (54.96 bar)
Critical Temperature:	209.39 K (−63.76°C)
Critical Specific Volume:	1.098×10^{-3}m^3/kg

Triple Point:

Pressure:	0.07319×10^6Pa (0.7319 bar)
Temperature:	115.76 K (−157.39°C)

2.5.4 Formula

Equation of State:

Equations (2.44) and (3.36) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (1.70) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (2.44) and (3.36) for specific volume in reference [1].

Pressure and Temperature on Melting Line:

Equation (1.65) in reference [1].

Transport Properties:

Equations (4.25) and (6.13) in reference [1] for viscosity.

References

[1] V.A.Rabinovich, A.A.Vasserman, V.I.Nedstup and L.S.Veksler, Thermophysical Properties of NEON, ARGON, KRYPTON AND XENON, National Standard Reference Data Service of the USSR: A Series of Property Tables, Vol.10, English-Language Edition, edited by T.B.Selover, Jr., (1987).

Table II–2.5–1 Krypton Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)		
5	ALHT(T)		
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 5.496\times10^6$ [Pa] $0.7319 \leq P \leq 54.96$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 5.496\times10^6$ [Pa] $0.7319 \leq P \leq 54.96$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 209.39$ [K] $-157.39 \leq T \leq -63.76$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 209.39$ [K] $-157.39 \leq T \leq -63.76$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants P∗: 'A'='P': 5.496×10^6[Pa], 54.96 [bar] Pressure T∗: 'A'='T': 209.39 [K], −63.76 [°C] Temperature V: 'A'='V': 1.098×10^{-3} [m^3/kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 83.80 Relative Molecular Mass R: 'A'='R': 99.22 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		

Table II–2.5–1 Krypton Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)		
24	HPDD(P)		
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)		
27	HTD(T)		
28	HTDD(T)		
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'KR' Molecular Formula S: 'A'='S': 'KRYPTON' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 144$ [K] $-157.39 \leq T \leq -129.15$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 209.39$ [K] $-157.39 \leq T \leq -63.76$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)		
34	SPDD(P)		
35	SPT(P,T)		
36	SPX(P,X)		
37	STD(T)		
38	STDD(T)		
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K],[°C] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 100.7\times10^6$ [Pa] $0.7319 \leq P \leq 1007$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.07319×10^6 [Pa], 0.7319 [bar] Pressure T∗: 'A'='T': 115.76 [K], −157.39 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		

Table II–2.5–1 Krypton Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
40	TSP(P)	TSP∗: Saturation Temperature [K],[°C] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 5.496\times10^6$ [Pa] $0.7319 \leq P \leq 54.96$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)		
43	UPDD(P)		
79	UPS(P,S)		
44	UPT(P,T)		
45	UPX(P,X)		
46	UTD(T)		
47	UTDD(T)		
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 5.496\times10^6$ [Pa] $0.7319 \leq P \leq 54.96$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa],[bar]	$73.19\times10^3 \leq P \leq 5.496\times10^6$ [Pa] $0.7319 \leq P \leq 54.96$ [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 209.39$ [K] $-157.39 \leq T \leq -63.76$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K],[°C]	$115.76 \leq T \leq 209.39$ [K] $-157.39 \leq T \leq -63.76$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.6 Xenon

Equations for thermodynamic properties have been cited from the National Standard Reference Data Service of the USSR, A Series of Property Tables [1].

2.6.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.6.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Xenon
Library File for UNIX:	libjxe.a
Library File for DOS,Windows95/NT:	JXE.LIB
Single Shot Program for UNIX:	xe-ss
Single Shot Program for DOS,Windows95/NT:	XE–SS.EXE

2.6.3 Important Constants and Others

Molecular Formula:	Xe
Relative Molecular Mass:	131.3
Gas Constant:	63.32 J/(kg·K)

Critical Constants:

Critical Pressure:	5.821×10^{6}Pa (58.21 bar)
Critical Temperature:	289.74 K (16.59°C)
Critical Specific Volume:	0.9091×10^{-3}m^3/kg

Triple Point:

Pressure:	0.08160×10^{6}Pa (0.8160 bar)
Temperature:	161.36 K (−111.79°C)

2.6.4 Formula

Equation of State:
Equations (2.44) and (3.37) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:
Equation (1.70) in reference [1].

Properties at Vapor-Liquid Equilibrium:
Equations (2.44) and (3.37) for specific volume in reference [1].

Pressure and Temperature on Melting Line:
Equation (1.69) in reference [1].

Transport Properties:
Equations (4.25) and (6.13) in reference [1] for viscosity.

References

[1] V.A.Rabinovich, A.A.Vasserman, V.I.Nedstup and L.S.Veksler, Thermophysical Properties of NEON, ARGON, KRYPTON AND XENON, National Standard Reference Data Service of the USSR: A Series of Property Tables, Vol.10, English-Language Edition, edited by T.B.Selover, Jr.,(1987).

Table II–2.6–1 Xenon Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)		
5	ALHT(T)		
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 5.821\times10^6$ [Pa] $0.816 \leq P \leq 58.21$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 5.821\times10^6$ [Pa] $0.816 \leq P \leq 58.21$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$161.36 \leq T \leq 289.74$ [K] $-111.79 \leq T \leq 16.59$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$161.36 \leq T \leq 289.74$ [K] $-111.79 \leq T \leq 16.59$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants P∗: 'A'='P': 5.821×10^6[Pa], 58.21 [bar] Pressure T∗: 'A'='T': 289.74 [K], 16.59 [°C] Temperature V: 'A'='V': 0.9091×10^{-3} [m^3/kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 131.3 Relative Molecular Mass R: 'A'='R': 63.32 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		

Table II–2.6–1 Xenon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)		
24	HPDD(P)		
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)		
27	HTD(T)		
28	HTDD(T)		
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'XE' Molecular Formula S: 'A'='S': 'XENON' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	161.36≤T≤198 [K] −111.79≤T≤−75.15 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	161.36≤T≤289.74 [K] −111.79≤T≤16.59 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)		
34	SPDD(P)		
35	SPT(P,T)		
36	SPX(P,X)		
37	STD(T)		
38	STDD(T)		
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 100.1\times10^6$ [Pa] 0.816≤P≤1001 [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.08160×10^6 [Pa], 0.8160 [bar] Pressure T∗: 'A'='T': 161.36 [K], −111.79 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 5.821\times10^6$ [Pa] 0.816≤P≤58.21 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)		
43	UPDD(P)		
79	UPS(P,S)		

Table II–2.6–1 Xenon Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)		
45	UPX(P,X)		
46	UTD(T)		
47	UTDD(T)		
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 5.821\times10^6$ [Pa] $0.816 \leq P \leq 58.21$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$81.6\times10^3 \leq P \leq 5.821\times10^6$ [Pa] $0.816 \leq P \leq 58.21$ [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$161.36 \leq T \leq 289.74$ [K] $-111.79 \leq T \leq 16.59$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$161.36 \leq T \leq 289.74$ [K] $-111.79 \leq T \leq 16.59$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.7 n-Hydrogen

Equations for thermodynamic properties have been cited from reference [1], one for surface tension from Miller et al.[2], and those for viscosity and thermal conductivity from reference [3].

2.7.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.7.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	n-Hydrogen
Library File for UNIX:	libjh2.a
Library File for DOS,Windows95/NT:	JH2.LIB
Single Shot Program for UNIX:	h2-ss
Single Shot Program for DOS,Windows95/NT:	H2–SS.EXE

2.7.3 Important Constants and Others

Molecular Formula:	n-H_2
Relative Molecular Mass:	2.016
Gas Constant:	4124.62 J/(kg·K)

Critical Constants:

Critical Pressure:	1.315×10^6Pa (13.15 bar)
Critical Temperature:	33.19 K (−239.96°C)
Critical Specific Volume:	0.0332 m^3/kg

Triple Point:

Pressure:	7.199×10^3 Pa (0.07199 bar)
Temperature:	13.96 K (−259.19°C)

Reference State:

At 1.01325 bar(1 atm) and 25.01°C(298.16 K), 142.196 J/(mol·K) and 8.473×10^3 J/mol are assigned to the specific entropy and the specific enthalpy, respectively.

2.7.4 Formula

Equation of State:

Equations (4.8) and (4.14) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (4.14) and Table 31 in reference [1].

Properties on Bubble-Point Curve:

Equation (7.2) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated liquid: Equation (8.1) and Table 31 for specific volume, equation (4.14) and Table 19 for specific entropy and for specific enthalpy.

saturated liquid: Equations (4.14) and (4.15) and Table 19 for specific volume. Equations (5.1) and (5.3) for the calculation of specific entropy and specific enthalpy. Equations (5.7) and (5.8) for isochoric specific heat and isobaric specific heat.

All of these have been cited from reference [1].

Transport Properties:
Thermal conductivity and viscosity from reference [3].

The Other Properties:
Surface tension from reference [2].

References

[1] Wooly, H.W., Scott, R.B. and Brickwedde, F.C., Compilation of Thermal Properties of Hydrogen in Its Various Isotopic and Ortho-Para Modifications, J. Res. Nat. Bur. Stand., vol.41, (1948), pp.379–475.
[2] J.W. Miller, Jr. and C.L. Yaws, Chemical Engineering, vol.83, No.23, (1976), p.127.
[3] RC–72 Committee Report, Japan Society of Mechanical Engineers, (1987), pp.527–531.

Table II–2.7–1 n−Hydrogen Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $273.15 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $0 \leq T \leq 400$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $273.15 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $0 \leq T \leq 400$ [°C]
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $273.15 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $0 \leq T \leq 400$ [°C]
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $56 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $-217.15 \leq T \leq 400$ [°C]
19	CPTD(T)		
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.86902×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 1.3152×10^6 [Pa], 13.152 [bar] Pressure S: 'A'='S': 44.760×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 33.19 [K], −239.96 [°C] Temperature V: 'A'='V': 33.20×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		

Table II–2.7–1 n−Hydrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $56 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $-217.15 \leq T \leq 400$ [°C]
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 2.016 Relative Molecular Mass R: 'A'='R': 4124.62 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,13.96K)≤S≤ SPT(P,673.15K) [J/(kg·K)] $0.07199 \leq P \leq 500$ [bar] SPT(P,−259.19°C)≤S≤ SPT(P,400°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $13.96 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $-259.19 \leq T \leq 400$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'N-H2' Molecular Formula S: 'A'='S': 'N-HYDROGEN' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		

Table II–2.7–1 n−Hydrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $273.15 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $0 \leq T \leq 400$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] $13.96 \leq T \leq 673.15$ [K] $0.07199 \leq P \leq 500$ [bar] $-259.19 \leq T \leq 400$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.199\times10^3 \leq P \leq 1.3152\times10^6$ [Pa] $0.07199 \leq P \leq 13.152$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$13.96 \leq T \leq 33.19$ [K] $-259.19 \leq T \leq -239.96$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] HPT(P,13.96K)≤H≤ HPT(P,673.15K) [J/kg] $0.07199 \leq P \leq 500$ [bar] HPT(P,−259.19°C)≤H≤ HPT(P,400°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.199\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,13.96K)≤S≤ SPT(P,673.15K) [J/(kg·K)] $0.07199 \leq P \leq 500$ [bar] SPT(P,−259.19°C)≤S≤ SPT(P,400°C) [J/(kg·K)]

Table II–2.7–1 n−Hydrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$7.199\times10^3 \le P \le 50\times10^6$ [Pa] VPT(P,13.96K)≤V≤ VPT(P,673.15K) [m^3/kg] 0.07199≤P≤500 [bar] VPT(P,−259.19°C)≤V≤ VPT(P,400°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 7.199×10^3 [Pa], 0.07199 [bar] Pressure T∗: 'A'='T': 13.96 [K], −259.19 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar]
79	UPS(P,S)		
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \le P \le 50\times10^6$ [Pa] 13.96≤T≤673.15 [K] 0.07199≤P≤500 [bar] −259.19≤T≤400 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar]
80	VPS(P,S)		
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.199\times10^3 \le P \le 50\times10^6$ [Pa] 13.96≤T≤673.15 [K] 0.07199≤P≤500 [bar] −259.19≤T≤400 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.199\times10^3 \le P \le 1.3152\times10^6$ [Pa] 0.07199≤P≤13.152 [bar] 0≤X≤1.0 [–]

Table II–2.7–1 n−Hydrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	7.199×10^3≤P≤50×10^6 [Pa] 273.15≤T≤673.15 [K] 0.07199≤P≤500 [bar] 0≤T≤400 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	7.199×10^3≤P≤1.3152×10^6 [Pa] 0.07199≤P≤13.152 [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	7.199×10^3≤P≤1.3152×10^6 [Pa] 0.07199≤P≤13.152 [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	7.199×10^3≤P≤1.3152×10^6 [Pa] 0.07199≤P≤13.152 [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	7.199×10^3≤P≤1.3152×10^6 [Pa] 0.07199≤P≤13.152 [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	13.96≤T≤33.19 [K] −259.19≤T ≤−239.96 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.8 Fluorine

Equations for thermodynamic properties have been cited from the IUPAC Table [1].

2.8.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.8.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Fluorine
Library File for UNIX:	libjf2.a
Library File for DOS,Windows95/NT:	JF2.LIB
Single Shot Program for UNIX:	f2-ss
Single Shot Program for DOS,Windows95/NT:	F2–SS.EXE

2.8.3 Important Constants and Others

Molecular Formula:	F_2
Relative Molecular Mass:	37.99681
Gas Constant:	218.8205 J/(kg·K)

Critical Constants:

Critical Pressure:	5.23952×10^6Pa (52.3952 bar)
Critical Temperature:	144.414 K (−128.736°C)
Critical Specific Volume:	1.686727×10^{-3}m^3/kg

Triple Point:

Pressure:	239 Pa (2.39×10^{-3} bar)
Temperature:	53.481 K (−219.669°C)

Reference State:

At 1 bar and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.8.4 Formula

Equation of State:

Equation (4.1) in a function form of $A = A(\rho, T)$ in reference [1]. Here A=specific Helmholtz free energy, ρ=density and T=temperature.

Vapor Pressure:

Equation (4.1) [equation of state] and equation (4.25) [the Gibbs condition for phase equilibrium] in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (4.1) [equation of state] and equation (4.25) [the Gibbs condition for phase equilibrium] for specific volume of both saturated liquid and saturated vapor. Equations (4.7) and (4.10) using these specific volumes for specific entropy and specific enthalpy, respectively. Equations (4.13) and (4.11) using these specific volumes for isobaric specific heat and isochoric specific heat, respectively. All of these equations have been cited from reference [1].

Pressure and Temperature on Melting Line:

Equations (4.26) in reference [1].

References

[1] K.M.de Reuck, International Thermodynamic Table of the Fluid State-11, Fluorine, IUPAC, vol.11, (1990).

Table II–2.8–1 Fluorine Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]

Table II–2.8–1 Fluorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -0.210537×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 5.23952×10^6 [Pa], 52.3952 [bar] Pressure S: 'A'='S': -1.96455×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 144.414 [K], −128.736 [°C] Temperature V: 'A'='V': 1.68673×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 37.99681 Relative Molecular Mass R: 'A'='R': 218.8205 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \leq P \leq 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \leq P \leq 200$ [bar] TMLP(P)≤T≤26.85 [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \leq P \leq 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \leq P \leq 52.3952$ [bar]

Table II–2.8–1 Fluorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,300K) [J/(kg·K)] $2.39\times10^{-3} \le P \le 200$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,26.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \le P \le 200$ [bar] TMLP(P)≤T≤26.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'F2' Molecular Formula S: 'A'='S': 'FLUORINE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	53.481≤T≤55.399 [K] −219.669≤T≤−217.751 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \le P \le 200$ [bar] TMLP(P)≤T≤26.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] 0≤X≤1.0 [–]

Table II–2.8–1 Fluorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$53.481 \le T \le 144.414$ [K] $-219.669 \le T \le -128.736$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$53.481 \le T \le 144.414$ [K] $-219.669 \le T \le -128.736$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$53.481 \le T \le 144.414$ [K] $-219.669 \le T \le -128.736$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 200$ [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,300K) [J/kg] $2.39\times10^{-3} \le P \le 200$ [bar] HPT(P,TMLP(P))≤H≤ HPT(P,26.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,300K) [J/(kg·K)] $2.39\times10^{-3} \le P \le 200$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,26.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$5.23952\times10^6 < P \le 20\times10^6$ [Pa] $52.3952 < P \le 200$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,300K) [m^3/kg] $2.39\times10^{-3} \le P \le 200$ [bar] VPT(P,TMLP(P))≤V≤ VPT(P,26.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.239×10^3 [Pa], 2.39×10^{-3} [bar] Pressure T∗: 'A'='T': 53.481 [K], −219.669 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]

Table II–2.8–1 Fluorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,300K) [J/(kg·K)] $2.39\times10^{-3} \le P \le 200$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,26.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \le P \le 200$ [bar] TMLP(P)≤T≤26.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy[J/(kg·K)]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,300K) [J/(kg·K)] $2.39\times10^{-3} \le P \le 200$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,26.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \le P \le 200$ [bar] TMLP(P)≤T≤26.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.239\times10^3 \le P \le 20\times10^6$ [Pa] TMLP(P)≤T≤300 [K] $2.39\times10^{-3} \le P \le 200$ [bar] TMLP(P)≤T≤26.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.8–1 Fluorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.239\times10^3 \le P \le 5.23952\times10^6$ [Pa] $2.39\times10^{-3} \le P \le 52.3952$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	53.481≤T≤144.414 [K] −219.669≤T≤−128.736 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.9 Chlorine

Equations for thermodynamic properties have been cited from the IUPAC Table [1], those for transport properties from Miller et al.[2]-[4], and one for surface tension from Miller et al.[5].

2.9.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.9.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Chlorine
Library File for UNIX:	libjcl2.a
Library File for DOS,Windows95/NT:	JCL2.LIB
Single Shot Program for UNIX:	cl2-ss
Single Shot Program for DOS,Windows95/NT:	CL2–SS.EXE

2.9.3 Important Constants and Others

Molecular Formula:	$C\ell_2$
Relative Molecular Mass:	70.906
Gas Constant:	117.259 J/(kg·K)

Critical Constants:

Critical Pressure:	7.9914×10^6Pa (79.914 bar)
Critical Temperature:	416.956 K (143.806°C)
Critical Specific Volume:	1.7337×10^{-3}m^3/kg

Triple Point:

Pressure:	1.387×10^3 Pa (0.01387 bar)
Temperature:	172.17 K (−100.98°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.9.4 Formula

Equation of State:

Equation (21) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (21) [equation of state] and the Gibbs condition for phase equilibrium in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (21) [equation of state] and Gibbs condition for phase equilibrium for specific volume, equation (24) for specific entropy, equation (29) for specific enthalpy and equation (34) for isobaric specific heat, respectively. All of these have been cited from reference [1]. However, the third term in the right side of equation (34)

$$C_p(\rho,T) = C_p^{id}(T) - R + R[\sum_{i=1}^{18} N_i(XC)_i]_0^w + \cdots$$

has been corrected to

$$C_p(\rho, T) = C_p^{id}(T) - R - R[\sum_{i=1}^{18} N_i(XC)_i]_0^w + \cdots$$

Transport Properties:
Thermal conductivity at room pressure from reference [2], viscosity at room pressure from reference [3], and viscosity of saturated liquid from reference [4].

The Other Properties:
Surface tension from reference [5].

References

[1] S.Angus, B.Armstrong and K.M.de Reuck, International Thermodynamic Table of the Fluid State-8, Chlorine, IUPAC, (1974).
[2] J.W.Miller Jr., P.N.Shah and C.L.Yaws, Chem. Eng., 83–24, (1976), p.153.
[3] J.W.Miller Jr., G.R.Schorr and C.L.Yaws, Chem. Eng., 83–24, (1976), p.155.
[4] J.W.Miller Jr., G.R.Schorr and C.L.Yaws, Chem. Eng., 83–24, (1976), p.157.
[5] J.W.Miller Jr. and C.L.Yaws, Chem. Eng., 83–23, (1976), p.127.

Table II–2.9–1 Chlorine Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P < 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P < 79.914$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $193.15 \leq T \leq 1473.15$ [K] $-80 \leq T \leq 1200$ [°C]
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity at Ordinary Pressure [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $73.15 \leq T \leq 1473.15$ [K] $-200 \leq T \leq 1200$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]

Table II–2.9–1 Chlorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P < 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P < 79.914$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P < 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P < 79.914$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -81.188×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 7.9914×10^6 [Pa], 79.914 [bar] Pressure S: 'A'='S': −632.74 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 416.956 [K], 143.806 [°C] Temperature V: 'A'='V': 1.7337×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		

Table II–2.9–1 Chlorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 70.906 Relative Molecular Mass R: 'A'='R': 117.259 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$1.3871\times10^3\leq P\leq 7.9914\times10^6$ [Pa] $13.871\times10^{-3}\leq P\leq 79.914$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0\leq P\leq 25\times10^6$ [Pa] $180\leq T\leq 900$ [K] $0\leq P\leq 250$ [bar] $-93.15\leq T\leq 626.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$172.17\leq T\leq 416.956$ [K] $-100.98\leq T\leq 143.806$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.3871\times10^3\leq P\leq 7.9914\times10^6$ [Pa] $13.871\times10^{-3}\leq P\leq 79.914$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.3871\times10^3\leq P\leq 7.9914\times10^6$ [Pa] $13.871\times10^{-3}\leq P\leq 79.914$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\leq P\leq 25\times10^6$ [Pa] SPT(P,180K)≤S≤ SPT(P,900K) [J/(kg·K)] $0.1\times10^{-3}\leq P\leq 250$ [bar] SPT(P,−93.15°C)≤S≤ SPT(P,626.95°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0\leq P\leq 25\times10^6$ [Pa] $180\leq T\leq 900$ [K] $0\leq P\leq 250$ [bar] $-93.15\leq T\leq 626.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.3871\times10^3\leq P\leq 7.9914\times10^6$ [Pa] $13.871\times10^{-3}\leq P\leq 79.914$ [bar] $0\leq X\leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$172.17\leq T\leq 416.956$ [K] $-100.98\leq T\leq 143.806$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$172.17\leq T\leq 416.956$ [K] $-100.98\leq T\leq 143.806$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$172.17\leq T\leq 416.956$ [K] $-100.98\leq T\leq 143.806$ [°C] $0\leq X\leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CL2' Molecular Formula S: 'A'='S': 'CHLORINE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		

Table II–2.9–1 Chlorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $193.15 \leq T \leq 900$ [K] $-80 \leq T \leq 626.85$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10 \leq P \leq 25 \times 10^6$ [Pa] $180 \leq T \leq 900$ [K] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDLP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$10 \leq P \leq 25 \times 10^6$ [Pa] HPT(P,180K)≤H≤ HPT(P,900K) [J/kg] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] HPT(P,−93.15°C)≤H≤ HPT(P,626.95°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10 \leq P \leq 25 \times 10^6$ [Pa] SPT(P,180K)≤S≤ SPT(P,900K) [J/(kg·K)] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] SPT(P,−93.15°C)≤S≤ SPT(P,626.95°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$7.9914 \times 10^6 < P \leq 25 \times 10^6$ [Pa] $79.914 < P \leq 250$ [bar]

Table II–2.9–1 Chlorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$10 \leq P \leq 25 \times 10^6$ [Pa] VPT(P,180K)≤V≤ VPT(P,900K) [m^3/kg] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] VPT(P,−93.15°C)≤V≤ VPT(P,626.95°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 1.3871×10^3 [Pa], 13.871×10^{-3} [bar] Pressure T∗: 'A'='T': 172.170 [K], −100.980 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10 \leq P \leq 25 \times 10^6$ [Pa] SPT(P,180K)≤S≤ SPT(P,900K) [J/(kg·K)] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] SPT(P,−93.15°C)≤S≤ SPT(P,626.95°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25 \times 10^6$ [Pa] 180≤T≤900 [K] 0≤P≤250 [bar] −93.15≤T≤626.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	172.17≤T≤416.956 [K] −100.98≤T≤143.806 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	172.17≤T≤416.956 [K] −100.98≤T≤143.806 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	172.17≤T≤416.956 [K] −100.98≤T≤143.806 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.3871 \times 10^3 \leq P \leq 7.9914 \times 10^6$ [Pa] $13.871 \times 10^{-3} \leq P \leq 79.914$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10 \leq P \leq 25 \times 10^6$ [Pa] SPT(P,180K)≤S≤ SPT(P,900K) [J/(kg·K)] $0.1 \times 10^{-3} \leq P \leq 250$ [bar] SPT(P,−93.15°C)≤S≤ SPT(P,626.95°C) [J/(kg·K)]

Table II–2.9–1 Chlorine Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10 \leq P \leq 25\times10^6$ [Pa] $180 \leq T \leq 900$ [K] $0.1\times10^{-3} \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.3871\times10^3 \leq P \leq 7.9914\times10^6$ [Pa] $13.871\times10^{-3} \leq P \leq 79.914$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$172.17 \leq T \leq 416.956$ [K] $-100.98 \leq T \leq 143.806$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 25\times10^6$ [Pa] $180 \leq T \leq 900$ [K] $0 \leq P \leq 250$ [bar] $-93.15 \leq T \leq 626.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.3871\times10^3 \leq P < 7.9914\times10^6$ [Pa] $13.871\times10^{-3} \leq P < 79.914$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.3871\times10^3 \leq P < 7.9914\times10^6$ [Pa] $13.871\times10^{-3} \leq P < 79.914$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.3871\times10^3 \leq P < 7.9914\times10^6$ [Pa] $13.871\times10^{-3} \leq P < 79.914$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.3871\times10^3 \leq P < 7.9914\times10^6$ [Pa] $13.871\times10^{-3} \leq P < 79.914$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$172.17 \leq T < 416.956$ [K] $-100.98 \leq T < 143.806$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.10 Nitrogen

Equations for thermodynamic properties have been cited from the IUPAC Tables[1], those for transport properties from Stephan et al.[2], and those for other properties from Jacobsen et al.[3].

2.10.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.10.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Nitrogen
Library File for UNIX:	libjn2.a
Library File for DOS,Windows95/NT:	JN2.LIB
Single Shot Program for UNIX:	n2-ss
Single Shot Program for DOS,Windows95/NT:	N2–SS.EXE

2.10.3 Important Constants and Others

Molecular Formula:	N_2
Relative Molecular Mass:	28.0134
Gas Constant:	296.8115 J/(kg·K)

Critical Constants:

Critical Pressure:	3.4000×10^6Pa (34.000 bar)
Critical Temperature:	126.20 K (−146.95°C)
Critical Specific Volume:	3.1847×10^{-3}m^3/kg

Triple Point:

Pressure:	0.01253×10^6Pa (0.1253 bar)
Temperature:	63.148 K (−210.002°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.10.4 Formula

Equation of State:

Equation (9) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=Temperature.

Vapor Pressure:

Equation (2) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (2) and (9) for specific volume, equation (12) for specific enthalpy, equation (15) for specific entropy and equation (19) for isobaric specific heat, respectively. All of these have been cited from reference [1]. However, the third term in the right side of equation (19),

$$C_p(\rho,T) = C_p^{id}(T) - R + R[\sum_{i=1}^{32} N_i(XC)_i]_0^w + \cdots$$

has been corrected to

$$C_p(\rho, T) = C_p^{id}(T) - R - R[\sum_{i=1}^{32} N_i(XC)_i]_0^w + \cdots$$

Pressure and Temperature on Melting Line:
Equation (1) in reference [1].

Transport Properties:
Viscosity and thermal conductivity from Equations (1) and (5) in reference [2], respectively.

The Other Properties:
Surface tension and static dielectric constant from equations (19) and (20) in reference [3], respectively.

References

[1] S.Angus, B.Armstrong and K.M.de Reuck, Nitrogen International Thermodynamic Table of the Fluid State-6, IUPAC, (1979).
[2] K.Stephan, R.Krauss and A.Laesecke, J. Phys. Chem. Ref. Data, 16–4, (1987), pp.993–1023.
[3] R.T.Jacobsen, R.B.Stewart, R.D.McCarty and H.J.M. Hanley, N.B.S. Technical Note 648, (December, 1973).

Table II–2.10–1 Nitrogen Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \leq P \leq 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \leq P \leq 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \leq P < 3.4\times10^6$ [Pa] 0.1253≤P<34 [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \leq P \leq 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \leq P < 3.4\times10^6$ [Pa] 0.1253≤P<34 [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$12.53\times10^3 \leq P < 3.4\times10^6$ [Pa] 0.1253≤P<34 [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \leq P \leq 100\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤1000 [bar] TMLP(P)≤T≤826.85 [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \leq P \leq 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \leq P \leq 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \leq P \leq 100\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤1000 [bar] TMLP(P)≤T≤826.85 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P < 3.4\times10^6$ [Pa] 0.1253≤P<34 [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P < 3.4\times10^6$ [Pa] 0.1253≤P<34 [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 30.703×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.4×10^6 [Pa], 34.0 [bar] Pressure S: 'A'='S': 4.2266×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 126.2 [K], −146.95 [°C] Temperature V: 'A'='V': 3.1847×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)	EPSPT: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1000 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤726.85 [°C]
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 28.0134 Relative Molecular Mass R: 'A'='R': 296.8115 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.398\times10^6$ [Pa] 0.1253≤P≤33.98 [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$12.53\times10^3 \le P \le 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] 0.1253≤P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C] 0≤X≤1.0 [–]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'N2' Molecular Formula S: 'A'='S': 'NITROGEN' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$63.148 \le T \le 190.4$ [K] $-210.002 \le T \le -82.75$ [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P < 3.4\times10^6$ [Pa] $0.1253 \le P < 34$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P < 3.4\times10^6$ [Pa] $0.1253 \le P < 34$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 100\times10^6$ [Pa] TMLP(P)$\le T \le 1100$ [K] $0.1253 \le P \le 1000$ [bar] TMLP(P)$\le T \le 826.85$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$63.148 \le T < 126.2$ [K] $-210.002 \le T < -146.95$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$63.148 \le T < 126.2$ [K] $-210.002 \le T < -146.95$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$63.148 \le T \le 126.2$ [K] $-210.002 \le T \le -146.95$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] $0.1253 \le P \le 34$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$63.148 \le T \le 126.2$ [K] $-210.002 \le T \le -146.95$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] $0.1253 \le P \le 34$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] $0.1253 \le P \le 34$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3 \le P \le 10^9$ [Pa] TMLP(P)$\le T \le 1100$ [K] $0.1253 \le P \le 10000$ [bar] TMLP(P)$\le T \le 826.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$12.53\times10^3 \le P \le 3.4\times10^6$ [Pa] $0.1253 \le P \le 34$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$63.148 \le T \le 126.2$ [K] $-210.002 \le T \le -146.95$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$63.148 \le T \le 126.2$ [K] $-210.002 \le T \le -146.95$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$63.148 \le T \le 126.2$ [K] $-210.002 \le T \le -146.95$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$12.53\times10^3 \le P \le 10^9$ [Pa] $0.1253 \le P \le 10000$ [bar]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$12.53\times10^3\leq P\leq10^9$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,1100K) [J/kg] 0.1253≤P≤10000 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,826.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$12.53\times10^3\leq P\leq10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] 0.1253≤P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$3.4\times10^6<P\leq100\times10^6$ [Pa] 34<P≤1000 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$12.53\times10^3\leq P\leq10^9$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1100K) [m^3/kg] 0.1253≤P≤10000 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,826.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 12.53×10^3 [Pa], 0.1253 [bar] Pressure T∗: 'A'='T': 63.148 [K], −210.002 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$12.53\times10^3\leq P\leq3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$12.53\times10^3\leq P\leq3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$12.53\times10^3\leq P\leq3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$12.53\times10^3\leq P\leq10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] 0.1253≤P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53\times10^3\leq P\leq10^9$ [Pa] TMLP(P)≤T≤1100 [K] 0.1253≤P≤10000 [bar] TMLP(P)≤T≤826.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$12.53\times10^3\leq P\leq3.4\times10^6$ [Pa] 0.1253≤P≤34 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	63.148≤T≤126.2 [K] −210.002≤T≤−146.95 [°C]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$63.148 \leq T \leq 126.2$ [K] $-210.002 \leq T \leq -146.95$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$63.148 \leq T \leq 126.2$ [K] $-210.002 \leq T \leq -146.95$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$12.53 \times 10^3 \leq P \leq 3.4 \times 10^6$ [Pa] $0.1253 \leq P \leq 34$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$12.53 \times 10^3 \leq P \leq 3.4 \times 10^6$ [Pa] $0.1253 \leq P \leq 34$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$12.53 \times 10^3 \leq P \leq 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] $0.1253 \leq P \leq 10000$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53 \times 10^3 \leq P \leq 10^9$ [Pa] TMLP(P)≤T≤1100 [K] $0.1253 \leq P \leq 10000$ [bar] TMLP(P)≤T≤826.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$12.53 \times 10^3 \leq P \leq 3.4 \times 10^6$ [Pa] $0.1253 \leq P \leq 34$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$63.148 \leq T \leq 126.2$ [K] $-210.002 \leq T \leq -146.95$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$63.148 \leq T \leq 126.2$ [K] $-210.002 \leq T \leq -146.95$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$63.148 \leq T \leq 126.2$ [K] $-210.002 \leq T \leq -146.95$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$12.53 \times 10^3 \leq P \leq 10^9$ [Pa] TMLP(P)≤T≤1100 [K] $0.1253 \leq P \leq 10000$ [bar] TMLP(P)≤T≤826.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$12.53 \times 10^3 \leq P < 3.4 \times 10^6$ [Pa] $0.1253 \leq P < 34$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$12.53 \times 10^3 \leq P < 3.4 \times 10^6$ [Pa] $0.1253 \leq P < 34$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$12.53 \times 10^3 \leq P < 3.4 \times 10^6$ [Pa] $0.1253 \leq P < 34$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]

Table II–2.10–1 Nitrogen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$12.53\times10^3 \leq P < 3.4\times10^6$ [Pa] $0.1253 \leq P < 34$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	63.148≤T<126.2 [K] −210.002≤T<−146.95 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.11 Oxygen

Equations for thermodynamic properties have been cited from Sychev et al.[1].

2.11.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.11.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Oxygen
Library File for UNIX:	libjo2.a
Library File for DOS,Windows95/NT:	JO2.LIB
Single Shot Program for UNIX:	o2-ss
Single Shot Program for DOS,Windows95/NT:	O2–SS.EXE

2.11.3 Important Constants and Others

Molecular Formula:	O_2
Relative Molecular Mass:	31.9988
Gas Constant:	259.835 J/(kg·K)

Critical Constants:

Critical Pressure:	5.043×10^6Pa (50.43 bar)
Critical Temperature:	154.581 K (−118.569°C)
Critical Specific Volume:	2.2925×10^{-3}m^3/kg

Triple Point:

Pressure:	0.1463×10^3 Pa (1.463×10^{-3}bar)
Temperature:	54.361 K (−218.789°C)

Reference State:

At 0K(−273.15°C), 275.542×10^3 J/kg is assigned to the heat of sublimation and 0 J/(kg·K) to the specific entropy.

2.11.4 Formula

Equation of State:

Equation (3.6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (3.6) [equation of state] in reference [1] and the Gibbs condition for phase equilibrium.

Properties at Vapor-Liquid Equilibrium:

Equation (3.6) [equation of state] and the Gibbs condition for phase equilibrium for specific volume of both saturated liquid and saturated vapor. Equation (2.5) together with these specific volumes for specific entropy, specific enthalpy, isobaric specific heat and isochoric specific heat. All of these equations have been cited from reference [1].

References

[1] V.V.Sychev, A.A.Vasserman, A.D.Kozlov, G.A.Spiridonov and V.A.Tsymarny, Thermodynamic Properties of Oxygen, National Standard Reference Data of the USSR: A Series of Property Tables, Vol.5, Hemisphere Pub. Corp., (1987).

Table II–2.11–1 Oxygen Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6\leq P\leq5.43\times10^6$ [Pa] $55\leq T\leq1500$ [K], $5.43\times10^6<P\leq100\times10^6$ [Pa] $T_L\leq T\leq1500$ [K], $T_L=54.3+0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0\leq P\leq54.3$ [bar] $-218.15\leq T\leq1226.85$ [°C], $54.3<P\leq1000$ [bar] $T_L\leq T\leq1226.85$ [°C], $T_L=54.3+0.011347\times P$ $-0.68962\times10^{-6}\times P^2-273.15$
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$55\leq T\leq154.581$ [K] $-218.15\leq T\leq-118.569$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] $55 \leq T \leq 1500$ [K], $5.43\times10^6 < P \leq 100\times10^6$ [Pa] $T_L \leq T \leq 1500$ [K], $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 54.3$ [bar] $-218.15 \leq T \leq 1226.85$ [°C], $54.3 < P \leq 1000$ [bar] $T_L \leq T \leq 1226.85$ [°C], $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.30904×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 5.043×10^6 [Pa], 50.43 [bar] Pressure S: 'A'='S': 4.2077×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 154.581 [K], −118.569 [°C] Temperature V: 'A'='V': 2.2925×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] $55 \leq T \leq 1500$ [K], $5.43\times10^6 < P \leq 100\times10^6$ [Pa] $T_L \leq T \leq 1500$ [K], $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 54.3$ [bar] $-218.15 \leq T \leq 1226.85$ [°C], $54.3 < P \leq 1000$ [bar] $T_L \leq T \leq 1226.85$ [°C], $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 31.9988 Relative Molecular Mass R: 'A'='R': 259.835 [J/(kg·K)] Gas Constant	one of 'M' and 'R'

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] SPT(P,55K)≤S≤ SPT(P,1500K) [J/(kg·K)] $5.43\times10^6 < P \leq 100\times10^6$ [Pa] SPT(P,T_L)≤S≤ SPT(P,1500K) [J/(kg·K)] $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 50.43$ [bar] SPT(P,−218.15°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $50.43 < P \leq 1000$ [bar] SPT(P,T_L)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] $55 \leq T \leq 1500$ [K], $5.43\times10^6 < P \leq 100\times10^6$ [Pa] $T_L \leq T \leq 1500$ [K], $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 54.3$ [bar] $-218.15 \leq T \leq 1226.85$ [°C], $54.3 < P \leq 1000$ [bar] $T_L \leq T \leq 1226.85$ [°C], $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'O2' Molecular Formula S: 'A'='S': 'OXYGEN' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] $55 \leq T \leq 1500$ [K], $5.43\times10^6 < P \leq 100\times10^6$ [Pa] $T_L \leq T \leq 1500$ [K], $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 54.3$ [bar] $-218.15 \leq T \leq 1226.85$ [°C], $54.3 < P \leq 1000$ [bar] $T_L \leq T \leq 1226.85$ [°C], $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.1\times10^6 \le P \le 5.43\times10^6$ [Pa] HPT(P, 55K)≤H≤ HPT(P,1500K) [J/kg] $5.43\times10^6 < P \le 100\times10^6$ [Pa] HPT(P,T_L)≤H≤ HPT(P,1500K) [J/kg] $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ 1.0≤P≤50.43 [bar] HPT(P,−218.15°C)≤H≤ HPT(P,1226.85°C) [J/kg] 50.43<P≤1000 [bar] HPT(P,T_L)≤H≤ HPT(P,1226.85°C) [J/kg] $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \le P \le 5.43\times10^6$ [Pa] SPT(P,55K)≤S≤ SPT(P,1500K) [J/(kg·K)] $5.43\times10^6 < P \le 100\times10^6$ [Pa] SPT(P,T_L)≤S≤ SPT(P,1500K) [J/(kg·K)] $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ 1.0≤P≤50.43 [bar] SPT(P,−218.15°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 50.43<P≤1000 [bar] SPT(P,T_L)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$5.043\times10^6 < P \le 50.0\times10^6$ [Pa] 50.43<P≤500 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.1\times10^6 \le P \le 5.43\times10^6$ [Pa] VPT(P,55K)≤V≤ VPT(P,1500K) [m^3/kg] $5.43\times10^6 < P \le 100\times10^6$ [Pa] VPT(P,T_L)≤V≤ VPT(P,1500K) [m^3/kg] $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ 1.0≤P≤50.43 [bar] VPT(P,−218.15°C)≤V≤ VPT(P,1226.85°C) [m^3/kg] 50.43<P≤1000 [bar] VPT(P,T_L)≤V≤ VPT(P,1226.85°C) [m^3/kg] $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 146.3 [Pa], 1.463×10^{-3} [bar] Pressure T∗: 'A'='T': 54.361 [K], −218.789 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6\leq P\leq5.43\times10^6$ [Pa] SPT(P,55K)≤S≤ SPT(P,1500K) [J/(kg·K)] $5.43\times10^6<P\leq100\times10^6$ [Pa] SPT(P,T_L)≤S≤ SPT(P,1500K) [J/(kg·K)] $T_L=54.3+0.11347\times10^{-6}\times P-0.68962\times10^{-16}\times P^2$ $1.0\leq P\leq50.43$ [bar] SPT(P,−218.15°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $50.43<P\leq1000$ [bar] SPT(P,T_L)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $T_L=54.3+0.011347\times P-0.68962\times10^{-6}\times P^2-273.15$
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6\leq P\leq5.43\times10^6$ [Pa] $55\leq T\leq1500$ [K], $5.43\times10^6<P\leq100\times10^6$ [Pa] $T_L\leq T\leq1500$ [K], $T_L=54.3+0.11347\times10^{-6}\times P-0.68962\times10^{-16}\times P^2$ $1.0\leq P\leq54.3$ [bar] $-218.15\leq T\leq1226.85$ [°C], $54.3<P\leq1000$ [bar] $T_L\leq T\leq1226.85$ [°C], $T_L=54.3+0.011347\times P-0.68962\times10^{-6}\times P^2-273.15$
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.2\times10^3\leq P\leq5.043\times10^6$ [Pa] $2.0\times10^{-3}\leq P\leq50.43$ [bar] $0\leq X\leq1.0$ [–]

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] SPT(P,55K)≤S≤ SPT(P,1500K) [J/(kg·K)] $5.43\times10^6 < P \leq 100\times10^6$ [Pa] SPT(P,T_L)≤S≤ SPT(P,1500K) [J/(kg·K)] $T_L=54.3+0.11347\times10^{-6}\times P -0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 50.43$ [bar] SPT(P,−218.15°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $50.43 < P \leq 1000$ [bar] SPT(P,T_L)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] $T_L=54.3+0.011347\times P -0.68962\times10^{-6}\times P^2-273.15$
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 5.43\times10^6$ [Pa] $55 \leq T \leq 1500$ [K], $5.43\times10^6 < P \leq 100\times10^6$ [Pa] $T_L \leq T \leq 1500$ [K], $T_L=54.3+0.11347\times10^{-6}\times P -0.68962\times10^{-16}\times P^2$ $1.0 \leq P \leq 54.3$ [bar] $-218.15 \leq T \leq 1226.85$ [°C], $54.3 < P \leq 1000$ [bar] $T_L \leq T \leq 1226.85$ [°C], $T_L=54.3+0.011347\times P -0.68962\times10^{-6}\times P^2-273.15$
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.2\times10^3 \leq P \leq 5.043\times10^6$ [Pa] $2.0\times10^{-3} \leq P \leq 50.43$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$55 \leq T \leq 154.581$ [K] $-218.15 \leq T \leq -118.569$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		

Table II–2.11–1 Oxygen Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 5.43\times10^6$ [Pa] $55 \le T \le 1500$ [K], $5.43\times10^6 < P \le 100\times10^6$ [Pa] $T_L \le T \le 1500$ [K], $T_L = 54.3 + 0.11347\times10^{-6}\times P$ $-0.68962\times10^{-16}\times P^2$ $1.0 \le P \le 54.3$ [bar] $-218.15 \le T \le 1226.85$ [°C], $54.3 < P \le 1000$ [bar] $T_L \le T \le 1226.85$ [°C], $T_L = 54.3 + 0.011347\times P$ $-0.68962\times10^{-6}\times P^2 - 273.15$
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.2\times10^3 \le P \le 5.043\times10^6$ [Pa] $2.0\times10^{-3} \le P \le 50.43$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.2\times10^3 \le P \le 5.043\times10^6$ [Pa] $2.0\times10^{-3} \le P \le 50.43$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.2\times10^3 \le P \le 5.043\times10^6$ [Pa] $2.0\times10^{-3} \le P \le 50.43$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.2\times10^3 \le P \le 5.043\times10^6$ [Pa] $2.0\times10^{-3} \le P \le 50.43$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$55 \le T \le 154.581$ [K] $-218.15 \le T \le -118.569$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$55 \le T \le 154.581$ [K] $-218.15 \le T \le -118.569$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$55 \le T \le 154.581$ [K] $-218.15 \le T \le -118.569$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$55 \le T \le 154.581$ [K] $-218.15 \le T \le -118.569$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.12 Air

Equations for the thermodynamic properties have been cited from Baehr et al.[1], and those for transport properties from Kadoya et al.[2].

2.12.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.12.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Air
Library File for UNIX:	libjair.a
Library File for DOS,Windows95/NT:	JAIR.LIB
Single Shot Program for UNIX:	air-ss
Single Shot Program for DOS,Windows95/NT:	AIR–SS.EXE

2.12.3 Important Constants and Others

Molecular Formula:	Air mixture
	N_2= 0.7841 (kmol $_{N_2}$/kmol $_{Air}$)
	O_2= 0.2066 (kmol $_{O_2}$/kmol $_{Air}$)
	Ar= 0.0093 (kmol $_{Ar}$/kmol $_{Air}$)
Molecular Weight:	28.96
Gas Constant:	287.22 J/(kg·K)

Critical Constants (Maximum Temperature):	Critical Pressure:	3.76625×10^6Pa (37.6625 bar)
	Critical Temperature:	132.52K(−140.63°C)
	Critical Specific Volume:	3.19489×10^{-3}m^3/kg

Critical Constants (Minimum Pressure):	Critical Pressure:	3.77431×10^6Pa (37.7431 bar)
	Critical Temperature:	132.42K(−140.73°C)
	Critical Specific Volume:	2.96020×10^{-3}m^3/kg

Reference State:
At 1.01325 bar (1 atm) and −233.15°C(40 K)(ideal gas), 4845.72J/(kg·K) is assigned to the specific entropy. At −233.15°C(40 K)(ideal gas), 28325.0 J/kg is assigned to the specific internal energy.

2.12.4 Formula

Equation of State:
Equations (28) and (43b) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Pressure and Temperature on Dew-Point Curve (Saturated Vapor):
Equation (36) in reference [1].

Pressure and Temperature on Bubble-Point Curve (Saturated Liquid):
Equation (37) in reference [1].

Properties at Vapor-Liquid Equilibrium:
saturated liquid; Equations (38a), (54) and (56) for specific volume, specific entropy, and specific enthalpy, respectively.
saturated vapor; Equations (36) and (43b) for specific volume, (36) and (46) for specific entropy, (36) and (45) for specific enthalpy, (36) and (48) for isochoric specific heat, and (36) and (49) for isobaric specific heat.

All of these equations have been cited from reference [1].

Transport Properties:
Viscosity and thermal conductivity from reference[2].

References

[1] H.D.Baehr and K.Schwier, Die thermodynamischen Eigenschaften der Luft, Springer-Verlag, (1961).
[2] K.Kadoya, N.Matsunaga and A.Nagashima, Viscosity and Thermal Conductivity of Dry Air in the Gaseous Phase, Journal of Physical and Chemical Reference Data, vol.14, No.4, (1985), p.947.

Table II–2.12–1 Air Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 450 \times 10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$40 \times 10^3 \leq P \leq 3.6 \times 10^6$ [Pa] $0.4 \leq P \leq 36$ [bar]
5	ALHT(T)		
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 100 \times 10^6$ [Pa] $85 \leq T \leq 2000$ [K] $0 \leq P \leq 1000$ [bar] $-188.15 \leq T \leq 1726.85$ [°C] see Fig.II-2-1
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 100 \times 10^6$ [Pa] $85 \leq T \leq 2000$ [K] $0 \leq P \leq 1000$ [bar] $-188.15 \leq T \leq 1726.85$ [°C] see Fig.II-2-2
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1000 \leq P \leq 3.76625 \times 10^6$ [Pa] $0.01 \leq P \leq 37.6625$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 450 \times 10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3
19	CPTD(T)		
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$60 \leq T \leq 132.52$ [K] $-213.15 \leq T \leq -140.63$ [°C]

Table II–2.12–1 Air Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 34.248×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.76625×10^6[Pa],37.6625 [bar] Pressure S: 'A'='S': 4.3843×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 132.52 [K],−140.63 [°C] Temperature V: 'A'='V': 3.19489×10^{-3}[m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1000\leq P\leq3.76625\times10^6$ [Pa] $0.01\leq P\leq37.6625$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0\leq P\leq450\times10^6$ [Pa] $60\leq T\leq1523.15$ [K] $0\leq P\leq4500$ [bar] $-213.15\leq T\leq1250$ [°C] see Fig.II-2-3
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$60\leq T\leq132.52$ [K] $-213.15\leq T\leq-140.63$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 28.96 Relative Molecular Mass R: 'A'='R': 287.22 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3\leq P\leq3.6\times10^6$ [Pa] $0.4\leq P\leq36$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1000\leq P\leq3.76625\times10^6$ [Pa] $0.01\leq P\leq37.6625$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000\leq P\leq450\times10^6$ [Pa] $0.01\leq P\leq4500$ [bar] see Fig.II-2-5 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000\leq P\leq450\times10^6$ [Pa] $60\leq T\leq1523.15$ [K] $0.01\leq P\leq4500$ [bar] $-213.15\leq T\leq1250$ [°C] see Fig.II-2-3
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3\leq P\leq3.6\times10^6$ [Pa] $0.4\leq P\leq36$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$68\leq T\leq132$ [K] $-205.15\leq T\leq-141.15$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$60\leq T\leq132.52$ [K] $-213.15\leq T\leq-140.63$ [°C]
29	HTX(T,X)		

Table II–2.12–1 Air Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
84	IDENTF('A')	IDENTF : CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'AIR' Molecular Formula S: 'A'='S': 'AIR' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 0.1473 \times 10^6$ [Pa] $85 \leq T \leq 1523.15$ [K] $0.1473 \times 10^6 < P \leq 3.3 \times 10^6$ [Pa] TSPDD(P)$\leq T \leq 1523.15$ [K] $3.3 \times 10^6 < P \leq 42.791 \times 10^6$ [Pa] $159 \leq T \leq 1523.15$ [K] $42.791 \times 10^6 < P \leq 92.72 \times 10^6$ [Pa] TPV(P,1.42×10^{-3} m^3/kg) $\leq T \leq 1523.15$ [K] $92.72 \times 10^6 < P \leq 100 \times 10^6$ [Pa] $223.15 \leq T \leq 1523.15$ [K] $0 \leq P \leq 1.473$ [bar] $-188.15 \leq T \leq 1250$ [°C] $1.473 < P < 33$ [bar] TSPDD(P)$\leq T \leq 1250$ [°C] $33 < P \leq 427.91$ [bar] $-78.15 \leq T \leq 1250$ [°C] $427.91 < P \leq 927.2$ [bar] TPV(P,1.42×10^{-3} m^3/kg) $\leq T \leq 1250$ [°C] $927.2 < P \leq 1000$ [bar] $-40 \leq T \leq 1250$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)		
72	PSTD(T)	PSTD∗: Pressure [Pa], [bar] on Bubble-Point Curve (Saturated Liquid) T∗: Temperature [K], [°C]	$68 \leq T \leq 132.42$ [K] $-205.15 \leq T \leq -140.73$ [°C]
73	PSTDD(T)	PSTDD∗: Pressure [Pa], [bar] on Dew-Point Curve (Saturated Vapor) T∗: Temperature [K], [°C]	$60 \leq T \leq 132.52$ [K] $-213.15 \leq T \leq -140.63$ [°C]
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40 \times 10^3 \leq P \leq 3.6 \times 10^6$ [Pa] $0.4 \leq P \leq 36$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1000 \leq P \leq 3.76625 \times 10^6$ [Pa] $0.01 \leq P \leq 37.6625$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 450 \times 10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0.01 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3

Table II–2.12–1 Air Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$68 \leq T \leq 132$ [K] $-205.15 \leq T \leq -141.15$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$60 \leq T \leq 132.52$ [K] $-213.15 \leq T \leq -140.63$ [°C]
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$1000 \leq P \leq 450\times10^6$ [Pa] $0.01 \leq P \leq 4500$ [bar] see Fig.II-2-4 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 450\times10^6$ [Pa] $0.01 \leq P \leq 4500$ [bar] see Fig.II-2-5 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$1000 \leq P \leq 450\times10^6$ [Pa] $0.01 \leq P \leq 4500$ [bar] see Fig.II-2-6 for V
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)		
74	TSPD(P)	TSPD∗: Temperature [K], [°C] on Bubble-Point Curve (Saturated Liquid) P∗: Pressure [Pa], [bar]	$40\times10^3 \leq P \leq 3.77434\times10^6$ [Pa] $0.4 \leq P \leq 37.7434$ [bar]
75	TSPDD(P)	TSPDD∗: Temperature [K], [°C] on Dew-Point Curve (Saturated Vapor) P∗: Pressure [Pa], [bar]	$1000 \leq P \leq 3.76625\times10^6$ [Pa] $0.01 \leq P \leq 37.6625$ [bar]
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1000 \leq P \leq 3.76625\times10^6$ [Pa] $0.01 \leq P \leq 37.6625$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 450\times10^6$ [Pa] $0.01 \leq P \leq 4500$ [bar] see Fig.II-2-5 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 450\times10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0.01 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$68 \leq T \leq 132$ [K] $-205.15 \leq T \leq -141.15$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$60 \leq T \leq 132.52$ [K] $-213.15 \leq T \leq -140.63$ [°C]

Table II–2.12–1 Air Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1000 \leq P \leq 3.76625\times10^6$ [Pa] $0.01 \leq P \leq 37.6625$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 450\times10^6$ [Pa] $0.01 \leq P \leq 4500$ [bar] see Fig.II-2-5 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 450\times10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0.01 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$68 \leq T \leq 132.52$ [K] $-205.15 \leq T \leq -140.63$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$60 \leq T \leq 132.52$ [K] $-213.15 \leq T \leq -140.63$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 450\times10^6$ [Pa] $60 \leq T \leq 1523.15$ [K] $0 \leq P \leq 4500$ [bar] $-213.15 \leq T \leq 1250$ [°C] see Fig.II-2-3
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/(kg·K)]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$40\times10^3 \leq P \leq 3.6\times10^6$ [Pa] $0.4 \leq P \leq 36$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

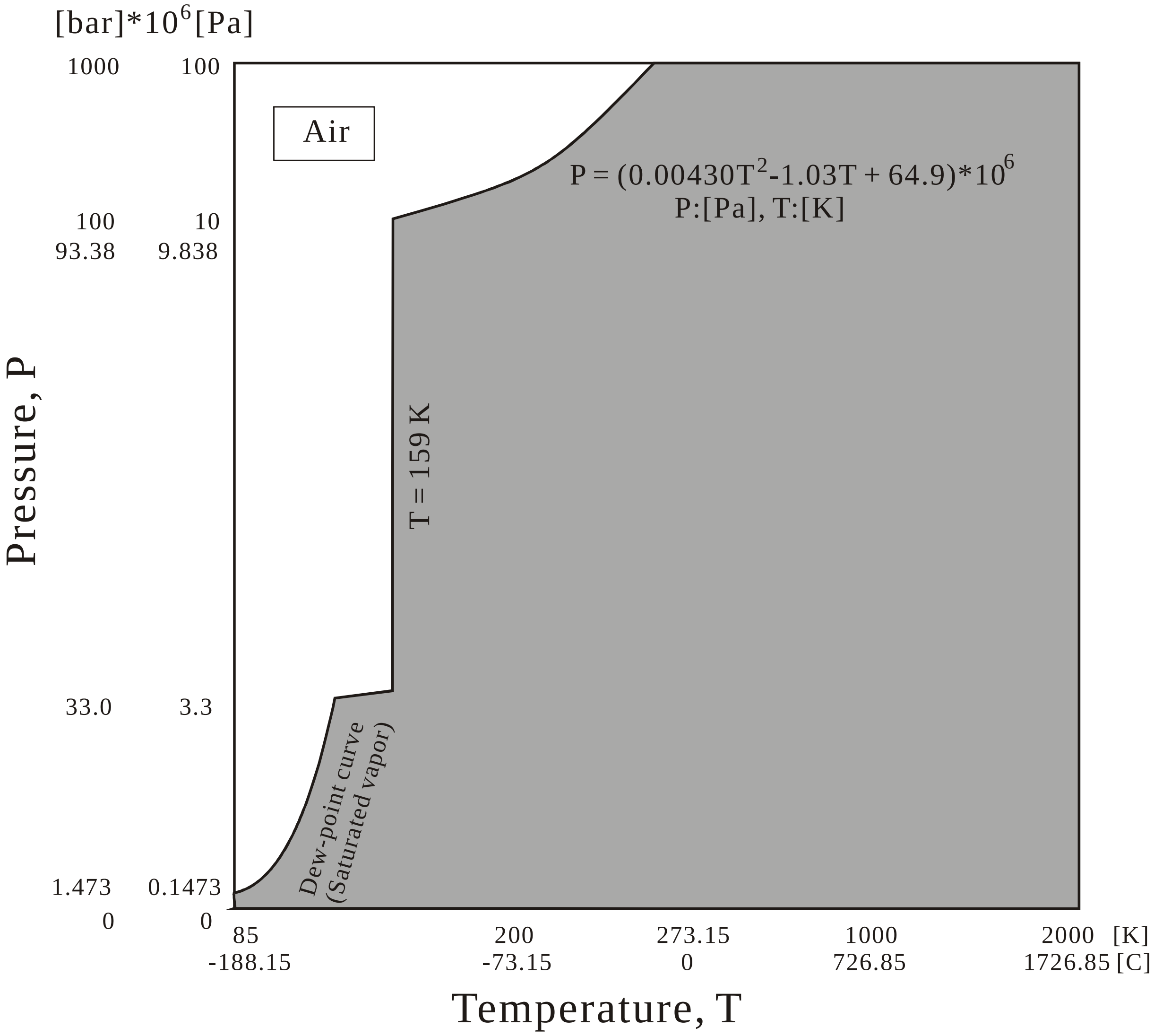


Fig.II–2.12–1 Range of Arguments(P,T) for ALMPT(P,T).

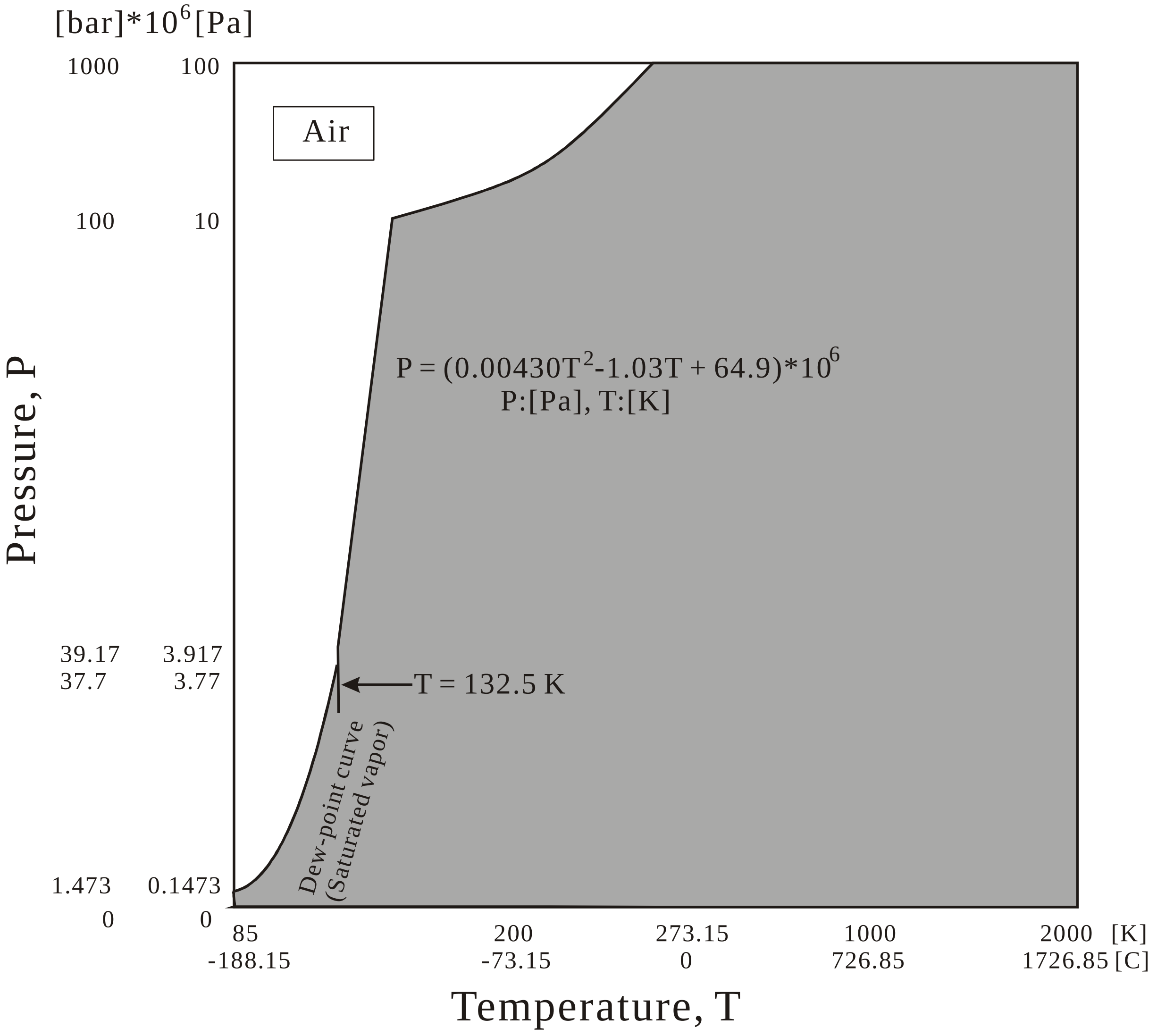


Fig.II–2.12–2 Range of Arguments(P,T) for AMUPT(P,T).

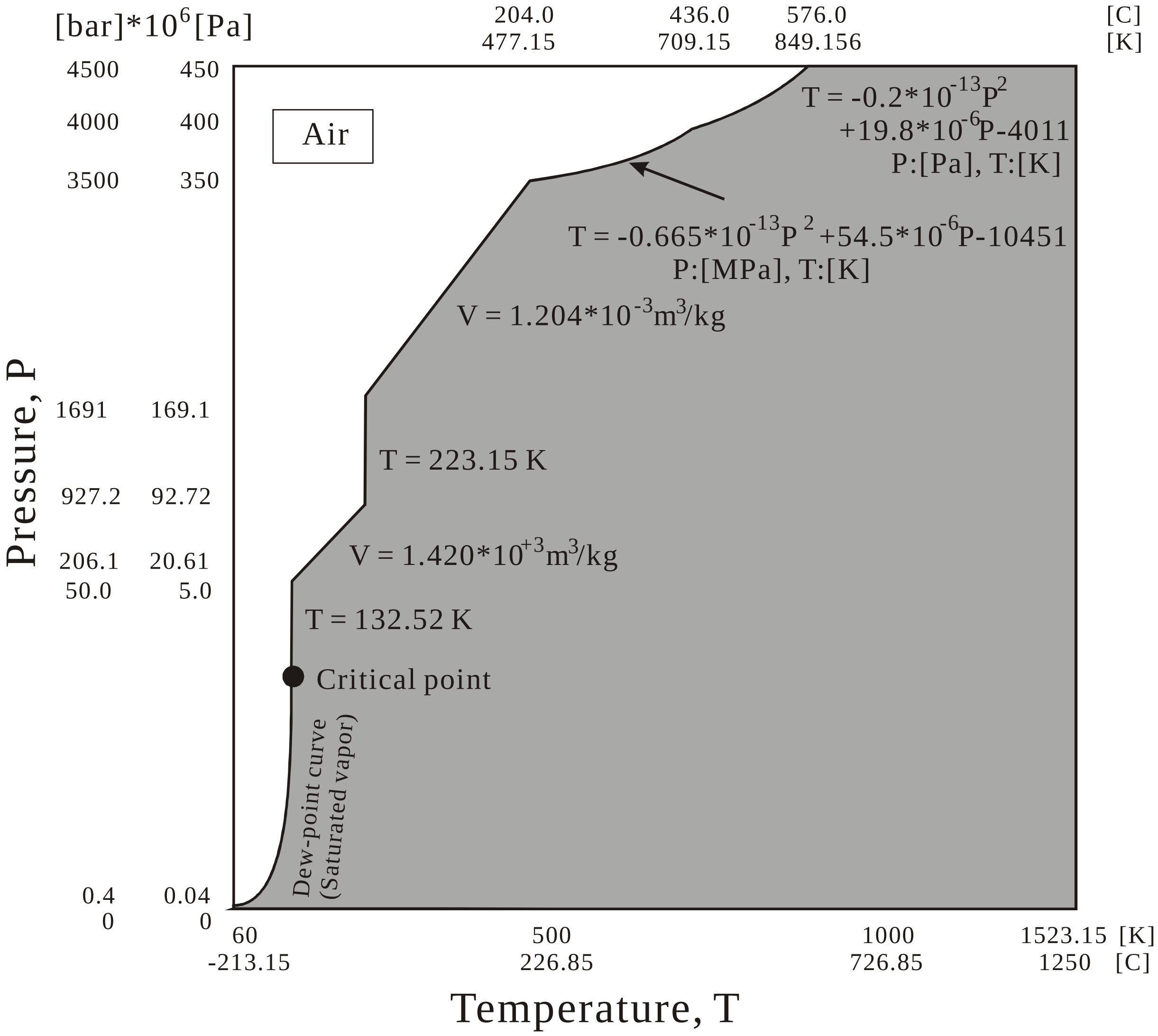


Fig.II–2.12–3 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T),VPT(P,T) and WPT(P,T).

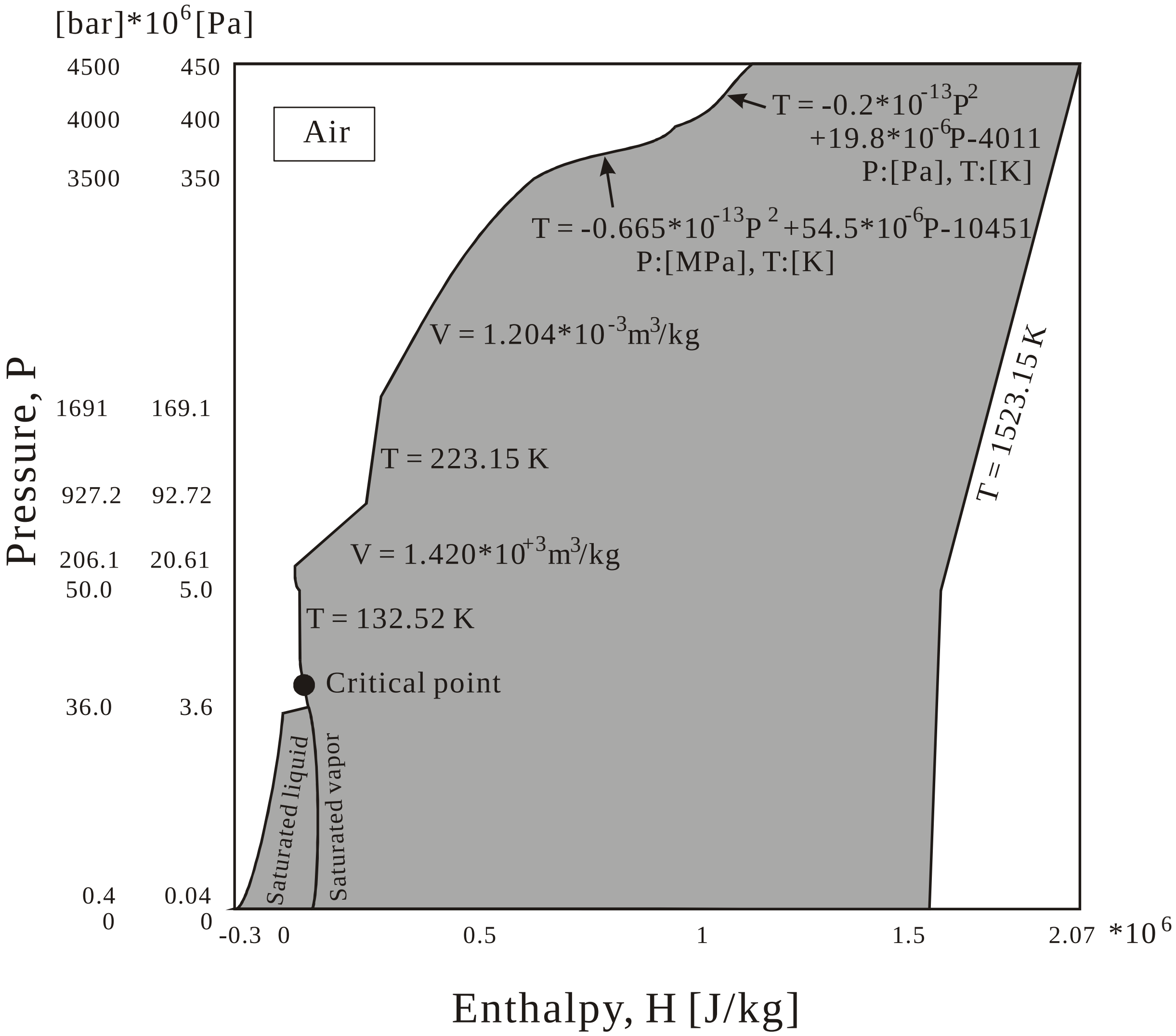


Fig.II–2.12–4 Range of Arguments(P,H) for TPH(P,H).

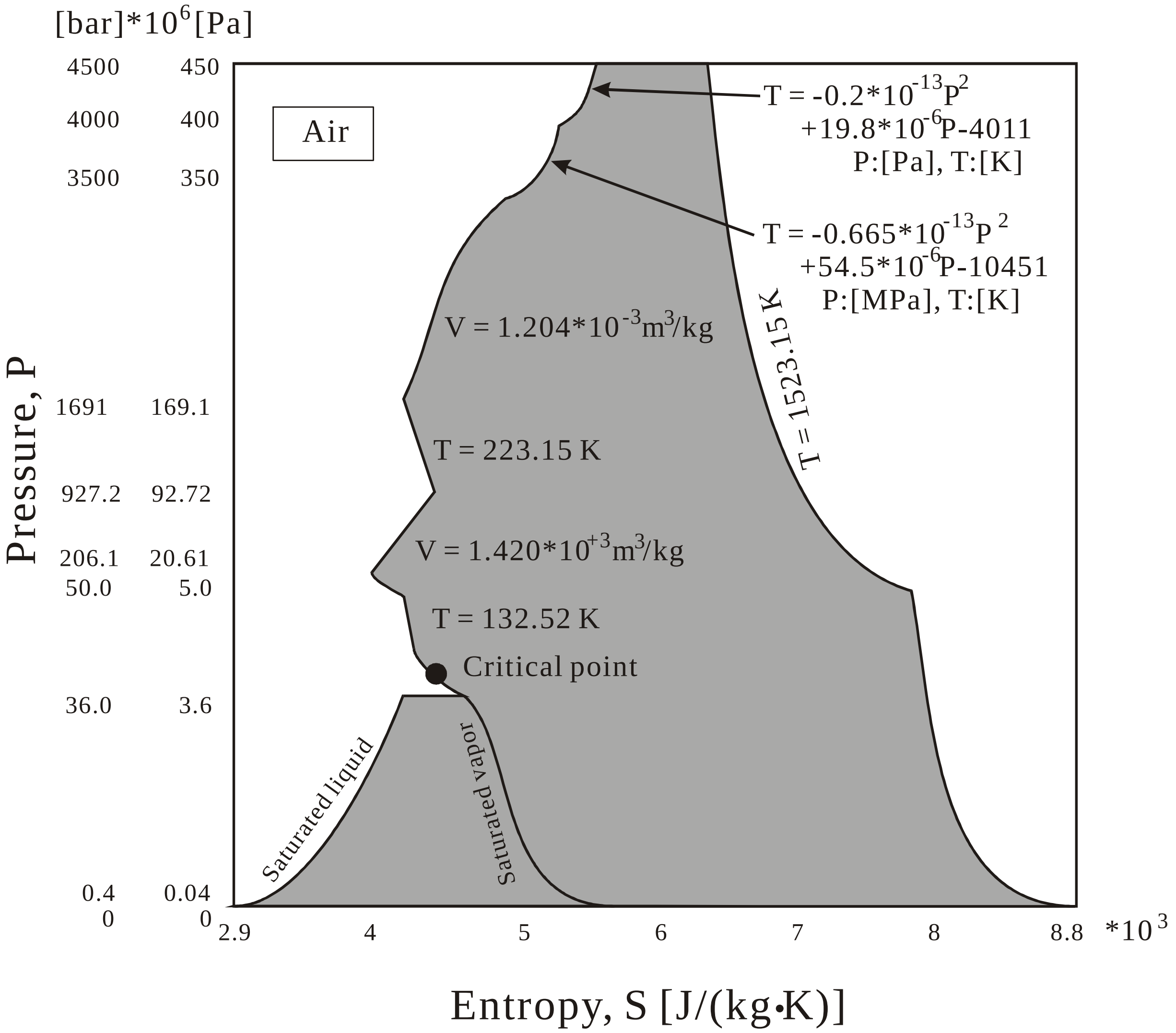


Fig.II–2.12–5 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

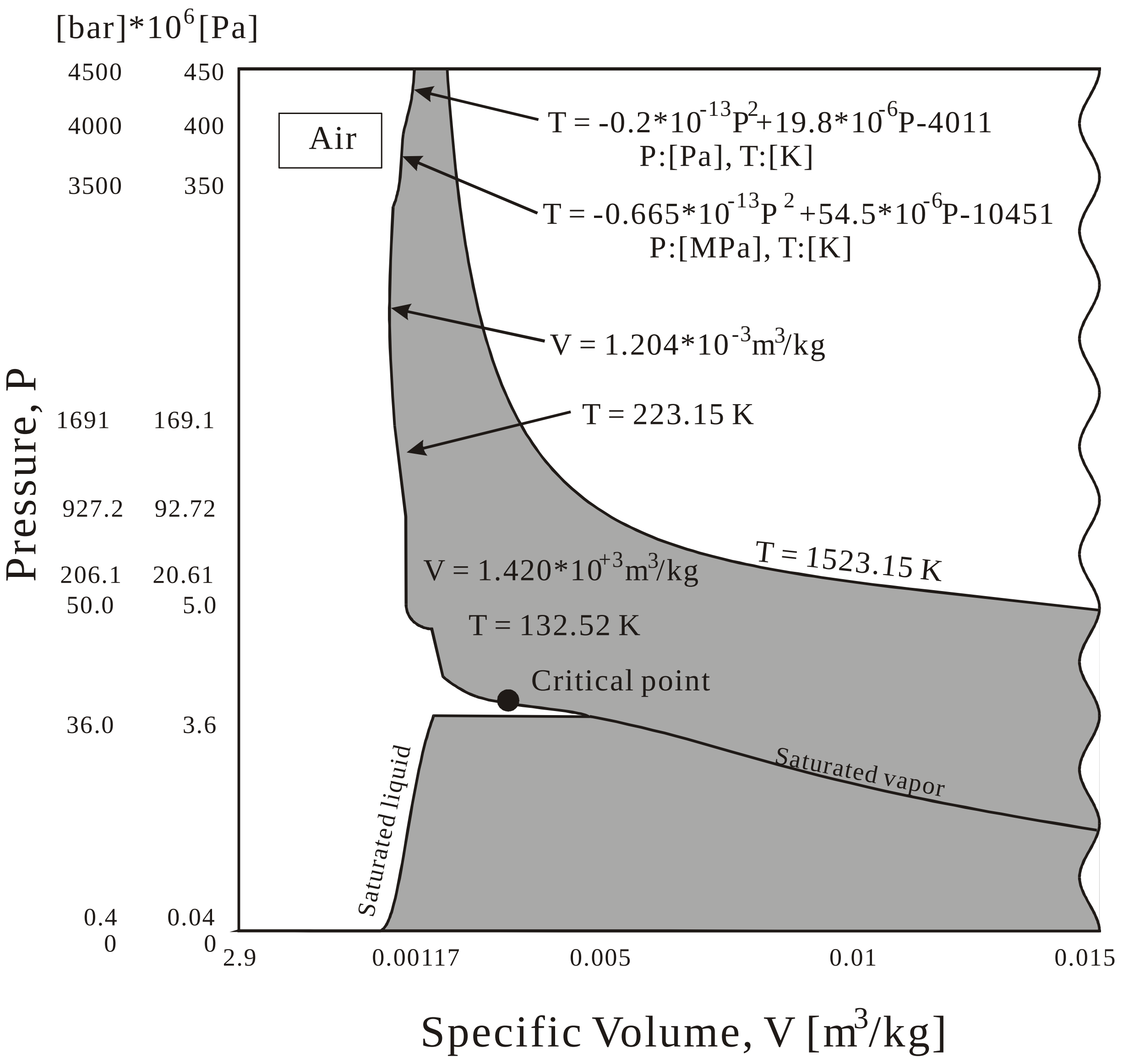


Fig.II–2–6 Range of Arguments(P,V) for TPV(P,V).

2.13 Carbon Monoxide

Equations for thermodynamic properties have been cited from reference [1].

2.13.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.13.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Carbon Monoxide
Library File for UNIX:	libjco.a
Library File for DOS,Windows95/NT:	JCO.LIB
Single Shot Program for UNIX:	co-ss
Single Shot Program for DOS,Windows95/NT:	CO–SS.EXE

2.13.3 Important Constants and Others

Molecular Formula:	CO
Relative Molecular Mass:	28.01
Gas Constant:	296.84 J/(kg·K)

Critical Constants:

Critical Pressure:	3.4935×10^6Pa (34.935 bar)
Critical Temperature:	132.85 K (−140.30°C)
Critical Specific Volume:	3.29×10^{-3}m^3/kg

Triple Point:

Pressure:	0.01540×10^6Pa (0.1540 bar)
Temperature:	68.127 K (−205.023°C)

Reference State:
Zero is assigned to the specific internal energy of saturated liquid at the triple point.

2.13.4 Formula

Equation of State:
Equation (6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:
Equation (2) in reference [1].

Properties at Vapor-Liquid Equilibrium:
Equations (3) for specific volume of saturated liquid and equation (4) for specific volume of saturated vapor, equations (10) and (19) for specific entropy, equations (9) and (19) for specific enthalpy, and equation (16) for isobaric specific heat, respectively. All of these have been cited from reference [1].

Pressure and Temperature on Melting Line:
Equation (1) in reference [1].

References

[1] R.D.Goodwin, Carbon Monoxide Thermophysical Properties from 68 to 1000K at Pressures to 100MPa, J. Phys. & Chem. Ref. Data, vol.14, No.4, (1985), p.849.

Table II–2.13–1 Carbon Monoxide Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P$*$: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T$*$: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P$*$: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T$*$: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 188.2×10^3 [J/kg] Specific Enthalpy P$*$: 'A'='P': 3.4935×10^6 [Pa], 34.935 [bar] Pressure S: 'A'='S': 4.435×10^3 [J/(kg·K)] Specific Entropy T$*$: 'A'='T': 132.85 [K], −140.3 [°C] Temperature V: 'A'='V': 3.29×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		

Table II–2.13–1 Carbon Monoxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 28.01 Relative Molecular Mass R: 'A'='R': 296.84 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)		
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CO' Molecular Formula S: 'A'='S': 'CARBON MONOXIDE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 88.317$ [K] $-205.023 \leq T \leq -184.833$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(P)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$15.4\times10^3 \leq P \leq 3.4935\times10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
35	SPT(P,T)		
36	SPX(P,X)		

Table II–2.13–1 Carbon Monoxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 100 \times 10^6$ [Pa] $0.154 \leq P \leq 1000$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 15.4×10^3 [Pa], 0.154 [bar] Pressure T∗: 'A'='T': 68.127 [K], −205.023 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 3.4935 \times 10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 3.4935 \times 10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 3.4935 \times 10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
79	UPS(P,S)		
44	UPT(P,T)		
45	UPX(P,X)		
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$68.127 \leq T \leq 132.85$ [K] $-205.023 \leq T \leq -140.3$ [°C]
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 3.4935 \times 10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$15.4 \times 10^3 \leq P \leq 3.4935 \times 10^6$ [Pa] $0.154 \leq P \leq 34.935$ [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)		

Table II–2.13–1 Carbon Monoxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	68.127≤T≤132.85 [K] −205.023≤T≤−140.3 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	68.127≤T≤132.85 [K] −205.023≤T≤−140.3 [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.14 Carbon Dioxide

Equations for thermodynamic properties have been cited from the IUPAC Table[1], those for transport properties from Altunin et al.[2][3], and one for surface tension from Miller et al.[4].

2.14.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.14.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Carbon Dioxide
Library File for UNIX:	libjco2.a
Library File for DOS,Windows95/NT:	JCO2.LIB
Single Shot Program for UNIX:	co2-ss
Single Shot Program for DOS,Windows95/NT:	CO2–SS.EXE

2.14.3 Important Constants and Others

Molecular Formula:	CO_2
Relative Molecular Mass:	44.009
Gas Constant:	188.92 J/(kg·K)

Critical Constants:

Critical Pressure:	7.3825×10^6Pa (73.825 bar)
Critical Temperature:	304.21 K (31.06°C)
Critical Specific Volume:	2.1459×10^{-3}m^3/kg

Triple Point:

Pressure:	0.5185×10^6Pa (5.185 bar)
Temperature:	216.58 K (−56.57°C)

Reference State:

At the state of the perfect crystal at 0 K, 0 J/(kg·K) and 0 J/kg are assigned to the specific entropy and the specific enthalpy, respectively.

2.14.4 Formula

Equation of State:

Equation (14) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (3) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (4) and (5) for specific volume, equation (16) for specific entropy, and equation (18) for specific enthalpy, and equations (20) and (22) for isobaric specific heat, respectively. All of these have been cited from reference [1].

Pressure and Temperature on Melting Line:

Equation (2) in reference [1].

Transport Properties:

Equations (7) and (9) in reference [2] for viscosity. Equations (5) and (6) in reference [3] for thermal conductivity.

The Other Properties:
Surface tension from reference [4].

References

[1] S.Angus, B.Armstrong and K.M.de Reuck, International Thermodynamic Table of the Fluid State-3 Carbon Dioxide, IUPAC, vol.3, (1976).
[2] V.V.Altunin and M.A.Sakhabetdinov, Teploenergetika, 19–8, (1972), p.85.
[3] V.V.Altunin and M.A.Sakhabetdinov, Teploenergetika, 20–5, (1973), p.85.
[4] J.W.Miller Jr. and C.L.Yaws, Chem. Eng.,83–23, (1976), p.127.

Table II–2.14–1 Carbon Dioxide Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185 \times 10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185 \times 10^6 \leq P \leq 60 \times 10^6$ [Pa] $TMLP(P) \leq T \leq 1100$ [K] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] $TMLP(P) \leq T \leq 700$ [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] $TMLP(P) \leq T \leq 826.85$ [°C] $600 < P < 1000$ [bar] $TMLP(P) \leq T \leq 426.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Aidabatic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185 \times 10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185 \times 10^6 \leq P \leq 60 \times 10^6$ [Pa] $TMLP(P) \leq T \leq 1100$ [K] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] $TMLP(P) \leq T \leq 700$ [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] $TMLP(P) \leq T \leq 826.85$ [°C] $600 < P < 1000$ [bar] $TMLP(P) \leq T \leq 426.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$0.5185 \times 10^6 \leq P < 7.3825 \times 10^6$ [Pa] $5.185 \leq P < 73.825$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$216.58 \leq T < 304.21$ [K] $-56.57 \leq T < 31.06$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.5185 \times 10^6 \leq P \leq 7.3825 \times 10^6$ [Pa] $5.185 \leq P \leq 73.825$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$216.58 \leq T \leq 304.21$ [K] $-56.57 \leq T \leq 31.06$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$1.286 \times 10^6 \leq P < 7.3825 \times 10^6$ [Pa] $12.86 \leq P < 73.825$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$0.5185 \times 10^6 \leq P < 7.3825 \times 10^6$ [Pa] $5.185 \leq P < 73.825$ [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185 \times 10^6$ [Pa] $220 \le T \le 1100$ [K] $0.5185 \times 10^6 \le P \le PST(240K)$ [Pa] $TSP(P) \le T \le 1100$ [K] $PST(240K) < P \le 60 \times 10^6$ $240 \le T \le 1100$ [K] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] $240 \le T \le 700$ [K] $0.1 \le P < 5.185$ [bar] $-53.15 \le T \le 826.85$ [°C] $5.185 \le P \le PST(-33.15°C)$ [bar] $TSP(P) \le T \le 826.85$ [°C] $PST(-33.15°C) < P \le 600$ [bar] $-33.15 \le T \le 826.85$ [°C] $600 < P < 1000$ [bar] $-33.15 \le T \le 426.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$240 \le T < 304.21$ [K] $-33.15 \le T < 31.06$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$216.58 \le T < 304.21$ [K] $-56.57 \le T < 31.06$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$1.286 \times 10^6 \le P \le 7.3825 \times 10^6$ [Pa] $12.86 \le P \le 73.825$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.5185 \times 10^6 \le P \le 7.3825 \times 10^6$ [Pa] $5.185 \le P \le 73.825$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185 \times 10^6$ [Pa] $220 \le T \le 1100$ [K] $0.5185 \times 10^6 \le P \le PST(240K)$ [Pa] $TSP(P) \le T \le 1100$ [K] $PST(240K) < P \le 60 \times 10^6$ $240 \le T \le 1100$ [K] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] $240 \le T \le 700$ [K] $0.1 \le P < 5.185$ [bar] $-53.15 \le T \le 826.85$ [°C] $5.185 \le P \le PST(-33.15°C)$ [bar] $TSP(P) \le T \le 826.85$ [°C] $PST(-33.15°C) < P \le 600$ [bar] $-33.15 \le T \le 826.85$ [°C] $600 < P < 1000$ [bar] $-33.15 \le T \le 426.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$240 \le T \le 304.21$ [K] $-33.15 \le T \le 31.06$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$216.58 \le T \le 304.21$ [K] $-56.57 \le T \le 31.06$ [°C]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤600 [bar] TMLP(P)≤T≤826.85 [°C] 600<P<1000 [bar] TMLP(P)≤T≤426.85 [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	216.58≤T<304.21 [K] −56.57≤T<31.06 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	216.58≤T<304.21 [K] −56.57≤T<31.06 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 636.64×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 7.3825×10^6[Pa], 73.825 [bar] Pressure S: 'A'='S': 3.5579×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 304.21 [K], 31.06 [°C] Temperature V: 'A'='V': 2.1459×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P \leq 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤600 [bar] TMLP(P)≤T≤826.85 [°C] 600<P<1000 [bar] TMLP(P)≤T≤426.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 44.009 Relative Molecular Mass R: 'A'='R': 188.92 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P \leq 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185\times10^6$ [Pa] $220 \le T \le 1100$ [K] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \le P < 5.185$ [bar] $-53.15 \le T \le 826.85$ [°C] $5.185 \le P \le 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$216.58 \le T \le 304.21$ [K] $-56.57 \le T \le 31.06$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \le P \le 7.3825\times10^6$ [Pa] $5.185 \le P \le 73.825$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \le P \le 7.3825\times10^6$ [Pa] $5.185 \le P \le 73.825$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \le P < 0.5185\times10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,1100K) [J/(kg·K)] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] $60\times10^6 < P < 100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] $0.1 \le P < 5.185$ [bar] SPT(P,−53.15°C)≤S≤ SPT(P,826.85°C) [J/(kg·K)] $5.185 \le P \le 600$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)] $600 < P < 1000$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185\times10^6$ [Pa] $220 \le T \le 1100$ [K] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.1 \le P < 5.185$ [bar] $-53.15 \le T \le 826.85$ [°C] $5.185 \le P \le 600$ [bar] TMLP(P)≤T≤826.85 [°C] $600 < P < 1000$ [bar] TMLP(P)≤T≤426.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.5185\times10^6 \le P \le 7.3825\times10^6$ [Pa] $5.185 \le P \le 73.825$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$216.58 \le T \le 304.21$ [K] $-56.57 \le T \le 31.06$ [°C]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CO2' Molecular Formula S: 'A'='S': 'CARBON DIOXIDE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	216.58≤T≤237 [K] −56.57≤T≤−36.15 [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	1.286×10^6≤P<7.3825×10^6 [Pa] 12.86≤P<73.825 [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P<7.3825×10^6 [Pa] 5.185≤P<73.825 [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	10000≤P<0.5185×10^6 [Pa] 220≤T≤1100 [K] 0.5185×10^6≤P≤PST(240K) [Pa] TSP(P)≤T≤1100 [K] PST(240K)<P≤60×10^6 240≤T≤1100 [K] 60×10^6<P<100×10^6 [Pa] 240≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤PST(−33.15°C) [bar] TSP(P)≤T≤826.85 [°C] PST(−33.15°C)<P≤600 [bar] −33.15≤T≤826.85 [°C] 600<P<1000 [bar] −33.15≤T≤426.85 [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	240≤T<304.21 [K] −33.15≤T<31.06 [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	216.58≤T<304.21 [K] −56.57≤T<31.06 [°C]
99	PSBT(P)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
72	PSTD(P)		
73	PSTDD(P)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185 \times 10^6$ [Pa] $220 \leq T \leq 1100$ [K] $0.5185 \times 10^6 \leq P \leq 60 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 1100$ [K] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 700$ [K] $0.1 \leq P < 5.185$ [bar] $-53.15 \leq T \leq 826.85$ [°C] $5.185 \leq P \leq 600$ [bar] TMLP(P)$\leq T \leq 826.85$ [°C] $600 < P < 1000$ [bar] TMLP(P)$\leq T \leq 426.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.5185 \times 10^6 \leq P \leq 7.3825 \times 10^6$ [Pa] $5.185 \leq P \leq 73.825$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$216.58 \leq T \leq 304.21$ [K] $-56.57 \leq T \leq 31.06$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$216.58 \leq T \leq 304.21$ [K] $-56.57 \leq T \leq 31.06$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$216.58 \leq T \leq 304.21$ [K] $-56.57 \leq T \leq 31.06$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$0.5185 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $5.185 \leq P \leq 1000$ [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$10000 \leq P < 0.5185 \times 10^6$ [Pa] HPT(P,220K)$\leq H \leq$ HPT(P,1100K) [J/kg] $0.5185 \times 10^6 \leq P \leq 60 \times 10^6$ [Pa] HPT(P,TMLP(P))$\leq H \leq$ HPT(P,1100K) [J/kg] $60 \times 10^6 < P < 100 \times 10^6$ [Pa] HPT(P,TMLP(P))$\leq H \leq$ HPT(P,700K) [J/kg] $0.1 \leq P < 5.185$ [bar] HPT(P,−53.15°C)$\leq H \leq$ HPT(P,826.85°C) [J/kg] $5.185 \leq P \leq 600$ [bar] HPT(P,TMLP(P))$\leq H \leq$ HPT(P,826.85°C) [J/kg] $600 < P < 1000$ [bar] HPT(P,TMLP(P))$\leq H \leq$ HPT(P,426.85°C) [J/kg]
6H	TPH2(P,H)		

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	10000≤P<0.5185×10^6 [Pa] SPT(P,220K)≤S≤ SPT(P,1100K) [J/(kg·K)] 0.5185×10^6≤P≤60×10^6 [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] 60×10^6<P<100×10^6 [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 0.1≤P<5.185 [bar] SPT(P,−53.15°C)≤S≤ SPT(P,826.85°C) [J/(kg·K)] 5.185≤P≤600 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)] 600<P<1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	7.3825×10^6<P≤30×10^6 [Pa] 73.825<P≤300 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	10000≤P<0.5185×10^6 [Pa] VPT(P,220K)≤V≤ VPT(P,1100K) [m^3/kg] 0.5185×10^6≤P≤60×10^6 [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1100K) [m^3/kg] 60×10^6<P<100×10^6 [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,700K) [m^3/kg] 0.1≤P<5.185 [bar] VPT(P,−53.15°C)≤V≤ VPT(P,826.85°C) [m^3/kg] 5.185≤P≤600 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,826.85°C) [m^3/kg] 600<P<1000 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,426.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.5185×10^6 [Pa], 5.185 [bar] Pressure T∗: 'A'='T': 216.58 [K], −56.57 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	0.5185×10^6≤P≤7.3825×10^6 [Pa] 5.185≤P≤73.825 [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \leq P < 0.5185\times10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,1100K) [J/(kg·K)] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] $60\times10^6 < P < 100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 0.1≤P<5.185 [bar] SPT(P,−53.15°C)≤S≤ SPT(P,826.85°C) [J/(kg·K)] 5.185≤P≤600 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)] 600<P<1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P < 0.5185\times10^6$ [Pa] 220≤T≤1100 [K] $0.5185\times10^6 \leq P \leq 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤600 [bar] TMLP(P)≤T≤826.85 [°C] 600<P<1000 [bar] TMLP(P)≤T≤426.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.5185\times10^6 \leq P \leq 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P \leq 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.5185\times10^6 \leq P \leq 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar]

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \le P < 0.5185\times10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,1100K) [J/(kg·K)] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1100K) [J/(kg·K)] $60\times10^6 < P < 100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 0.1≤P<5.185 [bar] SPT(P,−53.15°C)≤S≤ SPT(P,826.85°C) [J/(kg·K)] 5.185≤P≤600 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,826.85°C) [J/(kg·K)] 600<P<1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185\times10^6$ [Pa] 220≤T≤1100 [K] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤600 [bar] TMLP(P)≤T≤826.85 [°C] 600<P<1000 [bar] TMLP(P)≤T≤426.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.5185\times10^6 \le P \le 7.3825\times10^6$ [Pa] 5.185≤P≤73.825 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	216.58≤T≤304.21 [K] −56.57≤T≤31.06 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P < 0.5185\times10^6$ [Pa] 220≤T≤1100 [K] $0.5185\times10^6 \le P \le 60\times10^6$ [Pa] TMLP(P)≤T≤1100 [K] $60\times10^6 < P < 100\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 0.1≤P<5.185 [bar] −53.15≤T≤826.85 [°C] 5.185≤P≤600 [bar] TMLP(P)≤T≤826.85 [°C] 600<P<1000 [bar] TMLP(P)≤T≤426.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.14–1 Carbon Dioxide Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.5185\times10^6 \leq P < 7.3825\times10^6$ [Pa] $5.185 \leq P < 73.825$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$216.58 \leq T < 304.21$ [K] $-56.57 \leq T < 31.06$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$216.58 \leq T < 304.21$ [K] $-56.57 \leq T < 31.06$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$216.58 \leq T < 304.21$ [K] $-56.57 \leq T < 31.06$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$216.58 \leq T < 304.21$ [K] $-56.57 \leq T < 31.06$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.15 Water (IFC 1967 Formulation for Industrial Use-IPTS 1968)

Equations have been cited from 1980 SI JSME Steam Table [1] and reference[2].

2.15.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.15.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Water, Light Water
Library File for UNIX:	libjh2o.a
Library File for DOS,Windows95/NT:	JH2O.LIB
Single Shot Program for UNIX:	h2o-ss
Single Shot Program for DOS,Windows95/NT:	H2O–SS.EXE

2.15.3 Important Constants and Others

Molecular Formula:	H_2O
Relative Molecular Mass:	18.0153
Gas Constant:	461.51 J/(kg·K)

Critical Constants:

Critical Pressure:	22.12×10^6Pa (221.2 bar)
Critical Temperature:	647.30 K (374.15°C)
Critical Specific Volume:	3.17×10^{-3}m^3/kg

Triple Point:

Pressure:	611.2 Pa (6.112×10^{-3}bar)
Temperature:	273.16 K (0.01°C)

Reference State:

At the triple point, 0 J/(kg·K) and 0 J/kg are assigned to the specific entropy and the specific free internal energy of saturated liquid, respectively.

2.15.4 Formula

Equation of State:

The function forms of $g = g(P,T)$ and $f = f(v,T)$. Here g=specific free enthalpy, f=specific free energy, P=pressure, T=temperature and v=specific volume. The equations, which are divided into six subregions, have been cited from Section 3.1 in chapter 3 in reference [1].

Vapor Pressure:

K-function given at 5 of section 3.1 in chapter 3 in reference [1] for vapor pressuure above 0°C, and equation (3) in chapter 6 in reference [2] for vapor pressure below 0°C. However, the coefficient $C_6 = 0.9484024 \times 10^{-12}$ in the latter equation has been corrected to $C_6 = -0.9484024 \times 10^{-12}$.

Properties at Vapor-Liquid Equilibrium:

Derived functions given at 4.5 and 4.6 of 4 of section 3.1 in chapter 3.1 in reference [1] for specific volume, specific enthalpy and specific entropy. The expressions for isobaric specific heat, which is divided into four subregions, given at section 3.2 in chapter 3 in reference [1].

Transport Properties:

Internationally recommended interpolation equations given at sections 3.3 and 3.4 in chapter 3 in reference [1] for dynamic viscosity and thermal conductivity, respectively.

The Other Properties:
Internationally recommended interpolation equations given at sections 3.5, 3.6 and 3.7 in chapter 3 in reference [1] for surface tension, static dielectric constant and ion products, respectively.

References

[1] Japan Society of Mechanical Engineers, 1980 SI JSME Steam Tables, (1981).
[2] ASHRAE, 1985 Fundamentals Handbook, Chap.6, (1985), p.6.4.

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)	AIPPT: Ion Product [(mol/kg)^2] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112\times10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112\times10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112\times10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12\times10^6$ [Pa] $6.112\times10^{-3} \leq P \leq 221.2$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112\times10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P \leq 221.2$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P \leq 221.2$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112 \times 10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 647.3$ [K] $0 \leq T \leq 374.15$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 2.1074×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 22.12×10^6 [Pa], 221.2 [bar] Pressure S: 'A'='S': 4.4429×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 647.3 [K], 374.15 [°C] Temperature V: 'A'='V': 3.17×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)	EPSPT: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.112 \times 10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 18.0153 Relative Molecular Mass R: 'A'='R': 461.51 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P \leq 221.2$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.2 \leq P \leq 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P \leq 221.2$ [bar]

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.2\leq P\leq 100\times 10^6$ [Pa] SPT(P,273.16K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] $6.112\times 10^{-3}\leq P\leq 1000$ [bar] SPT(P,0.01°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2\leq P\leq 100\times 10^6$ [Pa] $273.15\leq T\leq 1073.15$ [K] $6.112\times 10^{-3}\leq P\leq 1000$ [bar] $0\leq T\leq 800$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar] $0\leq X\leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C] $0\leq X\leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'H2O' Molecular Formula S: 'A'='S': 'WATER(IFC1967−IPTS1968)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2\leq P\leq 100\times 10^6$ [Pa] $273.15\leq T\leq 1073.15$ [K] $6.112\times 10^{-3}\leq P\leq 1000$ [bar] $0\leq T\leq 800$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$173.15\leq T\leq 647.3$ [K] $-100\leq T\leq 374.15$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$273.15\leq T\leq 647.3$ [K] $0\leq T\leq 374.15$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.2\leq P\leq 22.12\times 10^6$ [Pa] $6.112\times 10^{-3}\leq P\leq 221.2$ [bar]

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.2 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $6.112\times10^{-3} \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.2 \le P \le 22.12\times10^6$ [Pa] $6.112\times10^{-3} \le P \le 221.2$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15 \le T \le 647.3$ [K] $0 \le T \le 374.15$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15 \le T \le 647.3$ [K] $0 \le T \le 374.15$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.15 \le T \le 647.3$ [K] $0 \le T \le 374.15$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$611.2 \le P \le 100\times10^6$ [Pa] HPT(P,273.16K)≤H≤ HPT(P,1073.15K) [J/kg] $6.112\times10^{-3} \le P \le 1000$ [bar] HPT(P,0.01°C)≤H≤ HPT(P,800°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.2 \le P \le 100\times10^6$ [Pa] SPT(P,273.16K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] $6.112\times10^{-3} \le P \le 1000$ [bar] SPT(P,0.01°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$22.12\times10^6 < P \le 100\times10^6$ [Pa] $221.2 < P \le 1000$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$611.2 \le P \le 100\times10^6$ [Pa] VPT(P,273.16K)≤V≤ VPT(P,1073.15K) [m^3/kg] $6.112\times10^{-3} \le P \le 1000$ [bar] VPT(P,0.01°C)≤V≤ VPT(P,800°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 611.20 [Pa], 6.112×10^{-3} [bar] Pressure T∗: 'A'='T': 273.16 [K], 0.01 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.40749\times10^{-3} \le P \le 22.12\times10^6$ [Pa] $14.0749\times10^{-9} \le P \le 221.2$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.2 \le P \le 22.12\times10^6$ [Pa] $6.112\times10^{-3} \le P \le 221.2$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.2 \le P \le 22.12\times10^6$ [Pa] $6.112\times10^{-3} \le P \le 221.2$ [bar]

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	611.2≤P≤100×10^6 [Pa] SPT(P,273.16K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] 6.112×10^{-3}≤P≤1000 [bar] SPT(P,0.01°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	611.2≤P≤100×10^6 [Pa] 273.15≤T≤1073.15 [K] 6.112×10^{-3}≤P≤1000 [bar] 0≤T≤800 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	611.2≤P≤22.12×10^6 [Pa] 6.112×10^{-3}≤P≤221.2 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	611.2≤P≤22.12×10^6 [Pa] 6.112×10^{-3}≤P≤221.2 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	611.2≤P≤22.12×10^6 [Pa] 6.112×10^{-3}≤P≤221.2 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	611.2≤P≤100×10^6 [Pa] SPT(P,273.16K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] 6.112×10^{-3}≤P≤1000 [bar] SPT(P,0.01°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	611.2≤P≤100×10^6 [Pa] 273.15≤T≤1073.15 [K] 6.112×10^{-3}≤P≤1000 [bar] 0≤T≤800 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	611.2≤P≤22.12×10^6 [Pa] 6.112×10^{-3}≤P≤221.2 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	273.15≤T≤647.3 [K] 0≤T≤374.15 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	611.2≤P≤100×10^6 [Pa] 273.15≤T≤1073.15 [K] 6.112×10^{-3}≤P≤1000 [bar] 0≤T≤800 [°C]

Table II–2.15–1 Water(IFC 1967−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$611.2 \leq P < 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P < 221.2$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$611.2 \leq P < 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P < 221.2$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$611.2 \leq P < 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P < 221.2$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$611.2 \leq P < 22.12 \times 10^6$ [Pa] $6.112 \times 10^{-3} \leq P < 221.2$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	273.15≤T<647.3 [K] 0≤T<374.15 [°C] HPD(T)≤H≤HPDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	273.15≤T<647.3 [K] 0≤T<374.15 [°C] SPD(T)≤S≤SPDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	273.15≤T<647.3 [K] 0≤T<374.15 [°C] UPD(T)≤U≤UPDD(P) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	273.15≤T<647.3 [K] 0≤T<374.15 [°C] VPD(T)≤V≤VPDD(T) [m^3/kg]

2.16 Water (IFC 1967 Formulation for Industrial Use-ITS 1990)

Equations have been cited from reference [1] and [2].

2.16.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.16.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Water, Light Water
Library File for UNIX:	libjh2oi90.a
Library File for DOS,Windows95/NT:	JH2OI90.LIB
Single Shot Program for UNIX:	h2oi90-ss
Single Shot Program for DOS,Windows95/NT:	H2OI90SS.EXE

2.16.3 Important Constants and Others

Molecular Formula:	H_2O
Relative Molecular Mass:	18.0153
Gas Constant:	461.51 J/(kg·K)

Critical Constants:

Critical Pressure:	22.064×10^{6}Pa (220.64 bar)
Critical Temperature:	647.096 K (373.946°C)
Critical Specific Volume:	$3.1055\times10^{-3}\text{m}^3/\text{kg}$

Triple Point:

Pressure:	611.657 Pa (6.11657×10^{-3}bar)
Temperature:	273.16 K (0.01°C)

Reference State:

At the triple point, the internal energy and specific entropy of liquid have been set equal to 0 J/(kg·K) and 0 J/kg, respectively.

2.16.4 Formula

Vapor Pressure:

Equation (1) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (1) and (2) for specific volumes (densities) of saturated liquid and vapor, respectively. Equations (4) and (6) for specific enthalpy of saturated liquid, equations (4) and (7) for specific enthalpy of saturated vapor, equations (5) and (8) for specific entropy of saturated liquid, and equations (5) and (9) for specific entropy of saturated vapor. All these equations have been cited from reference [1].

Pressure and Temperature on Melting Curve:

Equations (1) to (5) in reference [2].

Pressure and Temperature on Sublimation Curve:

Equation (6) in reference [2].

References

[1] J.M.H.L.Sengers and B.Dooley, 'Revised Supplementary Release on Saturation Properties of Ordinary Water Substance', The international Association for the Properties of Water and Steam, St. Petersburg, Russia, (1992)
[2] J.M.H.L.Sengers and B.Dooley, 'Revised Release on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance', The international Association for the Properties of Water and Steam, St. Petersburg, Russia, (1992)

Table II–2.16–1 Water(IFC 1967−ITS 1990) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 221.064$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
21	CRP(‘A’)	CRP: Critical Constants H: ‘A’=‘H’: 2.0866×10^6 [J/kg] Specific Enthalpy P∗: ‘A’=‘P’: 22.064×10^6 [Pa], 220.64 [bar] Pressure S: ‘A’=‘S’: 4.410×10^3 [J/(kg·K)] Specific Entropy T∗: ‘A’=‘T’: 647.096 [K], 373.946 [°C] Temperature V: ‘A’=‘V’: 3.1055×10^{-3} [m^3/kg] Specific Volume	one of ‘H’, ‘P’, ‘S’, ‘T’ and ‘V’
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
22	EPSPT(P,T)		

Table II–2.16–1 Water(IFC 1967−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 18.0153 Relative Molecular Mass R: 'A'='R': 461.51 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'H2O' Molecular Formula S: 'A'='S': 'WATER(IFC1967−ITS1990)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$251.165 \leq T \leq 273.16$ [K] $-21.985 \leq T \leq 0.01$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)	PSBT∗: Pressure on Sublimation Curve [Pa], [bar] T∗: Temperature [K], [°C]	$190 \leq T \leq 273.16$ [K] $-83.15 \leq T \leq 0.01$ [°C]
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]

Table II–2.16–1 Water(IFC 1967−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
35	SPT(P,T)		
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 209.9 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 2099$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗:'A'='P': 611.657 [Pa], 6.11657×10^{-3} [bar] Pressure T∗:'A'='T': 273.16 [K], 0.01 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)	TSBP∗: Temperature on Sublimation Curve [K], [°C] P∗: Pressure [Pa], [bar]	$41.532 \times 10^{-3} \leq P \leq 611.657$ [Pa] $0.41532 \times 10^{-6} \leq P \leq 6.11657 \times 10^{-3}$ [bar]
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
79	UPS(P,S)		
44	UPT(P,T)		
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]

Table II–2.16–1 Water(IFC 1967−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar] $HPD(P) \leq H \leq HPDD(P)$ [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: pecific Entropy of Mixture [J/(kg·K)]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar] $SPD(P) \leq S \leq SPDD(P)$ [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar] $UPD(P) \leq U \leq UPDD(P)$ [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar] $VPD(P) \leq V \leq VPDD(P)$ [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C] $HPD(T) \leq H \leq HPDD(T)$ [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C] $SPD(T) \leq S \leq SPDD(T)$ [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C] $UPD(T) \leq U \leq UPDD(P)$ [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C] $VPD(T) \leq V \leq VPDD(T)$ [m^3/kg]

2.17 Water (IAPS 1984 Formulation for Scientific and General Use)

All equations have been cited from NBS/NRC Steam Tables[1].

2.17.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.17.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Water (IAPS 1984)
Library File for UNIX:	libjhgk.a
Library File for DOS,Windows95/NT:	JHGK.LIB
Single Shot Program for UNIX:	hgk-ss
Single Shot Program for DOS,Windows95/NT:	HGK–SS.EXE

2.17.3 Important Constants and Others

Molecular Formula:	H_2O
Relative Molecular Mass:	18.0152
Gas Constant:	461.52 J/(kg·K)

Critical Constants:

Critical Pressure:	22.055×10^6Pa (220.55 bar)
Critical Temperature:	647.126 K (373.976 °C)
Critical Specific Volume:	3.1056×10^{-3}m^3/kg

Triple Point:

Pressure:	611.731 Pa (6.11731×10^{-3}bar)
Temperature:	273.16 K (0.01 °C)

Reference State:

For the liquid state at the triple point, 0 J/(kg·K) and 0 J/kg are assigned to the specific entropy and the specific internal energy of saturated liquid, respectively.

2.17.4 Formula

Equation of State:

Equations (A.1)-(A.6) in a function form of $A = A(\rho, T)$ in reference [1]. Here A=specific helmholtz function, ρ=density and T=Temperature. However, $\sum_{j=0,1,3,5}$ in equation (A.3) has been corrected to $\sum_{j=0,3,5}$.

Vapor Pressure:

Equations (A.1)-(A.6) for specific Helmholtz function and equation (A.7) for the Gibbs condition for phase equlibrium.

Properties at Vapor-Liquid Equilibrium:

Equations (A.1)-(A.6) and equation (A.7) in reference [1] for specific volume. Equations as functions of density and temperature, which have been derived directly by partial differentiation of the specific Helmholtz function, equations (A.1)-(A.6), for specific entropy, specific enthalpy and isobaric specific heat, respectively.

Transport Properties:

Viscosity and thermal conductivity from equations (C.1) and (C.2) in reference [1], respectively. However,

$$\exp(-A((T^*/T)-1)^2 - B((\rho/\rho^*)-1)^4)$$

in equation (C.2) has been corrected to

$$\exp(-A((T/T^*)-1)^2 - B((\rho/\rho^*)-1)^4)$$

Further the values of a_3=0.0036744 in Table C.1 and $b_{14} = -0.0273093$ in Table C.2 have been corrected as a_3=$-$0.0036744 and b_{14}=$-$0.0253093, respectively.

The Other Properties:
Static dielectric constant and surface tension from equations (C.4) and (C.5).

References

[1] L.Haar, J.S.Gallagher and G.S.Kell, NBS/NRC Steam Tables, Hemisphere,N.Y., (1984).

Table II–2.17–1 Water(IAPS 1984) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100 \times (5+(T-273.15)/15) \times 10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500 \times 10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731 \times 10^{-3} \le P \le$ $1000 \times (5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731 \times 10^{-3} \le P \le 15000$ [bar]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100 \times (5+(T-273.15)/15) \times 10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500 \times 10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731 \times 10^{-3} \le P \le$ $1000 \times (5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731 \times 10^{-3} \le P \le 15000$ [bar]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$611.731 \le P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P < 220.55$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$273.16 \le T < 647.126$ [K] $0.01 \le T < 373.976$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P \le 220.55$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$611.731 \le P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P < 220.55$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$611.731 \le P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P < 220.55$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.731 \le P \le 100 \times 10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $6.11731 \times 10^{-3} \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.126$ [K] $0.01 \le T < 373.976$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.126$ [K] $0.01 \le T < 373.976$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P \le 220.55$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \le P \le 220.55$ [bar]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.731 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.11731\times10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity Saturated of Vapor [Pa·s] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500\times10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731\times10^{-3} \leq P \leq$ $1000\times(5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731\times10^{-3} \leq P \leq 15000$ [bar]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500\times10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731\times10^{-3} \leq P \leq$ $1000\times(5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731\times10^{-3} \leq P \leq 15000$ [bar]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500\times10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731\times10^{-3} \leq P \leq$ $1000\times(5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731\times10^{-3} \leq P \leq 15000$ [bar]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500\times10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731\times10^{-3} \leq P \leq$ $1000\times(5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731\times10^{-3} \leq P \leq 15000$ [bar]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.731 \leq P < 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \leq P < 220.55$ [bar]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.731 \le P < 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P < 220.55$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500\times10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731\times10^{-3} \le P \le$ $1000\times(5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731\times10^{-3} \le P \le 15000$ [bar]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.126$ [K] $0.01 \le T < 373.976$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.126$ [K] $0.01 \le T < 373.976$ [°C]
21	CRP('A')	CRP: Critical Constants A: 'A'='H': 2.086×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 22.055×10^6 [Pa], 220.55 [bar] Pressure S: 'A'='S': 4.409×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 647.126 [K], 373.976 [°C] Temperature V: 'A'='V': 3.1056×10^{-3}[m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P \le 220.55$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500\times10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731\times10^{-3} \le P \le$ $1000\times(5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731\times10^{-3} \le P \le 15000$ [bar]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)	EPSPT: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.731 \le P \le 500\times10^6$ [Pa] $273.15 \le T \le 823.15$ [K] $6.11731\times10^{-3} \le P \le 5000$ [bar] $0 \le T \le 550$ [°C]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 18.0152 Relative Molecular Mass R: 'A'='R': 461.52 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P$*$: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P$*$: Pressure [Pa], [bar] T$*$: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100 \times (5+(T-273.15)/15) \times 10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500 \times 10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731 \times 10^{-3} \leq P \leq$ $1000 \times (5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731 \times 10^{-3} \leq P \leq 15000$ [bar]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [J/kg] T$*$: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P$*$: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P$*$: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P$*$: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.731 \leq P \leq 500 \times 10^6$ [Pa] SPT(P,273.15K)$\leq$S$\leq$ SPT(P,1273.15K) [J/(kg·K)] $500 \times 10^6 \leq P \leq 1500 \times 10^6$ [Pa] SPT(P,T_0)$\leq$S$\leq$ SPT(P,1273.15K) [J/(kg·K)] where $T_0=(P \times 10^{-8}-5) \times 15+273.15$ [K] $6.11731 \times 10^{-3} \leq P \leq 5000$ [bar] SPT(P,0°C)$\leq$S$\leq$ SPT(P,1000°C) [J/(kg·K)] $5000 \leq P \leq 15000$ [bar] SPT(P,T_0)$\leq$S$\leq$ SPT(P,1000°C) [J/(kg·K)] where $T_0=(P \times 10^{-3}-5) \times 15$ [°C]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P$*$: Pressure [Pa], [bar] T$*$: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100 \times (5+(T-273.15)/15) \times 10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500 \times 10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731 \times 10^{-3} \leq P \leq$ $1000 \times (5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731 \times 10^{-3} \leq P \leq 15000$ [bar]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'H2O' Molecular Formula S: 'A'='S': 'WATER(IAPS 1984)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.731 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.11731 \times 10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C]
99	PSBT(P)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
72	PSTD(P)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500\times10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731\times10^{-3} \le P \le$ $1000\times(5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731\times10^{-3} \le P \le 15000$ [bar]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.731 \le P \le 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P \le 220.55$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] A: Specific Enthalpy [J/kg]	$611.731 \le P \le 500\times10^6$ [Pa] HPT(P,273.15K)≤H≤ HPT(P,1273.15K) [J/kg] $500\times10^6 \le P \le 1500\times10^6$ [Pa] HPT(P,T_0)≤H≤ HPT(P,1273.15K) [J/kg] where $T_0=(P\times10^{-8}–5)\times15+273.15$[K] $6.11731\times10^{-3} \le P \le 5000$ [bar] HPT(P,0°C)≤H≤ HPT(P,1000°C) [J/kg] $5000 \le P \le 15000$ [bar] HPT(P,T_0)≤H≤ HPT(P,1000°C) [J/kg] where $T_0=(P\times10^{-3}–5)\times15$ [°C]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.731 \le P \le 500\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,1273.15K) [J/(kg·K)] $500\times10^6 \le P \le 1500\times10^6$ [Pa] SPT(P,T_0)≤S≤ SPT(P,1273.15K) [J/(kg·K)] where $T_0=(P\times10^{-8}–5)\times15+273.15$ [K] $6.11731\times10^{-3} \le P \le 5000$ [bar] SPT(P,0°C)≤S≤ SPT(P,1000°C) [J/(kg·K)] $5000 \le P \le 15000$ [bar] SPT(P,T_0)≤S≤ SPT(P,1000°C) [J/(kg·K)] where $T_0=(P\times10^{-3}–5)\times15$ [°C]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	611.731≤P≤500×10^6 [Pa] VPT(P,273.15K)≤V≤ VPT(P,1273.15K) [m^3/kg] 500×10^6≤P≤1500×10^6 [Pa] VPT(P,T_0)≤V≤ VPT(P,1273.15K) [m^3/kg] where T_0=(P×10^{-8}–5)×15+273.15[K] 6.11731×10^{-3}≤P≤5000 [bar] VPT(P,0°C)≤V≤ VPT(P,1000°C) [m^3/kg] 5000≤P≤15000 [bar] VPT(P,T_0)≤V≤ VPT(P,1000°C) [m^3/kg] where T_0=(P×10^{-3}–5)×15[°C]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 611.731 [Pa], 6.11731×10^{-3} [bar] Pressure T∗: 'A'='T': 273.16 [K], 0.01 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	611.731≤P≤22.055×10^6 [Pa] 6.11731×10^{-3}≤P≤220.55 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	611.731≤P≤22.055×10^6 [Pa] 6.11731×10^{-3}≤P≤220.55 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	611.731≤P≤22.055×10^6 [Pa] 6.11731×10^{-3}≤P≤220.55 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	611.731≤P≤500×10^6 [Pa] SPT(P,273.15K)≤S≤ SPT(P,1273.15K) [J/(kg·K)] 500×10^6≤P≤1500×10^6 [Pa] SPT(P,T_0)≤S≤ SPT(P,1273.15K) [J/(kg·K)] where T_0=(P×10^{-8}–5)×15+273.15 [K] 6.11731×10^{-3}≤P≤5000 [bar] SPT(P,0°C)≤S≤ SPT(P,1000°C) [J/(kg·K)] 5000≤P≤15000 [bar] SPT(P,T_0)≤S≤ SPT(P,1000°C) [J/(kg·K)] where T_0=(P×10^{-3}–5)×15 [°C]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500\times10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731\times10^{-3} \le P \le$ $1000\times(5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731\times10^{-3} \le P \le 15000$ [bar]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.731 \le P \le 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P \le 220.55$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \le T \le 647.126$ [K] $0.01 \le T \le 373.976$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P \le 220.55$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$611.731 \le P \le 22.055\times10^6$ [Pa] $6.11731\times10^{-3} \le P \le 220.55$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.731 \le P \le 500\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,1273.15K) [J/(kg·K)] $500\times10^6 \le P \le 1500\times10^6$ [Pa] SPT(P,T_0)≤S≤ SPT(P,1273.15K) [J/(kg·K)] where $T_0=(P\times10^{-8}–5)\times15+273.15$ [K] $6.11731\times10^{-3} \le P \le 5000$ [bar] SPT(P,0°C)≤S≤ SPT(P,1000°C) [J/(kg·K)] $5000 \le P \le 15000$ [bar] SPT(P,T_0)≤S≤ SPT(P,1000°C) [J/(kg·K)] where $T_0=(P\times10^{-3}–5)\times15$ [°C]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \le T \le 423.15$ [K] $611.731 \le P \le$ $100\times(5+(T-273.15)/15)\times10^6$ [Pa] $423.15 \le T \le 1273.15$ [K] $611.731 \le P \le 1500\times10^6$ [Pa] $0 \le T \le 150$ [°C] $6.11731\times10^{-3} \le P \le$ $1000\times(5+T/15)$ [bar] $150 \le T \le 1000$ [°C] $6.11731\times10^{-3} \le P \le 15000$ [bar]

Table II–2.17–1 Water(IAPS 1984) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.731 \leq P \leq 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P \leq 220.55$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.126$ [K] $0.01 \leq T \leq 373.976$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 423.15$ [K] $611.731 \leq P \leq$ $100 \times (5+(T-273.15)/15) \times 10^6$ [Pa] $423.15 \leq T \leq 1273.15$ [K] $611.731 \leq P \leq 1500 \times 10^6$ [Pa] $0 \leq T \leq 150$ [°C] $6.11731 \times 10^{-3} \leq P \leq$ $1000 \times (5+T/15)$ [bar] $150 \leq T \leq 1000$ [°C] $6.11731 \times 10^{-3} \leq P \leq 15000$ [bar]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$611.731 \leq P < 22.055 \times 10^6$ [Pa] $6.11731 \times 10^{-3} \leq P < 220.55$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] A: Specific Enthalpy of Mixture [J/kg]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$273.16 \leq T < 647.126$ [K] $0.01 \leq T < 373.976$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.18 Water(IAPWS Industrial Formulation 1997-ITS 1990)

All equations have been cited from 1999 JSME Steam Tables [1].

2.18.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.18.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Water, Light Water
Library File for UNIX:	libjh2of97.a
Library File for DOS,Windows95/NT:	JH2OF97.LIB
Single Shot Program for UNIX:	h2of97-ss
Single Shot Program for DOS,Windows95/NT:	H2OF97–SS.EXE

2.18.3 Important Constants and Others

Molecular Formula:	H_2O
Relative Molecular Mass:	18.015268
Gas Constant:	461.526 J/(kg·K)

Critical Constants:

Critical Pressure:	22.064×10^{6}Pa (220.64 bar)
Critical Temperature:	647.096 K (373.946°C)
Critical Specific Volume:	3.10559×10^{-3}m^3/kg

Triple Point:

Pressure:	611.657 Pa (6.11657×10^{-3}bar)
Temperature:	273.16 K (0.01°C)

Reference State:
At the triple point, 0 J/(kg·K) and 0 J/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.18.4 Formula

Equation of State:
The function forms of $g = g(P,T)$ and $f = f(v,T)$. Here g=specific free enthalpy, f=specific free energy, P=pressure, T=temperature and ρ=density. The equations, which are divided into five subregions, have been cited from Section 3.1 in chapter 3 in reference [1].

Vapor Pressure:
Equation given at section 3.1 in chapter 3 in reference [1] .

Properties at Vapor-Liquid Equilibrium:
Derived functions given at section 3.1 in chapter 3.1 in reference [1] .

Transport Properties:
Internationally recommended interpolation equations given at sections 3.5 and 3.6 in chapter 3 in reference [1] for dynamic viscosity and thermal conductivity, respectively.

The Other Properties:

Internationally recommended interpolation equations given at sections 3.2, 3.4 and 3.7 in chapter 3 in reference [1] for surface tension, static dielectric constant and ion products, respectively.

References

[1] Japan Society of Mechanical Engineers, 1999 JSME Steam Tables, (1999).

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)	AIPPT: Ion Product [(mol/kg)^2] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 1273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $1 \le P \le 100$ [bar] $0 \le T \le 1000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
8A	AKPD(P)	AKPD: Isentropic Exponent of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
8B	AKPDD(P)	AKPPD: Isentropic Exponent of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
8C	AKTD(T)	AKTD: Isentropic Exponent of Saturated Liquid [–] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
8D	AKTDD(T)	AKTDD: Isentropic Exponent of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \le P \le 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 220.64$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.096$ [K] $0.01 \le T \le 373.946$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $6.11657\times10^{-3} \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 1173.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.11657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 900$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 2.08755×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 22.064×10^6 [Pa], 220.64 [bar] Pressure S: 'A'='S': 4.41202×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 647.096 [K], 373.946 [°C] Temperature V: 'A'='V': 3.1056×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)	CVPD: Isochoric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \le P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P < 220.64$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
7B	CVTD(T)	CVTD: Isochoric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T < 647.096$ [K] $0.01 \le T < 373.946$ [°C]

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2A	EPSPD(P)	EPSPD: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
2B	EPSPDD(P)	EPSPD: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
22	EPSPT(P,T)	EPSPT: Static Dielectric Constant [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 1200.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.11657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 927$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
2C	EPSTD(T)	EPSTD: Static Dielectric Constant [–] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
2D	EPSTDD(T)	EPSTDD: Static Dielectric Constant [–] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 18.015268 Relative Molecular Mass R: 'A'='R': 461.526 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)	GAMPD: Ratio of Specific Heats of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar]
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar]
95	GAMPT(P,T)	GAMPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
9B	GAMTD(T)	GAMTD: Ratio of Specific Heats of Saturated Liquid [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.657 \leq P \leq 100 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 1000$ [bar] The range of the second argument S is the same as the range of the function SPT(P,T). See the range of arguments at SPT(P,T).

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10 \times 10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10 \times 10^6 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657 \times 10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'H2O' Molecular Formula S: 'A'='S': 'WATER(IF97−ITS1990)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P < 220.64$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 100 \times 10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $6.11657 \times 10^{-3} \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \le P \le 10\times10^6$ [Pa] $273.15 \le T \le 2273.15$ [K] $10\times10^6 \le P \le 100\times10^6$ [Pa] $273.15 \le T \le 1073.15$ [K] $611.657\times10^{-3} \le P \le 100$ [bar] $0 \le T \le 2000$ [°C] $100 \le P \le 1000$ [bar] $0 \le T \le 800$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \le P \le 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 220.64$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.096$ [K] $0.01 \le T \le 373.946$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.16 \le T \le 647.096$ [K] $0.01 \le T \le 373.946$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \le T \le 647.096$ [K] $0.01 \le T \le 373.946$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$611.657 \le P \le 100\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 1000$ [bar] The range of the second argument H is the same as the range of the function HPT(P,T). See the range of arguments at HPT(P,T).
6H	TPH2(P,H)	TPH2∗: Temperature [K], [°C] calculated using backward functions P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$611.657 \le P \le 100\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 1000$ [bar] The range of H is limited in the regions 1 and 2 shown in Fig.3.1.2 in ref.[1].
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.657 \le P \le 100\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 1000$ [bar] The range of the second argument S is the same as the range of the function SPT(P,T). See the range of arguments at SPT(P,T).
6S	TPS2(P,S)	TPS2∗: Temperature [K], [°C] calculated using backward functions P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.657 \le P \le 100\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 1000$ [bar] The range of S is limited in the regions 1 and 2 shown in Fig.3.1.2 in ref.[1].
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$611.657 \le P \le 100\times10^6$ [Pa] $6.11657\times10^{-3} \le P \le 1000$ [bar] The range of the second argument V is the same as the range of the function VPT(P,T). See the range of arguments at VPT(P,T).

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 611.657 [Pa], 6.11657×10^{-3} [bar] Pressure T∗: 'A'='T': 273.16 [K], 0.01 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.657\leq P\leq 100\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 1000$ [bar] The range of the second argument S is the same as the range of the function SPT(P,T). See the range of arguments at SPT(P,T)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657\leq P\leq 10\times10^6$ [Pa] $273.15\leq T\leq 2273.15$ [K] $10\times10^6\leq P\leq 100\times10^6$ [Pa] $273.15\leq T\leq 1073.15$ [K] $611.657\times10^{-3}\leq P\leq 100$ [bar] $0\leq T\leq 2000$ [°C] $100\leq P\leq 1000$ [bar] $0\leq T\leq 800$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar] $0\leq X\leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$273.16\leq T\leq 647.096$ [K] $0.01\leq T\leq 373.946$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$273.16\leq T\leq 647.096$ [K] $0.01\leq T\leq 373.946$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16\leq T\leq 647.096$ [K] $0.01\leq T\leq 373.946$ [°C] $0\leq X\leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$611.657\leq P\leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 220.64$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$611.657\leq P\leq 100\times10^6$ [Pa] $6.11657\times10^{-3}\leq P\leq 1000$ [bar] The range of the second argument S is the same as the range of the function SPT(P,T). See the range of arguments at SPT(P,T)

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10\times10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10\times10^6 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657\times10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$611.657 \leq P \leq 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)	WPD: Velocity of Sound of Saturated Liquid [m/s] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar]
8F	WPDD(P)	WPDD: Velocity of Sound of Saturated Vapor [m/s] P∗: Pressure [Pa], [bar]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar]
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$611.657 \leq P \leq 10\times10^6$ [Pa] $273.15 \leq T \leq 2273.15$ [K] $10\times10^6 \leq P \leq 100\times10^6$ [Pa] $273.15 \leq T \leq 1073.15$ [K] $611.657\times10^{-3} \leq P \leq 100$ [bar] $0 \leq T \leq 2000$ [°C] $100 \leq P \leq 1000$ [bar] $0 \leq T \leq 800$ [°C]
8G	WTD(T)	WTD: Velocity of Sound of Saturated Liquid [m/s] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
8H	WTDD(T)	WTDD: Velocity of Sound of Saturated Vapor [m/s] T∗: Temperature [K], [°C]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C]
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$611.657 \leq P < 22.064\times10^6$ [Pa] $6.11657\times10^{-3} \leq P < 220.64$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$273.16 \leq T < 647.096$ [K] $0.01 \leq T < 373.946$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]

Table II–2.18–1 Water(IAPWS IF97−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
61	XTS(T,S)	XTS: Dryness Fraction [–] T$*$: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	273.16≤T<647.096 [K] 0.01≤T<373.946 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T$*$: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	273.16≤T<647.096 [K] 0.01≤T<373.946 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T$*$: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	273.16≤T<647.096 [K] 0.01≤T<373.946 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.19 Heavy Water

Equations for thermodynamic properties have been cited from Hill et al.[1] and those for transport properties from Matsunaga and Nagashima[2] and one for surface tension from IAPS[3].

2.19.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.19.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Heavy Water
Library File for UNIX:	libjd2o.a
Library File for DOS,Windows95/NT:	JD2O.LIB
Single Shot Program for UNIX:	d2o-ss
Single Shot Program for DOS,Windows95/NT:	D2O–SS.EXE

2.19.3 Important Constants and Others

Molecular Formula:	D_2O
Relative Molecular Mass:	20.027
Gas Constant:	415.15 J/(kg·K)

Critical Constants:

Critical Pressure:	21.66×10^6Pa (216.6 bar)
Critical Temperature:	643.89 K (370.74 °C)
Critical Specific Volume:	2.7933×10^{-3}m^3/kg

Triple Point:

Pressure:	660.1 Pa (6.601×10^{-3}bar)
Temperature:	276.95 K (3.8 °C)

Reference State:

For the liquid state at the triple point, 0 J/(kg·K) and 0 J/kg are assigned to the specific entropy and the specific internal energy of saturated liquid, respectively.

2.19.4 Formula

Equation of State:

Equation (1) in a function form of $\psi = \psi(\rho, T)$ in reference [1]. Here ψ= specific helmholtz free energy, ρ= density and T= temperature.

Vapor Pressure:

Equation (1) in reference [1] for specific helmholtz free energy and the Gibbs condition for phase equilibrium.

Properties at Vapor-Liquid Equilibrium:

Equation (1) in reference [1] for specific volume. Equations (6) and (7) in reference [1] for specific entropy and specific enthalpy, respectively. Equation as a function of density and temperature, which has been derived directly by partial differentiation of the specific Helmholtz free energy, equation (1) in reference [1], for isobaric specific heat.

Transport Properties:

Viscosity and thermal conductivity from equations (6) and (7) in reference [2], respectively.

The Other Properties:
Surface tension from equation (10) in reference [3].

References

[1] P.G.Hill,R.D.MacMillan and V.Lee, Tables of Thermodynamic Properties of Heavy Water in S.I. Units, Atomic Energy of Canada Limited, Mississauga, Ontario, (1981).
[2] N.Matsunaga and A.Nagashima, J. Phys. Chem. Ref. Data, 12-4, (1983), pp.933–966.
[3] M.Uematsu, Netsu Bussei (Japan J. Thermophys. Prop.), 2-2, (1988), pp.84-88.

Table II–2.19–1 Heavy Water Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$276.95 \leq T \leq 643.89$ [K] $3.8 \leq T \leq 370.74$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 823.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 550$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 773.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 500$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$660.1 \leq P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P < 216.6$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$276.95 \leq T < 643.89$ [K] $3.8 \leq T < 370.74$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 1.9657×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 21.66×10^6 [Pa], 216.6 [bar] Pressure S: 'A'='S': 4.1815×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 643.89 [K], 370.74 [°C] Temperature V: 'A'='V': 2.7933×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$276.95 \leq T \leq 643.89$ [K] $3.8 \leq T \leq 370.74$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 20.027 Relative Molecular Mass R: 'A'='R': 415.15 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$276.95 \leq T \leq 643.89$ [K] $3.8 \leq T \leq 370.74$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] SPT(P,276.95K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] SPT(P,3.8°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \leq P \leq 100 \times 10^6$ [Pa] $276.95 \leq T \leq 1073.15$ [K] $6.601 \times 10^{-3} \leq P \leq 1000$ [bar] $3.8 \leq T \leq 800$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$660.1 \leq P \leq 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \leq P \leq 216.6$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$276.95 \leq T \leq 643.89$ [K] $3.8 \leq T \leq 370.74$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$276.95 \leq T \leq 643.89$ [K] $3.8 \leq T \leq 370.74$ [°C]

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'D2O' Molecular Formula S: 'A'='S': 'HEAVY WATER' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$660.1 \le P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P < 216.6$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$660.1 \le P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P < 216.6$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \le P \le 100 \times 10^6$ [Pa] $276.95 \le T \le 773.15$ [K] $6.601 \times 10^{-3} \le P \le 1000$ [bar] $3.8 \le T \le 500$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$276.95 \le T < 643.89$ [K] $3.8 \le T < 370.74$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$276.95 \le T < 643.89$ [K] $3.8 \le T < 370.74$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \le P \le 100 \times 10^6$ [Pa] $276.95 \le T \le 1073.15$ [K] $6.601 \times 10^{-3} \le P \le 1000$ [bar] $3.8 \le T \le 800$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	276.95≤T≤643.89 [K] 3.8≤T≤370.74 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	660.1≤P≤100×10^6 [Pa] HPT(P,276.95K)≤H≤ HPT(P,1073.15K) [J/kg] 6.601×10^{-3}≤P≤1000 [bar] HPT(P,3.8°C)≤H≤ HPT(P,800°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	660.1≤P≤100×10^6 [Pa] SPT(P,276.95K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] 6.601×10^{-3}≤P≤1000 [bar] SPT(P,3.8°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	21.66×10^6<P≤50×10^6 [Pa] 216.6<P≤500 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	660.1≤P≤100×10^6 [Pa] VPT(P,276.95K)≤V≤ VPT(P,1073.15K) [m^3/kg] 6.601×10^{-3}≤P≤1000 [bar] VPT(P,3.8°C)≤V≤ VPT(P,800°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗:'A'='P': 660.1 [Pa], 6.601×10^{-3} [bar] Pressure T∗:'A'='T': 276.95 [K], 3.8 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	660.1≤P≤21.66×10^6 [Pa] 6.601×10^{-3}≤P≤216.6 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	660.1≤P≤21.66×10^6 [Pa] 6.601×10^{-3}≤P≤216.6 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	660.1≤P≤21.66×10^6 [Pa] 6.601×10^{-3}≤P≤216.6 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	660.1≤P≤100×10^6 [Pa] SPT(P,276.95K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] 6.601×10^{-3}≤P≤1000 [bar] SPT(P,3.8°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	660.1≤P≤100×10^6 [Pa] 276.95≤T≤1073.15 [K] 6.601×10^{-3}≤P≤1000 [bar] 3.8≤T≤800 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	660.1≤P≤21.66×10^6 [Pa] 6.601×10^{-3}≤P≤216.6 [bar] 0≤X≤1.0 [–]

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$660.1 \le P \le 100 \times 10^6$ [Pa] SPT(P,276.95K)≤S≤ SPT(P,1073.15K) [J/(kg·K)] $6.601 \times 10^{-3} \le P \le 1000$ [bar] SPT(P,3.8°C)≤S≤ SPT(P,800°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \le P \le 100 \times 10^6$ [Pa] $276.95 \le T \le 1073.15$ [K] $6.601 \times 10^{-3} \le P \le 1000$ [bar] $3.8 \le T \le 800$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$660.1 \le P \le 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P \le 216.6$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$276.95 \le T \le 643.89$ [K] $3.8 \le T \le 370.74$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$660.1 \le P \le 100 \times 10^6$ [Pa] $276.95 \le T \le 1073.15$ [K] $6.601 \times 10^{-3} \le P \le 1000$ [bar] $3.8 \le T \le 800$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$660.1 \le P < 21.66 \times 10^6$ [Pa] $6.601 \times 10^{-3} \le P < 216.6$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]

Table II–2.19–1 Heavy Water Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$660.1 \leq P < 21.66\times10^6$ [Pa] $6.601\times10^{-3} \leq P < 216.6$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$660.1 \leq P < 21.66\times10^6$ [Pa] $6.601\times10^{-3} \leq P < 216.6$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$660.1 \leq P < 21.66\times10^6$ [Pa] $6.601\times10^{-3} \leq P < 216.6$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	276.95≤T<643.89 [K] 3.8≤T<370.74 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	276.95≤T<643.89 [K] 3.8≤T<370.74 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	276.95≤T<643.89 [K] 3.8≤T<370.74 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	276.95≤T<643.89 [K] 3.8≤T<370.74 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.20 Ammonia (Stewart, Jacobsen and Renoncello)

Equations for thermodynamic properties are based on the formulations by Stewart, Jacobsen and Renoncello used in a monograph from American Society of Heating, Refrigerating and Air-Conditioning Engineers [1]. The Equation for viscosity has been cited from Fenghour, Wakeham, Vesovic, Watson, Millat and Vogel [2], that for thermal conductivity from Yata [3], and that for surface tension from Liley and Desai [4].

2.20.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.20.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Ammonia
Library File for UNIX:	libjnh3.a
Library File for DOS,Windows95/NT:	JNH3.LIB
Single Shot Program for UNIX:	nh3-ss
Single Shot Program for DOS,Windows95/NT:	NH3–SS.EXE

2.20.3 Important Constants and Others

Molecular Formula:	NH_3
Relative Molecular Mass:	17.03026
Gas Constant:	488.18 J/(kg·K)

Critical Constants:

Critical Pressure:	11.304×10^6Pa (113.04 bar)
Critical Temperature:	405.4 K (132.25°C)
Critical Specific Volume:	4.255×10^{-3}m^3/kg

Triple Point:

Pressure:	6.063×10^3 Pa (0.06063 bar)
Temperature:	195.48 K (−77.67°C)

Reference State:

Ideal gas value of internal energy is defined as $U^0_{0\mathrm{K}} = 0$ J/kg at 0 K (−273.15 °C).

2.20.4 Formula

Equation of State:

Equations (6.1.1)-(6.1.4) in a function form of $A = A(\rho, T)$ in reference [1]. Here A=specific helmholtz function, ρ=density and T=temperature.

Vapor Pressure:

Equation (6.1.12) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (6.1.12) and (6.1.5) for specific volume, equation (6.1.6) for specific entropy, and equation (6.1.8) for specific enthalpy. All of these have been cited from reference [1].

Transport Properties:

Viscosiy, thermal conductivity and surface tension are cited from reference [2], [3] and [4], respectively.

References

[1] R. B. Stewart, R. T. Jacobsen and S. G. Renoncello, ASHRAE Thermodynamic Properties of Refrigerants, American Society of Heating, Refrigerating and Air-Conditioning Engineers, (1986), pp.93–97, pp.262–282.

[2] A. Fenghour, W. A. Wakeham, V. Vesovic, J. T. R. Watson, J. Millat and E. Vogel, J. Phys. Chem. Ref. Data, Vol. 24, 5, (1995), pp.1649.

[3] J. Yata, Private communication.

[4] P. E. Liley and P. D. Desai, Thermophysical Properties of Refrigerants (Inch–Pound Edition), American Society of Heating, Refrigerating and Air-Conditioning Engineers, (1993), pp.204.

Table II–2.20–1 Ammonia Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] $0.06063 \le P \le 112.939$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.20$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)]	$40.8339\times10^3 \le P \le 10.4652\times10^6$ [Pa] $0.408339 \le P \le 104.652$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)]	$40.8339\times10^3 \le P \le 9.7034\times10^6$ [Pa] $0.408339 \le P \le 97.034$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \le 50.0\times10^6$ [Pa] $223.15 \le T \le 573.15$ [K] $0 < P \le 500$ [bar] $-50.0 \le T \le 300$ [°C] out of range: $395.0 < T < 430.0$ [K] $112.5 < \rho < 337.5$ [kg/m^3]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$223.15 \le T \le 401.064$ [K] $-50.0 \le T \le 127.914$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$223.15 \le T \le 396.8669$ [K] $-50.0 \le T \le 123.7169$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$6.06\times10^3 \le P \le 11.2939\times10^6$ [Pa] $6.06\times10^{-2} \le P \le 112.939$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$6.06\times10^3 \le P \le 11.2939\times10^6$ [Pa] $6.06\times10^{-2} \le P \le 112.939$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \le 50.0\times10^6$ [Pa] $196.0 \le T \le 700.0$ [K] $0 < P \le 500$ [bar] $-77.15 \le T \le 426.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.2$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.2$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
21	CRP('A')	CRP: Critical Constants P∗: 'A'='P': 11.304×10^{6}[Pa], 113.04 [bar] Pressure T∗: 'A'='T': 405.4 [K], 132.25 [°C] Temperature V: 'A'='V': 4.255×10^{-3} [m^3/kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 17.03026 Relative Molecular Mass R: 'A'='R': 488.18 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^{3}\leq P\leq 11.2939\times10^{6}$ [Pa] $0.06063\leq P\leq 112.939$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^{3}\leq P\leq 11.2939\times10^{6}$ [Pa] $0.06063\leq P\leq 112.939$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.01\times10^{6}\leq P\leq 15\times10^{6}$ [Pa] SPT(P,208.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $15\times10^{6}<P\leq 150\times10^{6}$ [Pa] SPT(P,218.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $150\times10^{6}<P\leq 500\times10^{6}$ [Pa] SPT(P,(0.4×10^{-6})P+158.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $0.001\leq P\leq 150$ [bar] SPT(P,−65°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $150<P\leq 1500$ [bar] SPT(P,−55°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $1500<P\leq 5000$ [bar] SPT(P,0.04P−115°C)≤S≤ SPT(P,480C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.01\times10^{6}\leq P\leq 15\times10^{6}$ [Pa] $208.15\leq T\leq 753.15$ [K] $15\times10^{6}<P\leq 150\times10^{6}$ [Pa] $218.15\leq T\leq 753.15$ [K] $150\times10^{6}<P\leq 500\times10^{6}$ [Pa] $(0.4\times10^{-6})P+158.15\leq T\leq 753.15$ [K] $0.001\leq P\leq 150$ [bar] $-65.0\leq T\leq 480$ [°C] $150<P\leq 1500$ [bar] $-55.0\leq T\leq 480$ [°C] $1500<P\leq 5000$ [bar] $0.04P-115\leq T\leq 480$ [°C]

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'NH3' Molecular Formula S: 'A'='S': 'AMMONIA' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$10.8207\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $10.8207\times10^{-2} \leq P \leq 112.939$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$203.0 \leq T \leq 405.40$ [K] $-70.15 \leq T \leq 132.25$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.01\times10^6 \leq P \leq 15\times10^6$ [Pa] $208.15 \leq T \leq 753.15$ [K] $15\times10^6 < P \leq 150\times10^6$ [Pa] $218.15 \leq T \leq 753.15$ [K] $150\times10^6 < P \leq 500\times10^6$ [Pa] $(0.4\times10^{-6})P+158.15 \leq T \leq 753.15$ [K] $0.001 \leq P \leq 150$ [bar] $-65.0 \leq T \leq 480$ [°C] $150 < P \leq 1500$ [bar] $-55.0 \leq T \leq 480$ [°C] $1500 < P \leq 5000$ [bar] $0.04P-115 \leq T \leq 480$ [°C]

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.01\times10^6 \leq P \leq 15\times10^6$ [Pa] HPT(P,208.15K)≤H≤ HPT(P,753.15K) [J/kg] $15\times10^6 < P \leq 150\times10^6$ [Pa] HPT(P,218.15K)≤H≤ HPT(P,753.15K) [J/kg] $150\times10^6 < P \leq 500\times10^6$ [Pa] HPT(P,(0.4×10^{-6})P+158.15K)≤H≤ HPT(P,753.15K) [J/kg] $0.001 \leq P \leq 150$ [bar] HPT(P,−65°C)≤H≤ HPT(P,480°C) [J/kg] $150 < P \leq 1500$ [bar] HPT(P,−55°C)≤H≤ HPT(P,480°C) [J/kg] $1500 < P \leq 5000$ [bar] HPT(P,0.04P−115°C)≤H≤ HPT(P,480°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.01\times10^6 \leq P \leq 15\times10^6$ [Pa] SPT(P,208.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $15\times10^6 < P \leq 150\times10^6$ [Pa] SPT(P,218.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $150\times10^6 < P \leq 500\times10^6$ [Pa] SPT(P,(0.4×10^{-6})P+158.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $0.001 \leq P \leq 150$ [bar] SPT(P,−65°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $150 < P \leq 1500$ [bar] SPT(P,−55°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $1500 < P \leq 5000$ [bar] SPT(P,0.04P−115°C)≤S≤ SPT(P,480°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.01\times10^6 \le P \le 15\times10^6$ [Pa] VPT(P,208.15K)≤V≤ VPT(P,753.15K) [m^3/kg] $15\times10^6 < P \le 150\times10^6$ [Pa] VPT(P,218.15K)≤V≤ VPT(P,753.15K) [m^3/kg] $150\times10^6 < P \le 500\times10^6$ [Pa] VPT(P,(0.4×10^{-6})P+158.15K)≤V≤ VPT(P,753.15K) [m^3/kg] 0.001≤P≤150 [bar] VPT(P,−65°C)≤V≤ VPT(P,480°C) [m^3/kg] 150<P≤1500 [bar] VPT(P,−55°C)≤V≤ VPT(P,480°C) [m^3/kg] 1500<P≤5000 [bar] VPT(P,0.04P−115°C)≤V≤ VPT(P,480°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 6.063×10^3 [Pa], 0.06063 [bar] Pressure T∗: 'A'='T': 195.48 [K], −77.67 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] 0.06063≤P≤112.939 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] 0.06063≤P≤112.939 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] 0.06063≤P≤112.939 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.01\times10^6 \le P \le 15\times10^6$ [Pa] SPT(P,208.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $15\times10^6 < P \le 150\times10^6$ [Pa] SPT(P,218.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $150\times10^6 < P \le 500\times10^6$ [Pa] SPT(P,(0.4×10^{-6})P+158.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] 0.001≤P≤150 [bar] SPT(P,−65°C)≤S≤ SPT(P,480°C) [J/(kg·K)] 150<P≤1500 [bar] SPT(P,−55°C)≤S≤ SPT(P,480°C) [J/(kg·K)] 1500<P≤5000 [bar] SPT(P,0.04P−115°C)≤S≤ SPT(P,480°C) [J/(kg·K)]

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.01\times10^6 \le P \le 15\times10^6$ [Pa] $208.15 \le T \le 753.15$ [K] $15\times10^6 < P \le 150\times10^6$ [Pa] $218.15 \le T \le 753.15$ [K] $150\times10^6 < P \le 500\times10^6$ [Pa] $(0.4\times10^{-6})P+158.15 \le T \le 753.15$ [K] $0.001 \le P \le 150$ [bar] $-65 \le T \le 480$ [°C] $150 < P \le 1500$ [bar] $-55 \le T \le 480$ [°C] $1500 < P \le 5000$ [bar] $0.04P-115 \le T \le 480$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] $0.06063 \le P \le 112.939$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.20$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.20$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.48 \le T \le 405.35$ [K] $-77.67 \le T \le 132.20$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] $0.06063 \le P \le 112.939$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \le P \le 11.2939\times10^6$ [Pa] $0.06063 \le P \le 112.939$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.01\times10^6 \le P \le 15\times10^6$ [Pa] SPT(P,208.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $15\times10^6 < P \le 150\times10^6$ [Pa] SPT(P,218.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $150\times10^6 < P \le 500\times10^6$ [Pa] SPT(P,(0.4×10^{-6})P+158.15K)≤S≤ SPT(P,753.15K) [J/(kg·K)] $0.001 \le P \le 150$ [bar] SPT(P,−65°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $150 < P \le 1500$ [bar] SPT(P,−55°C)≤S≤ SPT(P,480°C) [J/(kg·K)] $1500 < P \le 5000$ [bar] SPT(P,0.04P−115°C)≤S≤ SPT(P,480°C) [J/(kg·K)]

Table II–2.20–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.01\times10^6 \leq P \leq 15\times10^6$ [Pa] $208.15 \leq T \leq 753.15$ [K] $15\times10^6 < P \leq 150\times10^6$ [Pa] $218.15 \leq T \leq 753.15$ [K] $150\times10^6 < P \leq 500\times10^6$ [Pa] $(0.4\times10^{-6})P+158.15 \leq T \leq 753.15$ [K] $0.001 \leq P \leq 150$ [bar] $-65 \leq T \leq 480$ [°C] $150 < P \leq 1500$ [bar] $-55 \leq T \leq 480$ [°C] $1500 < P \leq 5000$ [bar] $0.04P-115 \leq T \leq 480$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] $0 \leq X \leq 1.0$ [–]
8A	WPD(P)		
8B	WPDD(P)		
83	WPT(P,T)		
8C	WTD(T)		
8D	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$6.063\times10^3 \leq P \leq 11.2939\times10^6$ [Pa] $0.06063 \leq P \leq 112.939$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] HPD(T)≤H≤HPDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] SPD(T)≤S≤SPDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] UPD(T)≤U≤UPDD(P) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$195.48 \leq T \leq 405.35$ [K] $-77.67 \leq T \leq 132.20$ [°C] VPD(T)≤V≤VPDD(T) [m^3/kg]

2.21 Ammonia (Tillner–Roth, Harms–Watzenberg and Baehr)

Equations for thermodynamic properties are based on Tillner–Roth, Harms–Watzenberg and Baehr [1]. The Equation for viscosity has been cited from Fenghour, Wakeham, Vesovic, Watson, Millat and Vogel [2], that for thermal conductivity from Yata [3], and that for surface tension from Liley and Desai [4].

2.21.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.21.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Ammonia
Library File for UNIX:	libjnh32.a
Library File for DOS,Windows95/NT:	JNH32.LIB
Single Shot Program for UNIX:	nh32-ss
Single Shot Program for DOS,Windows95/NT:	NH32–SS.EXE

2.21.3 Important Constants and Others

Molecular Formula:	NH_3
Relative Molecular Mass:	17.03026
Gas Constant:	488.189 J/(kg·K)

Critical Constants:

Critical Pressure:	11.36×10^6Pa (113.6 bar)
Critical Temperature:	405.40 K (132.25°C)
Critical Specific Volume:	4.444×10^{-3}m^3/kg

Triple Point:

Pressure:	6.063×10^3 Pa (0.06063 bar)
Temperature:	195.495 K (−77.655°C)

Reference State:
At 273.15 K (0°C), 200 kJ/kg and 1 kJ/(kg·K) are assigned to the specific enthalpy and specific entropy of saturated liquid, respectively.

2.21.4 Formula

Equation of State:
Equations (1)–(4) in a function form of $\Phi = \Phi(\tau, \delta)$ in reference [1]. Here Φ=specific helmholtz free energy, $\tau = 405.40/T$, $\delta = \rho/225$, T = temperature (K), ρ = density (kg/m^3).

Properties at Vapor-Liquid Equilibrium:
The properties at Vapor–Liquid Equilibrium are calculated by Phase–equilibrium condition (Maxwell criterion). All of those have been cited from reference [1].

Transport Properties:
Viscosiy, thermal conductivity and surface tension are cited from reference [2], [3] and [4], respectively.

References

[1] R. Tillner–Roth, F. Harms–Watzenberg and H. D. Baehr, Eine neue Fundamentalgleichung für Ammoniakm, Proc. 20$^{\text{th}}$ DKV–Tagung Heidelberg, Germany, Vol. II, (1993), pp.167
[2] A. Fenghour, W. A. Wakeham, V. Vesovic, J. T. R. Watson, J. Millat and E. Vogel, J. Phys. Chem. Ref. Data, Vol. 24, 5, (1995), pp.1649.
[3] J. Yata, Private communication.
[4] P. E. Liley and P. D. Desai, Thermophysical Properties of Refrigerants (Inch–Pound Edition), American Society of Heating, Refrigerating and Air-Conditioning Engineers, (1993), pp.204.

Table II–2.21–1 Ammonia Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)]	$40.8339\times10^3 \leq P \leq 10.4652\times10^6$ [Pa] $0.408339 \leq P \leq 104.652$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)]	$40.8339\times10^3 \leq P \leq 9.71034\times10^6$ [Pa] $0.408339 \leq P \leq 97.1034$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \leq 50.0\times10^6$ [Pa] $223.15 \leq T \leq 573.15$ [K] $0 < P \leq 500$ [bar] $-50.0 \leq T \leq 300$ [°C] out of range: $395.0 < T < 430.0$ [K] $112.5 < \rho < 337.5$ [kg/m^3]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$223.15 \leq T \leq 401.064$ [K] $-50.0 \leq T \leq 127.914$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$223.15 \leq T \leq 396.8669$ [K] $-50.0 \leq T \leq 123.7169$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$6.06\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $6.06\times10^{-2} \leq P \leq 113.6$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$6.06\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $6.06\times10^{-2} \leq P \leq 113.6$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \leq 50.0\times10^6$ [Pa] $196.0 \leq T \leq 700.0$ [K] $0 < P \leq 500$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$196.0 \leq T \leq 405.40$ [K] $-77.15 \leq T \leq 132.25$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$196.0 \leq T \leq 405.40$ [K] $-77.15 \leq T \leq 132.25$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
21	CRP('A')	CRP: Critical Constants P∗: 'A'='P': 11.36×10^6[Pa], 113.6 [bar] Pressure T∗: 'A'='T': 405.4 [K], 132.25 [°C] Temperature V: 'A'='V': 4.444×10^{-3} [m^3/kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7A	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 17.03026 Relative Molecular Mass R: 'A'='R': 488.189 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3\leq P\leq11.36\times10^6$ [Pa] $0.06063\leq P\leq113.6$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3\leq P\leq11.36\times10^6$ [Pa] $0.06063\leq P\leq113.6$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0<P\leq1000\times10^6$ [Pa] SPT(P,196K)≤S≤ SPT(P,700K) [J/(kg·K)] $0<P\leq10000$ [bar] SPT(P,−77.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq1000\times10^6$ [Pa] $196\leq T\leq700$ [K] $0<P\leq10000$ [bar] $-77.15\leq T\leq426.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3\leq P\leq11.36\times10^6$ [Pa] $0.06063\leq P\leq113.6$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$195.495\leq T\leq405.4$ [K] $-77.655\leq T\leq132.25$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$195.495\leq T\leq405.4$ [K] $-77.655\leq T\leq132.25$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.495\leq T\leq405.4$ [K] $-77.655\leq T\leq132.25$ [°C] $0\leq X\leq1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'NH3' Molecular Formula S: 'A'='S': 'AMMONIA' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$10.8207 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $10.8207 \times 10^{-2} \leq P \leq 113.6$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$203.0 \leq T \leq 405.40$ [K] $-70.15 \leq T \leq 132.25$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \leq 1000 \times 10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0 < P \leq 1000 \times 10^6$ [Pa] HPT(P,196K)≤H≤ HPT(P,700K) [J/kg] $0 < P \leq 10000$ [bar] HPT(P,−77.15°C)≤H≤ HPT(P,426.85°C) [J/kg]
6H	TPH2(P,H)		

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0<P\leq 1000\times 10^6$ [Pa] SPT(P,196K)≤S≤ SPT(P,700K) [J/(kg·K)] 0<P≤10000 [bar] SPT(P,−77.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0<P\leq 1000\times 10^6$ [Pa] VPT(P,196K)≤V≤ VPT(P,700K) [m^3/kg] 0<P≤10000 [bar] VPT(P,−77.15°C)≤V≤ VPT(P,426.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 6.063×10^3 [Pa], 0.06063 [bar] Pressure T∗: 'A'='T': 195.495 [K], −77.655 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$6.063\times 10^3\leq P\leq 11.36\times 10^6$ [Pa] 0.06063≤P≤113.6 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times 10^3\leq P\leq 11.36\times 10^6$ [Pa] 0.06063≤P≤113.6 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$6.063\times 10^3\leq P\leq 11.36\times 10^6$ [Pa] 0.06063≤P≤113.6 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0<P\leq 1000\times 10^6$ [Pa] SPT(P,196K)≤S≤ SPT(P,700K) [J/(kg·K)] 0<P≤10000 [bar] SPT(P,−77.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 1000\times 10^6$ [Pa] 196≤T≤700 [K] 0<P≤10000 [bar] −77.15≤T≤426.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times 10^3\leq P\leq 11.36\times 10^6$ [Pa] 0.06063≤P≤113.6 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	195.495≤T≤405.4 [K] −77.655≤T≤132.25 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	195.495≤T≤405.4 [K] −77.655≤T≤132.25 [°C]

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0 < P \leq 1000\times10^6$ [Pa] SPT(P,196K)≤S≤ SPT(P,700K) [J/(kg·K)] $0 < P \leq 10000$ [bar] SPT(P,−77.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \leq 1000\times10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$6.063\times10^3 \leq P \leq 11.36\times10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] HPD(T)≤H≤HPDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] SPD(T)≤S≤SPDD(T) [J/(kg·K)]

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	195.495≤T≤405.4 [K] −77.655≤T≤132.25 [°C] UPD(T)≤U≤UPDD(P) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	195.495≤T≤405.4 [K] −77.655≤T≤132.25 [°C] VPD(T)≤V≤VPDD(T) [m^3/kg]

2.22 Sulfur Hexafluoride

Equations for thermodynamic properties have been cited from Oda et al.[1], that for transport properties from Tanaka et al.[2], Tauscher[3], Dawe et al.[4] and Harris[5] , and that for surface tension from Rathjen et al.[6].

2.22.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.22.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Sulfur Hexafloride
Library File for UNIX:	libjsf6.a
Library File for DOS,Windows95/NT:	JSF6.LIB
Single Shot Program for UNIX:	sf6-ss
Single Shot Program for DOS,Windows95/NT:	SF6–SS.EXE

2.22.3 Important Constants and Others

Molecular Formula:	SF_6
Relative Molecular Mass:	146.05
Gas Constant:	56.928 J/(kg·K)

Critical Constants:

Critical Pressure:	3.7461×10^6Pa (37.641 bar)
Critical Temperature:	318.748 K (−45.598°C)
Critical Specific Volume:	1.37266×10^{-3}m^3/kg

Triple Point:

Pressure:	0.22502×10^6Pa (2.22502 bar)
Temperature:	222.35 K (−50.8°C)

Reference State:
At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas. At 1.01325 bar(1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas.

2.22.4 Formula

Equation of State:
Equation (6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:
Equation (6) in reference [1] and equation for the Gibbs condition for phase equilibrium.

Properties at Vapor-Liquid Equilibrium:
Equation (6) in reference [1] and equation for the Gibbs condition for phase equilibrium for specific volume. Equations as functions of density and temperature, which have been derived directly by partial differentiation of the equation of state (6) in reference [1] for specific entropy, specific enthalpy, isochoric specific heat and isobaric specific heat, respectively.

Transport property:

Equation (7) in reference [2] for thermal conductivity of superheated vapor and equation(5) in reference [3] for thermal conductivity of saturated liquid. Equation (1) in reference [4] and equation (1) in reference [5] for viscosity at room pressure.

The other Properties:
Equation (25) in reference [6] for surface tension.

References

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[5] E.J.Harris, G.C.Hope, D.W.Gough and E.B.Smith, J. Chem. Soc.; Faraday I, 75(1979),pp.892-897.
[6] W.Rathjen and J.Straub, Waerme- und Stoeffuebertraegung,14 (1980),pp.59-73.

Table II–2.22–1 Sulfur Hexafluoride Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$0.28505\times10^6 \leq P \leq 1.2590\times10^6$ [Pa] $2.8505 \leq P \leq 12.59$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq (0.653\times$ (T[K]-273.15)+4.3)$\times10^5$ [Pa] $298.15 \leq T \leq 373.15$ [K] $0.1 \leq P \leq 0.653\times$T[°C]+4.3 [bar] $25 \leq T \leq 100$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$228.15 \leq T \leq 273.15$ [K] $-45 \leq T \leq 0$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity at Ordinary Pressure [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $298.15 \leq T \leq 373.15$ [K] $25 \leq T \leq 100$ [°C]
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]

Table II–2.22–1 Sulfur Hexafluoride Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
91	BTPT(P,T)	BTPT: Isothermal Comperssibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0,22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -40.9178×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.7641×10^6 [Pa], 37.641 [bar] Pressure S: 'A'='S': -0.309422×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 318.748 [K], 45.598 [°C] Temperature V: 'A'='V': 1.37266×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 146.05 Relative Molecular Mass R: 'A'='R': 56.928 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar]

Table II–2.22–1 Sulfur Hexafluoride Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \le P \le 50\times10^6$ [Pa] $222.35 \le T \le 500$ [K] $0.01 \le P \le 500$ [bar] $-50.8 \le T \le 226.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$222.35 \le T < 318.748$ [K] $-50.8 \le T < 45.598$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \le P \le 3.7641\times10^6$ [Pa] $2.2502 \le P \le 37.641$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \le P \le 3.7641\times10^6$ [Pa] $2.2502 \le P \le 37.641$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \le P \le 50\times10^6$ [Pa] SPT(P,222.35)≤S≤ SPT(P,500K) [J/(kg·K)] $0.01 \le P \le 500$ [bar] SPT(P,–50.8°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \le P \le 50\times10^6$ [Pa] $222.35 \le T \le 500$ [K] $0.01 \le P \le 500$ [bar] $-50.8 \le T \le 226.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.22502\times10^6 \le P \le 3.7641\times10^6$ [Pa] $2.2502 \le P \le 37.641$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$222.35 \le T \le 318.748$ [K] $-50.8 \le T \le 45.598$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$222.35 \le T \le 318.748$ [K] $-50.8 \le T \le 45.598$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$222.35 \le T \le 318.748$ [K] $-50.8 \le T \le 45.598$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'SF6' Molecular Formula S: 'A'='S': 'SULFUR HEXAFLUORIDE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $298.15 \le T \le 373.15$ [K] $25 \le T \le 100$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$222.35 \le T \le 318.748$ [K] $-50.8 \le T \le 45.598$ [°C]
72	PSTD(T)		
73	PSTDD(T)		

Table II–2.22–1 Sulfur Hexafluoride Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$1000 \leq P \leq 50\times10^6$ [Pa] HPT(P,222.35K)≤H≤ HPT(P,500K) [J/kg] $0.01 \leq P \leq 500$ [bar] HPT(P,−50.8°C)≤H≤ HPT(P,226.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 50\times10^6$ [Pa] SPT(P,222.35K)≤S≤ SPT(P,500K) [J/(kg·K)] $0.01 \leq P \leq 500$ [bar] SPT(P,−50.8°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$3.7641\times10^6 < P \leq 20\times10^6$ [Pa] $37.641 < P \leq 200$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$1000 \leq P \leq 50\times10^6$ [Pa] VPT(P,222.35K)≤V≤ VPT(P,500K) [m^3/kg] $0.01 \leq P \leq 500$ [bar] VPT(P,−50.8°C)≤V≤ VPT(P,226.85°C) [m^3/kg]

Table II–2.22–1 Sulfur Hexafluoride Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.22502×10^6 [Pa], 2.2502 [bar] Pressure T∗: 'A'='T': 222.35 [K], −50.8 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 50\times10^6$ [Pa] SPT(P,222.35K)≤S≤ SPT(P,500K) [J/(kg·K)] $0.01 \leq P \leq 500$ [bar] SPT(P,−50.8)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.22502\times10^3 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1000 \leq P \leq 50\times10^6$ [Pa] SPT(P,222.35K)≤S≤ SPT(P,500K) [J/(kg·K)] $0.01 \leq P \leq 500$ [bar] SPT(P,−50.8°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]

Table II–2.22–1 Sulfur Hexafluoride Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.22502\times10^6 \leq P \leq 3.7641\times10^6$ [Pa] $2.2502 \leq P \leq 37.641$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$222.35 \leq T \leq 318.748$ [K] $-50.8 \leq T \leq 45.598$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1000 \leq P \leq 50\times10^6$ [Pa] $222.35 \leq T \leq 500$ [K] $0.01 \leq P \leq 500$ [bar] $-50.8 \leq T \leq 226.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.22502\times10^6 \leq P < 3.7641\times10^6$ [Pa] $2.2502 \leq P < 37.641$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$222.35 \leq T < 318.748$ [K] $-50.8 \leq T < 45.598$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.23 Methane(IUPAC Table)

Equations for thermodynamic properties have been cited from the IUPAC Table [1], and those for viscosity from Ely et al.[2], thermal conductivity from reference [3] and surface tension from Miller et al.[4].

2.23.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.23.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Methane
Library File for UNIX:	libjch4.a
Library File for DOS,Windows95/NT:	JCH4.LIB
Single Shot Program for UNIX:	ch4-ss
Single Shot Program for DOS,Windows95/NT:	CH4–SS.EXE

2.23.3 Important Constants and Others

Molecular Formula:	CH_4
Relative Molecular Mass:	16.043
Gas Constant:	518.25 J/(kg·K)

Critical Constants:

Critical Pressure:	4.595×10^6Pa (45.95 bar)
Critical Temperature:	190.555 K (−82.595°C)
Critical Specific Volume:	6.1656×10^{-3}m^3/kg

Triple Point:

Pressure:	0.011719×10^6Pa (0.11719 bar)
Temperature:	90.68 K (−182.47°C)

Reference State:

The point at which the specific entropy and the specific enthalpy are assumed to be zero is that of the ideal gas at 25 °C(298.15 K) and 1.01325 bar (1 atm).

2.23.4 Formula

Equation of State:

Equation (24) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature. However the minus sign of the coefficient N_{32} in the Table G in reference [1] has been corrected to a plus sign.

Vapor Pressure:

Equation (50) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (24) for specific volume, equations (24) and (27) for specific entropy, equations (24) and (36) for specific enthalpy, and equations (24) and (43) for isobaric specific heat, respectively. All of these have been cited from reference [1]. However, the value of f_8=0.269386063023×10 in Table J has been corrected as f_8=$-0.145719286035\times10^{-10}$. Further the third term in the right side of equation (43),

$$C_p(\rho, T) = C_p^{id}(T) - R + R[\sum_{i=1}^{32} N_i(XC)_i]_0^w + \cdots$$

has been corrected to

$$C_p(\rho, T) = C_p^{id}(T) - R - R[\sum_{i=1}^{32} N_i (XC)_i]_0^w + \cdots$$

Pressure and Temperature on Melting Line:
Equation (52) in the reference [1].

Transport Properties:
Equation in Table III in reference [2] for viscosity and equation (4) in reference [3] for thermal conductivity.

The Other Properties:
Equation (23-1) in reference [4] for surface tension.

References

[1] S.Angus and K.M.de Reuck, International Thermodynamic Table of the Fluid State-5 Methane, IUPAC, vol.5, (1976).
[2] J.F.Ely and H.J.M.Hanley, Ind. Eng. Chem. Fundam., vol.20, No.4, (1981), p.323.
[3] Survey of Physical Data, High Pressure Fluids, vol.5, Science and Technology Agency, Tokyo, (1977-3), p.97.
[4] J.W.Miller,Jr. and C.L.Yaws, Chem. Eng., 83-23, (1976), p.127.

Table II–2.23–1 Methane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \leq P \leq 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \leq 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \leq P \leq 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \leq 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 70\times10^6$ [Pa] 298.15≤T≤423.15 [K] 1.0≤P≤700 [bar] 25≤T≤150 [°C]
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$PST(95K) \leq P \leq 4.595\times10^6$ [Pa] PST(−178.15°C)≤P≤45.95 [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$PST(95K) \leq P \leq 4.595\times10^6$ [Pa] PST(−178.15°C)≤P≤45.95 [bar]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq$P$\leq$PMLT(95K) [Pa] 95$\leq$T$\leq$500 [K] PMLT(95K)<P$\leq40\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$500 [K] $40\times10^6<$P$\leq50\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$470 [K] $50\times10^6<$P$\leq75\times10^6$ [Pa] 205$\leq$T$\leq$470 [K] 1.0$\leq$P$\leq$PMLT($-$178.15°C) [bar] $-$178.15$\leq$T$\leq$226.85 [°C] PMLT($-$178.15°C)<P$\leq$400 [bar] TMLP(P)$\leq$T$\leq$226.85 [°C] 400<P$\leq$500 [bar] TMLP(P)$\leq$T$\leq$196.85 [°C] 500<P$\leq$750 [bar] $-$68.15$\leq$T$\leq$196.85 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	95$\leq$T$\leq$190.555 [K] $-$178.15$\leq$T$\leq-$82.595 [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	95$\leq$T$\leq$190.555 [K] $-$178.15$\leq$T$\leq-$82.595 [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq$P$\leq40\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$620 [K] $40\times10^6<$P$\leq10^9$ [Pa] TMLP(P)$\leq$T$\leq$470 [K] 0.11719$\leq$P$\leq$400 [bar] TMLP(P)$\leq$T$\leq$346.85 [°C] 400<P$\leq$10000 [bar] TMLP(P)$\leq$T$\leq$196.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq$P$\leq40\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$620 [K] $40\times10^6<$P$\leq10^9$ [Pa] TMLP(P)$\leq$T$\leq$470 [K] 0.11719$\leq$P$\leq$400 [bar] TMLP(P)$\leq$T$\leq$346.85 [°C] 400<P$\leq$10000 [bar] TMLP(P)$\leq$T$\leq$196.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq$P$\leq40\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$620 [K] $40\times10^6<$P$\leq10^9$ [Pa] TMLP(P)$\leq$T$\leq$470 [K] 0.11719$\leq$P$\leq$400 [bar] TMLP(P)$\leq$T$\leq$346.85 [°C] 400<P$\leq$10000 [bar] TMLP(P)$\leq$T$\leq$196.85 [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq$P$\leq40\times10^6$ [Pa] TMLP(P)$\leq$T$\leq$620 [K] $40\times10^6<$P$\leq10^9$ [Pa] TMLP(P)$\leq$T$\leq$470 [K] 0.11719$\leq$P$\leq$400 [bar] TMLP(P)$\leq$T$\leq$346.85 [°C] 400<P$\leq$10000 [bar] TMLP(P)$\leq$T$\leq$196.85 [°C]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.719\times10^3\leq P\leq 4.595\times10^6$ [Pa] $0.11719\leq P\leq 45.95$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.719\times10^3\leq P\leq 4.595\times10^6$ [Pa] $0.11719\leq P\leq 45.95$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq P\leq 40\times10^6$ [Pa] TMLP(P)$\leq T\leq 620$ [K] $40\times10^6<P\leq 10^9$ [Pa] TMLP(P)$\leq T\leq 470$ [K] $0.11719\leq P\leq 400$ [bar] TMLP(P)$\leq T\leq 346.85$ [°C] $400<P\leq 10000$ [bar] TMLP(P)$\leq T\leq 196.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$90.68\leq T\leq 190.555$ [K] $-182.47\leq T\leq -82.595$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.68\leq T\leq 190.555$ [K] $-182.47\leq T\leq -82.595$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -492.05×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.595×10^6 [Pa], 45.95 [bar] Pressure S: 'A'='S': -4.098×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 190.555 [K], −82.595 [°C] Temperature V: 'A'='V': 6.1656×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.719\times10^3\leq P\leq 4.595\times10^6$ [Pa] $0.11719\leq P\leq 45.95$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3\leq P\leq 40\times10^6$ [Pa] TMLP(P)$\leq T\leq 620$ [K] $40\times10^6<P\leq 10^9$ [Pa] TMLP(P)$\leq T\leq 470$ [K] $0.11719\leq P\leq 400$ [bar] TMLP(P)$\leq T\leq 346.85$ [°C] $400<P\leq 10000$ [bar] TMLP(P)$\leq T\leq 196.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.68\leq T\leq 190.555$ [K] $-182.47\leq T\leq -82.595$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 16.043 Relative Molecular Mass R: 'A'='R': 518.25 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$11.719\times10^3\leq P\leq 4.595\times10^6$ [Pa] $0.11719\leq P\leq 45.95$ [bar]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,620K) [J/(kg·K)] $40\times10^6 < P \le 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,470K) [J/(kg·K)] 0.11719≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,346.85°C) [J/(kg·K)] 400<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,196.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CH4' Molecular Formula S: 'A'='S': 'METHANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	90.68≤T≤260 [K] −182.47≤T≤−13.15 [°C]
85	PRPD(P)		
86	PRPDD(P)		

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 50\times10^6$ [Pa] $300 \leq T \leq 423.15$ [K] $1.0 \leq P \leq 500$ [bar] $26.85 \leq T \leq 150$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \leq P \leq 40\times10^6$ [Pa] TMLP(P)$\leq T \leq 620$ [K] $40\times10^6 < P \leq 10^9$ [Pa] TMLP(P)$\leq T \leq 470$ [K] $0.11719 \leq P \leq 400$ [bar] TMLP(P)$\leq T \leq 346.85$ [°C] $400 < P \leq 10000$ [bar] TMLP(P)$\leq T \leq 196.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \leq P \leq 10^9$ [Pa] $0.11719 \leq P \leq 10000$ [bar]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,620K) [J/kg] $40\times10^6 < P \le 10^9$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,470K) [J/kg] 0.11719≤P≤400 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,346.85°C) [J/kg] 400<P≤10000 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,196.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,620K) [J/(kg·K)] $40\times10^6 < P \le 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,470K) [J/(kg·K)] 0.11719≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,346.85°C) [J/(kg·K)] 400<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,196.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP∗: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$4.595\times10^6 < P \le 50\times10^6$ [Pa] 45.95<P≤500 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,620K) [m^3/kg] $40\times10^6 < P \le 10^9$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,470K) [m^3/kg] 0.11719≤P≤400 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,346.85°C) [m^3/kg] 400<P≤10000 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,196.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 11.719×10^3 [Pa],0.11719 [bar] Pressure T∗: 'A'='T': 90.68 [K],−182.47 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)		
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar]
80	VPS(P,S)		
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.719\times10^3 \le P \le 4.595\times10^6$ [Pa] 0.11719≤P≤45.95 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.68≤T≤190.555 [K] −182.47≤T≤−82.595 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.719\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤620 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11719≤P≤400 [bar] TMLP(P)≤T≤346.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]

Table II–2.23–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$11.719\times10^3 \leq P \leq 4.595\times10^6$ [Pa] $0.11719 \leq P \leq 45.95$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$90.68 \leq T \leq 190.555$ [K] $-182.47 \leq T \leq -82.595$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.24 Methane(Friend, Ely and Ingham)

Equations for thermodynamic properties have been cited from Friend et al. [1], surface tension from Miller et al. [2], and pressure and temperature on melting line from the IUPAC [3].

2.24.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.24.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Methane
Library File for UNIX:	libjch42.a
Library File for DOS,Windows95/NT:	JCH42.LIB
Single Shot Program for UNIX:	ch42-ss
Single Shot Program for DOS,Windows95/NT:	CH42–SS.EXE

2.24.3 Important Constants and Others

Molecular Formula:	CH_4
Relative Molecular Mass:	16.043
Gas Constant:	518.264 J/(kg·K)

Critical Constants:

Critical Pressure:	4.5992×10^6Pa (45.992 bar)
Critical Temperature:	190.551 K (−82.599°C)
Critical Specific Volume:	6.1478×10^{-3}m^3/kg

Triple Point:

Pressure:	0.011696×10^6Pa (0.11696 bar)
Temperature:	90.6854 K (−182.4646°C)

Reference State:

At 1.01325bar (1 atm) and 25 °C(298.15 K), 186.266 J/(K.mol) is assigned to the specific entropy of the ideal gas, and 10.0177 kJ/mol assigned to the specific enthalpy of the ideal gas.

2.24.4 Formula

Equation of State:

Equation (1) in a function form of $A = A(\rho, T)$ in reference [1]. Here A=molar Helmholtz energy, ρ=density and T=Temperature.

Vapor Pressure:

Table 7 in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (4) and equation (5) in reference [1] for saturation density of liquid and vapor respectively, equation (3) in reference [1] for pressure at saturation.

Pressure and Temperature on Melting Line:

Equation (52) in the reference [3].

Transport Properties:

Equation (8) and equation (9) in reference [1] for viscosity and thermal conductivity respectively.

The Other Properties:
Equation (23-1) in reference [2] for surface tension.

References

[1] D.G.Friend, J.F.Ely, and H.Ingham, Thermal Properties of Methane, J. Phys. Chem. Ref. Data, Vol.18, No.2, 1989, pp.583-638.
[2] J.W.Miller, Jr. and C.L.Yaws, Chem. Eng.,83-23, (1976), p.127.
[3] S.Angus and K.M.de Reuck, International Thermodynamic Table of the Fluid State-5 Methane, IUPAC, vol.5, (1976).

Table II–2.24–1 Methane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3\leq P\leq 40\times10^6$ [Pa] TMLP(P)≤T≤600 [K] $40\times10^6<P\leq 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3\leq P\leq 40\times10^6$ [Pa] TMLP(P)≤T≤600 [K] $40\times10^6<P\leq 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$11.696\times10^3\leq P\leq 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$P\leq 70\times10^6$ [Pa] 91≤T≤600 [K] P≤1000 [bar] -182.15≤T≤326.85 [°C]
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$PST(95K)\leq P\leq 4.5992\times10^6$ [Pa] PST(−178.15°C)≤P≤45.992 [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$PST(95K)\leq P\leq 4.5992\times10^6$ [Pa] PST(−178.15°C)≤P≤45.992 [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$P\leq 55 times 10^6$ 91≤T≤400 [K] P≤550 [bar] −182.25≤T≤136.85 [°C]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$95 \leq T \leq 190.551$ [K] $-178.15 \leq T \leq -82.599$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$95 \leq T \leq 190.551$ [K] $-178.15 \leq T \leq -82.599$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 600$ [K] $40\times10^6 < P \leq 10^9$ [Pa] $TMLP(P) \leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] $TMLP(P) \leq T \leq 196.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 600$ [K] $40\times10^6 < P \leq 10^9$ [Pa] $TMLP(P) \leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] $TMLP(P) \leq T \leq 196.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 600$ [K] $40\times10^6 < P \leq 10^9$ [Pa] $TMLP(P) \leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] $TMLP(P) \leq T \leq 196.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 600$ [K] $40\times10^6 < P \leq 10^9$ [Pa] $TMLP(P) \leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] $TMLP(P) \leq T \leq 196.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 600$ [K] $40\times10^6 < P \leq 10^9$ [Pa] $TMLP(P) \leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] $TMLP(P) \leq T \leq 196.85$ [°C]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 1.36097×10^5 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.5992×10^6 [Pa], 45.992 [bar] Pressure S: 'A'='S': 5.19385×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 190.551 [K], −82.599 [°C] Temperature V: 'A'='V': 6.1478×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.696 \times 10^3 \leq P \leq 4.5992 \times 10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696 \times 10^3 \leq P \leq 40 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 600$ [K] $40 \times 10^6 < P \leq 10^9$ [Pa] TMLP(P)$\leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] TMLP(P)$\leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] TMLP(P)$\leq T \leq 196.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 16.043 Relative Molecular Mass R: 'A'='R': 518.25 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$11.696 \times 10^3 \leq P \leq 4.5992 \times 10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696 \times 10^3 \leq P \leq 40 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 600$ [K] $40 \times 10^6 < P \leq 10^9$ [Pa] TMLP(P)$\leq T \leq 470$ [K] $0.11696 \leq P \leq 400$ [bar] TMLP(P)$\leq T \leq 326.85$ [°C] $400 < P \leq 10000$ [bar] TMLP(P)$\leq T \leq 196.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$11.696 \times 10^3 \leq P \leq 4.5992 \times 10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$11.696 \times 10^3 \leq P \leq 4.5992 \times 10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$11.696\times10^3 \le P \le 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,600K) [J/(kg·K)] $40\times10^6 < P \le 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,470K) [J/(kg·K)] 0.11696≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,326.85°C) [J/(kg·K)] 400<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,196.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤600 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CH4' Molecular Formula S: 'A'='S': 'METHANE' Name of Substance V: 'A'='V': '11.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	90.6854≤T≤260 [K] −182.4646≤T≤−13.15 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 50\times10^6$ [Pa] 300≤T≤423.15 [K] 1.0≤P≤500 [bar] 26.85≤T≤150 [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] TMLP(P)≤T≤600 [K] $40\times10^6 < P \leq 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \leq P \leq 10^9$ [Pa] 0.11696≤P≤10000 [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$11.696\times10^3 \leq P \leq 40\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,600K) [J/kg] $40\times10^6 < P \leq 10^9$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,470K) [J/kg] 0.11696≤P≤400 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,326.85°C) [J/kg] 400<P≤10000 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,196.85°C) [J/kg]
6H	TPH2(P,H)		

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$11.696\times10^3 \le P \le 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,600K) [J/(kg·K)] $40\times10^6 < P \le 10^9$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,470K) [J/(kg·K)] 0.11696≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,326.85°C) [J/(kg·K)] 400<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,196.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP∗: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$4.5992\times10^6 < P \le 50\times10^6$ [Pa] 45.992<P≤500 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$11.696\times10^3 \le P \le 40\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,600K) [m^3/kg] $40\times10^6 < P \le 10^9$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,470K) [m^3/kg] 0.11696≤P≤400 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,326.85°C) [m^3/kg] 400<P≤10000 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,196.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 11.696×10^3 [Pa],0.11696 [bar] Pressure T∗: 'A'='T': 90.6854 [K],−182.4646 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar]
79	UPS(P,S)		
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$11.696\times10^3 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤600 [K] $40\times10^6 < P \le 10^9$ [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$11.696\times10^3 \le P \le 4.5992\times10^6$ [Pa] 0.11696≤P≤45.992 [bar] 0≤X≤1.0 [–]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	11.696×10^3≤P≤4.5992×10^6 [Pa] 0.11696≤P≤45.992 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	11.696×10^3≤P≤4.5992×10^6 [Pa] 0.11696≤P≤45.992 [bar]
80	VPS(P,S)		
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	11.696×10^3≤P≤40×10^6 [Pa] TMLP(P)≤T≤600 [K] 40×10^6<P≤10^9 [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	11.696×10^3≤P≤4.5992×10^6 [Pa] 0.11696≤P≤45.992 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	90.6854≤T≤190.551 [K] −182.4646≤T≤−82.599 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	11.696×10^3≤P≤40×10^6 [Pa] TMLP(P)≤T≤600 [K] 40×10^6<P≤10^9 [Pa] TMLP(P)≤T≤470 [K] 0.11696≤P≤400 [bar] TMLP(P)≤T≤326.85 [°C] 400<P≤10000 [bar] TMLP(P)≤T≤196.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	11.696×10^3≤P≤4.5992×10^6 [Pa] 0.11696≤P≤45.992 [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	11.696×10^3≤P≤4.5992×10^6 [Pa] 0.11696≤P≤45.992 [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]

Table II–2.24–1 Methane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$11.696\times10^3 \leq P \leq 4.5992\times10^6$ [Pa] $0.11696 \leq P \leq 45.992$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$90.6854 \leq T \leq 190.551$ [K] $-182.4646 \leq T \leq -82.599$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.25 Ethylene

Equations for thermodynamic properties have been cited from Jahangiri et al. [1], one for viscosity from Makita et al.[2] and one for surface tension from Miller et al.[3].

2.25.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.25.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Ethylene
Library File for UNIX:	libjc2h4.a
Library File for DOS,Windows95/NT:	JC2H4.LIB
Single Shot Program for UNIX:	c2h4-ss
Single Shot Program for DOS,Windows95/NT:	C2H4–SS.EXE

2.25.3 Important Constants and Others

Molecular Formula:	C_2H_4
Relative Molecular Mass:	28.054
Gas Constant:	296.37 J/(kg·K)

Critical Constants:

Critical Pressure:	5.0401×10^6Pa (50.401 bar)
Critical Temperature:	282.3452 K (9.1952°C)
Critical Specific Volume:	4.8405×10^{-3}m^3/kg

Triple Point:

Pressure:	122.5 Pa (1.225×10^{-3}bar)
Temperature:	103.986 K (−169.164°C)

Reference State:

At 1.01325 bar (1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.25.4 Formula

Equation of State:

Equation (5.1) in a function form of $A = A(\rho, T)$ in reference [1]. Here A=specific helmholtz energy, ρ=density and T=temperature.

Vapor Pressure:

Equation (3.1) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (5.1) in reference [1] for specific volume. Equations (5.13) and (5.14) in reference [1] for specific entropy and specific enthalpy, respectively. Equations (5.16) and (5.17) in reference [1] for isochoric specific heat and isobaric specific heat, respectively.

Transport Properties:

Viscosity from equation (4) in reference [2].

The Other Properties:

Surface tension from reference [3].

References

[1] M.Jahangiri, R.T.Jacobsen, R.B.Stewart and R.D.McCarty, J. Phys. Chem. Ref. Data, 15-2,(1986), pp.593-734.
[2] T.Makita, Y.Tanaka and A.Nagashima, Rev. Phys. Chem. Japan, 44-2,(1974), pp.98–111; 46–1, (1976), pp.54-55.
[3] J.W.Miller,Jr. and C.L.Yaws, Chem. Eng., 83–23, (1976), pp.127–129.

Table II–2.25–1 Ethylene Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 450$ [K] $40\times10^6 < P \leq 260\times10^6$ [Pa] $TMLP(P) \leq T \leq 350$ [K] $0.1 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 176.85$ [°C] $400 < P \leq 2600$ [bar] $TMLP(P) \leq T \leq 76.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 450$ [K] $40\times10^6 < P \leq 260\times10^6$ [Pa] $TMLP(P) \leq T \leq 350$ [K] $0.1 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 176.85$ [°C] $400 < P \leq 2600$ [bar] $TMLP(P) \leq T \leq 76.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$122.5 \leq P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \leq P < 50.401$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$103.986 \leq T < 282.3452$ [K] $-169.164 \leq T < 9.1952$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$122.5 \leq P \leq 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \leq P \leq 50.401$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$103.986 \leq T \leq 282.3452$ [K] $-169.164 \leq T \leq 9.1952$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 \leq P \leq 80\times10^6$ [Pa] $297.15 \leq T \leq 373.15$ [K] $0 \leq P \leq 800$ [bar] $24 \leq T \leq 100$ [°C]
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq 40\times10^6$ [Pa] $TMLP(P) \leq T \leq 450$ [K] $40\times10^6 < P \leq 260\times10^6$ [Pa] $TMLP(P) \leq T \leq 350$ [K] $0.1 \leq P \leq 400$ [bar] $TMLP(P) \leq T \leq 176.85$ [°C] $400 < P \leq 2600$ [bar] $TMLP(P) \leq T \leq 76.85$ [°C]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] $TMLP(P) \le T \le 450$ [K] $40\times10^6 < P \le 260\times10^6$ [Pa] $TMLP(P) \le T \le 350$ [K] $0.1 \le P \le 400$ [bar] $TMLP(P) \le T \le 176.85$ [°C] $400 < P \le 2600$ [bar] $TMLP(P) \le T \le 76.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] $TMLP(P) \le T \le 450$ [K] $40\times10^6 < P \le 260\times10^6$ [Pa] $TMLP(P) \le T \le 350$ [K] $0.1 \le P \le 400$ [bar] $TMLP(P) \le T \le 176.85$ [°C] $400 < P \le 2600$ [bar] $TMLP(P) \le T \le 76.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] $TMLP(P) \le T \le 450$ [K] $40\times10^6 < P \le 260\times10^6$ [Pa] $TMLP(P) \le T \le 350$ [K] $0.1 \le P \le 400$ [bar] $TMLP(P) \le T \le 176.85$ [°C] $400 < P \le 2600$ [bar] $TMLP(P) \le T \le 76.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] $TMLP(P) \le T \le 450$ [K] $40\times10^6 < P \le 260\times10^6$ [Pa] $TMLP(P) \le T \le 350$ [K] $0.1 \le P \le 400$ [bar] $TMLP(P) \le T \le 176.85$ [°C] $400 < P \le 2600$ [bar] $TMLP(P) \le T \le 76.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$103.986 \le T < 282.3452$ [K] $-169.164 \le T < 9.1952$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗ : Temperature [K], [°C]	$103.986 \le T < 282.3452$ [K] $-169.164 \le T < 9.1952$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.79537×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 5.0401×10^6 [Pa], 50.401 [bar] Pressure S: 'A'='S': 5.8587×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 282.3452 [K], 9.1952 [°C] Temperature V: 'A'='V': 4.8405×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$122.5 \le P < 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \le P < 50.401$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40 \times 10^6$ [Pa] TMLP(P)≤T≤450 [K] $40 \times 10^6 < P \le 260 \times 10^6$ [Pa] TMLP(P)≤T≤350 [K] 0.1≤P≤400 [bar] TMLP(P)≤T≤176.85 [°C] 400<P≤2600 [bar] TMLP(P)≤T≤76.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	103.986≤T<282.3452 [K] −169.164≤T<9.1952 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 28.054 Relative Molecular Mass R: 'A'='R': 296.37 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$122.5 \le P \le 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \le P \le 50.401$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40 \times 10^6$ [Pa] TMLP(P)≤T≤450 [K] $40 \times 10^6 < P \le 260 \times 10^6$ [Pa] TMLP(P)≤T≤350 [K] 0.1≤P≤400 [bar] TMLP(P)≤T≤176.85 [°C] 400<P≤2600 [bar] TMLP(P)≤T≤76.85 [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$122.5 \le P \le 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \le P \le 50.401$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$122.5 \le P \le 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \le P \le 50.401$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \le P \le 40 \times 10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,450K) [J/(kg·K)] $40 \times 10^6 < P \le 260 \times 10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,350K) [J/(kg·K)] 0.1≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,176.85°C) [J/(kg·K)] 400<P≤2600 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,76.85°C) [J/(kg·K)]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq 40 \times 10^6$ [Pa] TMLP(P)≤T≤450 [K] $40 \times 10^6 < P \leq 260 \times 10^6$ [Pa] TMLP(P)≤T≤350 [K] 0.1≤P≤400 [bar] TMLP(P)≤T≤176.85 [°C] 400<P≤2600 [bar] TMLP(P)≤T≤76.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$122.5 \leq P \leq 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \leq P \leq 50.401$ [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C2H4' Molecular Formula S: 'A'='S': 'ETHYLENE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	103.986≤T≤135.2 [K] −169.164≤T≤−137.95 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$122.5 \leq P \leq 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \leq P \leq 50.401$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$122.5 \leq P \leq 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \leq P \leq 50.401$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$122.5 \leq P \leq 5.0401 \times 10^6$ [Pa] $1.225 \times 10^{-3} \leq P \leq 50.401$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \leq P \leq 40 \times 10^6$ [Pa] TMLP(P)≤T≤450 [K] $40 \times 10^6 < P \leq 260 \times 10^6$ [Pa] TMLP(P)≤T≤350 [K] 0.1≤P≤400 [bar] TMLP(P)≤T≤176.85 [°C] 400<P≤2600 [bar] TMLP(P)≤T≤76.85 [°C]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$122.5 \leq P \leq 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \leq P \leq 50.401$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$103.986 \leq T \leq 282.3452$ [K] $-169.164 \leq T \leq 9.1952$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$103.986 \leq T \leq 282.3452$ [K] $-169.164 \leq T \leq 9.1952$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$103.986 \leq T \leq 282.3452$ [K] $-169.164 \leq T \leq 9.1952$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$10000 \leq P \leq 260\times10^6$ [Pa] $0.1 \leq P \leq 2600$ [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$10000 \leq P \leq 40\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,450K) [J/kg] $40\times10^6 < P \leq 260\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,350K) [J/kg] $0.1 \leq P \leq 400$ [bar] HPT(P,TMLP(P))≤H≤ HPT(P,176.85°C) [J/kg] $400 < P \leq 2600$ [bar] HPT(P,TMLP(P))≤H≤ HPT(P,76.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \leq P \leq 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,450K) [J/(kg·K)] $40\times10^6 < P \leq 260\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,350K) [J/(kg·K)] $0.1 \leq P \leq 400$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,176.85°C) [J/(kg·K)] $400 < P \leq 2600$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,76.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$5.0401\times10^6 < P \leq 40\times10^6$ [Pa] $50.401 < P \leq 400$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$10000 \leq P \leq 40\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,450K) [m^3/kg] $40\times10^6 < P \leq 260\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,350K) [m^3/kg] $0.1 \leq P \leq 400$ [bar] VPT(P,TMLP(P))≤V≤ VPT(P,176.85°C) [m^3/kg] $400 < P \leq 2600$ [bar] VPT(P,TMLP(P))≤V≤ VPT(P,76.85°C) [m^3/kg]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': $0.1225{\times}10^{3}$ [Pa], $1.225{\times}10^{-3}$ [bar] Pressure T∗: 'A'='T': 103.986 [K], −169.164 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000{\le}P{\le}40{\times}10^{6}$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,450K) [J/(kg·K)] $40{\times}10^{6}{<}P{\le}260{\times}10^{6}$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,350K) [J/(kg·K)] 0.1≤P≤400 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,176.85°C) [J/(kg·K)] 400<P≤2600 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,76.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000{\le}P{\le}40{\times}10^{6}$ [Pa] TMLP(P)≤T≤450 [K] $40{\times}10^{6}{<}P{\le}260{\times}10^{6}$ [Pa] TMLP(P)≤T≤350 [K] 0.1≤P≤400 [bar] TMLP(P)≤T≤176.85 [°C] 400<P≤2600 [bar] TMLP(P)≤T≤76.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$122.5{\le}P{\le}5.0401{\times}10^{6}$ [Pa] $1.225{\times}10^{-3}{\le}P{\le}50.401$ [bar]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10000 \le P \le 40\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,450K) [J/(kg·K)] $40\times10^6 < P \le 260\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,350K) [J/(kg·K)] $0.1 \le P \le 400$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,176.85°C) [J/(kg·K)] $400 < P \le 2600$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,76.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤450 [K] $40\times10^6 < P \le 260\times10^6$ [Pa] TMLP(P)≤T≤350 [K] $0.1 \le P \le 400$ [bar] TMLP(P)≤T≤176.85 [°C] $400 < P \le 2600$ [bar] TMLP(P)≤T≤76.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$122.5 \le P \le 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P \le 50.401$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	103.986≤T≤282.3452 [K] −169.164≤T≤9.1952 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10000 \le P \le 40\times10^6$ [Pa] TMLP(P)≤T≤450 [K] $40\times10^6 < P \le 260\times10^6$ [Pa] TMLP(P)≤T≤350 [K] $0.1 \le P \le 400$ [bar] TMLP(P)≤T≤176.85 [°C] $400 < P \le 2600$ [bar] TMLP(P)≤T≤76.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$122.5 \le P < 5.0401\times10^6$ [Pa] $1.225\times10^{-3} \le P < 50.401$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.25–1 Ethylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$103.986 \leq T < 282.3452$ [K] $-169.164 \leq T < 9.1952$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$103.986 \leq T < 282.3452$ [K] $-169.164 \leq T < 9.1952$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$103.986 \leq T < 282.3452$ [K] $-169.164 \leq T < 9.1952$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$103.986 \leq T < 282.3452$ [K] $-169.164 \leq T < 9.1952$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.26 Ethane

Equations for thermodynamic properties have been cited from Sychev et al.[1].

2.26.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.26.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Ethane
Library File for UNIX:	libjc2h6.a
Library File for DOS,Windows95/NT:	JC2H6.LIB
Single Shot Program for UNIX:	c2h6-ss
Single Shot Program for DOS,Windows95/NT:	C2H6–SS.EXE

2.26.3 Important Constants and Others

Molecular Formula:	C_2H_6
Relative Molecular Mass:	30.0694
Gas Constant:	276.507 J/(kg·K)

Critical Constants:

Critical Pressure:	4.8714×10^6Pa (48.714 bar)
Critical Temperature:	305.33 K (32.18°C)
Critical Specific Volume:	4.891×10^{-3}m^3/kg

Triple Point:

Pressure:	1.13 Pa (0.113×10^{-6} bar)
Temperature:	90.348 K (−182.802°C)

Reference State:

At 0 K(−273.15°C), 984.426×10^3 J/kg is assigned to the heat of sublimation and 0 J/(kg·K) to the specific entropy.

2.26.4 Formula

Equation of State:

Equation (3.7) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (3.7) [equation of state] in reference [1] and the Gibbs condition for phase equilibrium.

Properties at Vapor-Liquid Equilibrium:

Equation (3.7) [equation of state] and the Gibbs condition for phase equilibrium for specific volume of both saturated liquid and saturated vapor. Equation (2.4) together with these specific volumes for specific entropy, specific enthalpy, isobaric specific heat and isochoric specific heat. All of these equations have been cited from reference [1].

Pressure and Temperature on Melting Line:

Equation (3.6) in reference [1].

References

[1] V.V.Sychev, A.A.Vasserman, A.D.Kozlov, V.A.Zagoruchenko, G.A.Spiridonov and V.A.Tsymarny, Thermodynamic Properties of Ethane, National Standard Reference Data Service of the USSR: A Series of Property Tables, Hemisphere, (1987).

Table II–2.26–1 Ethane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6\leq P\leq 80\times10^6$ [Pa] $120\leq T\leq 700$ [K] $1.0\leq P\leq 800$ [bar] $-153.15\leq T\leq 426.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$2.0\leq P\leq 4.8714\times10^6$ [Pa] $20\times10^{-6}\leq P\leq 48.714$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$92\leq T\leq 305.33$ [K] $-181.15\leq T\leq 32.18$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.35\times10^6\leq P\leq 4.8714\times10^6$ [Pa] $3.5\leq P\leq 48.714$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0\leq P\leq 4.8714\times10^6$ [Pa] $20\times10^{-6}\leq P\leq 48.714$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6\leq P\leq 80\times10^6$ [Pa] $120\leq T\leq 700$ [K] $1.0\leq P\leq 800$ [bar] $-153.15\leq T\leq 426.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$120\leq T\leq 305.33$ [K] $-153.15\leq T\leq 32.18$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$92\leq T\leq 305.33$ [K] $-181.15\leq T\leq 32.18$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 1.1376×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.8714×10^6 [Pa], 48.714 [bar] Pressure S: 'A'='S': 5.9239×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 305.33 [K], 32.18 [°C] Temperature V: 'A'='V': 4.891×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0\leq P\leq 4.8714\times10^6$ [Pa] $20\times10^{-6}\leq P\leq 48.714$ [bar]

Table II–2.26–1 Ethane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 80\times10^6$ [Pa] $120 \leq T \leq 700$ [K] $1.0 \leq P \leq 800$ [bar] $-153.15 \leq T \leq 426.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$92 \leq T \leq 305.33$ [K] $-181.15 \leq T \leq 32.18$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 30.0694 Relative Molecular Mass R: 'A'='R': 276.507 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.0 \leq P \leq 4.8714\times10^6$ [Pa] $20\times10^{-6} \leq P \leq 48.714$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.0 \leq P \leq 4.8714\times10^6$ [Pa] $20\times10^{-6} \leq P \leq 48.714$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \leq P \leq 4.0421\times10^6$ [Pa] SPT(P,91K)≤S≤ SPT(P,700K) [J/(kg·K)] $4.0421\times10^6 < P \leq 80\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] $1.0 \leq P \leq 40.421$ [bar] SPT(P,−182.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)] $40.421 < P \leq 800$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 4.0421\times10^6$ [Pa] $91 \leq T \leq 700$ [K] $4.0421\times10^6 < P \leq 80\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $1.0 \leq P \leq 40.421$ [bar] $-182.15 \leq T \leq 426.85$ [°C] $40.421 < P \leq 800$ [bar] TMLP(P)≤T≤426.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0 \leq P \leq 4.8714\times10^6$ [Pa] $20\times10^{-6} \leq P \leq 48.714$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$92 \leq T \leq 305.33$ [K] $-181.15 \leq T \leq 32.18$ [°C]

Table II–2.26–1 Ethane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C2H6' Molecular Formula S: 'A'='S': 'ETHANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	91≤T≤102 [K] −182.15≤T≤−171.15 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0 \leq P \leq 4.8714 \times 10^6$ [Pa] $20 \times 10^{-6} \leq P \leq 48.714$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0 \leq P \leq 4.8714 \times 10^6$ [Pa] $20 \times 10^{-6} \leq P \leq 48.714$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1 \times 10^6 \leq P \leq 4.0421 \times 10^6$ [Pa] 91≤T≤700 [K] $4.0421 \times 10^6 < P \leq 80 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] 1.0≤P≤40.421 [bar] −182.15≤T≤426.85 [°C] 40.421<P≤800 [bar] TMLP(P)≤T≤426.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0 \leq P \leq 4.8714 \times 10^6$ [Pa] $20 \times 10^{-6} \leq P \leq 48.714$ [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$5.0 \times 10^6 \leq P \leq 80 \times 10^6$ [Pa] 50≤P≤800 [bar]

Table II–2.26–1 Ethane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] HPT(P,91K)≤H≤ HPT(P,700K) [J/kg] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,700K) [J/kg] 1.0≤P≤40.421 [bar] HPT(P,−182.15°C)≤H≤ HPT(P,426.85°C) [J/kg] 40.421<P≤800 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,426.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] SPT(P,91K)≤S≤ SPT(P,700K) [J/(kg·K)] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 1.0≤P≤40.421 [bar] SPT(P,−182.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)] 40.421<P≤800 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$4.8714\times10^6 < P \le 20\times10^6$ [Pa] 48.714<P≤200 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] VPT(P, 91K)≤V≤ VPT(P,700K) [m^3/kg] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,700K) [m^3/kg] 1.0≤P≤40.421 [bar] VPT(P,−182.15°C)≤V≤ VPT(P,426.85°C) [m^3/kg] 40.421<P≤800 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,426.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 1.13 [Pa], 0.113×10^{-6} [bar] Pressure T∗: 'A'='T': 90.348 [K], −182.802 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar]

Table II–2.26–1 Ethane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] SPT(P,91K)≤S≤ SPT(P,700K) [J/(kg·K)] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 1.0≤P≤40.421 [bar] SPT(P,−182.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)] 40.421<P≤800 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] 91≤T≤700 [K] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] TMLP(P)≤T≤700 [K] 1.0≤P≤40.421 [bar] −182.15≤T≤426.85 [°C] 40.421<P≤800 [bar] TMLP(P)≤T≤426.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	92≤T≤305.33 [K] −181.15≤T≤32.18 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar]
80	VPS(P,S)	VPS: Specific Volume[m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] SPT(P,91K)≤S≤ SPT(P,700K) [J/(kg·K)] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] SPT(P, TMLP(P))≤S≤ SPT(P,700K) [J/(kg·K)] 1.0≤P≤40.421 [bar] SPT(P,−182.15°C)≤S≤ SPT(P,426.85°C) [J/(kg·K)] 40.421<P≤800 [bar] SPT(P, TMLP(P))≤S≤ SPT(P,426.85°C) [J/(kg·K)]

Table II–2.26–1 Ethane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 4.0421\times10^6$ [Pa] $91 \le T \le 700$ [K] $4.0421\times10^6 < P \le 80\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $1.0 \le P \le 40.421$ [bar] $-182.15 \le T \le 426.85$ [°C] $40.421 < P \le 800$ [bar] TMLP(P)≤T≤426.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0 \le P \le 4.8714\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.714$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$92 \le T \le 305.33$ [K] $-181.15 \le T \le 32.18$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$92 \le T \le 305.33$ [K] $-181.15 \le T \le 32.18$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$92 \le T \le 305.33$ [K] $-181.15 \le T \le 32.18$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 80\times10^6$ [Pa] $120 \le T \le 700$ [K] $1.0 \le P \le 800$ [bar] $-153.15 \le T \le 426.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$2.0 \le P \le 4.867\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.67$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$2.0 \le P \le 4.867\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.67$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$2.0 \le P \le 4.867\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.67$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$2.0 \le P \le 4.867\times10^6$ [Pa] $20\times10^{-6} \le P \le 48.67$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$92 \le T \le 305.30$ [K] $-181.15 \le T \le 32.15$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$92 \le T \le 305.30$ [K] $-181.15 \le T \le 32.15$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$92 \le T \le 305.30$ [K] $-181.15 \le T \le 32.15$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$92 \le T \le 305.30$ [K] $-181.15 \le T \le 32.15$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.27 Propylene

Equations for thermodynamic properties have been cited from the IUPAC Table [1].

2.27.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.27.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Propylene
Library File for UNIX:	libjc3h6.a
Library File for DOS,Windows95/NT:	JC3H6.LIB
Single Shot Program for UNIX:	c3h6-ss
Single Shot Program for DOS,Windows95/NT:	C3H6–SS.EXE

2.27.3 Important Constants and Others

Molecular Formula:	C_3H_6
Relative Molecular Mass:	42.0804
Gas Constant:	197.582 J/(kg·K)

Critical Constants:

Critical Pressure:	4.6646×10^{6}Pa (46.646 bar)
Critical Temperature:	365.57 K (92.42°C)
Critical Specific Volume:	4.4765×10^{-3}m^3/kg

Triple Point:

Pressure:	0.95402×10^{-3}Pa (9.5402×10^{-9} bar)
Temperature:	87.89 K (−185.26°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.27.4 Formula

Equation of State:

Equation (11) in a function form of $P = P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature.

Vapor Pressure:

Equation (11) [equation of state] and equation (25) [the Gibbs condition for phase equilibrium] in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (11) [equation of state] and equation (25) [the Gibbs condition for phase equilibrium] for specific volume of both saturated liquid and saturated vapor. Equations (14) and (18) using these specific volumes for specific entropy and specific enthalpy, respectively. Equations (22) and (19) using these specific volumes for isobaric specific heat and isochoric specific heat, respectively. All of these equations have been cited from reference [1].

Pressure and Temperature on Melting Line:

Equations (8) and (9) in reference [1].

References

[1] S.Angus, B.Armstrong and K.M.de Reuck, International Thermodynamic Table of the Fluid State-7, Propylene (Propene), IUPAC, vol.7, (1980).

Table II–2.27–1 Propylene Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\le P\le 2.053\times10^{-3}$ [Pa] $90\le T\le 575$ [K] $2.053\times10^{-3}<P\le 0.60789$ [Pa] TSP(P)$\le T\le 575$ [K] $0.60789<P\le 10\times10^{6}$ [Pa] $110\le T\le 575$ [K] $10\times10^{6}<P\le 342.43\times10^{6}$ [Pa] $110\le T\le 475$ [K] $342.43\times10^{6}<P\le 1000\times10^{6}$ [Pa] TMLP(P)$\le T\le 475$ [K] $9.5402\times10^{-9}\le P\le 20.53\times10^{-9}$ [bar] $-183.15\le T\le 301.85$ [°C] $20.53\times10^{-9}<P\le 6.0789\times10^{-6}$ [bar] TSP(P)$\le T\le 301.85$ [°C] $6.0789\times10^{-6}<P\le 100$ [bar] $-163.15\le T\le 301.85$ [°C] $100<P\le 3424.3$ [bar] $-163.15\le T\le 201.85$ [°C] $3424.3\times10^{6}<P\le 10000$ [bar] TMLP(P)$\le T\le 201.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\le P\le 4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le 46.646$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$87.89\le T\le 365.57$ [K] $-185.26\le T\le 92.42$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.60789\le P\le 4.6646\times10^{6}$ [Pa] $6.0789\times10^{-6}\le P\le 46.646$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\le P\le 4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le 46.646$ [bar]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\leq P\leq 2.053\times10^{-3}$ [Pa] $90\leq T\leq 575$ [K] $2.053\times10^{-3}<P\leq 0.60789$ [Pa] TSP(P)≤T≤575 [K] $0.60789<P\leq 10\times10^{6}$ [Pa] $110\leq T\leq 575$ [K] $10\times10^{6}<P\leq 342.43\times10^{6}$ [Pa] $110\leq T\leq 475$ [K] $342.43\times10^{6}<P\leq 1000\times10^{6}$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9}\leq P\leq 20.53\times10^{-9}$ [bar] $-183.15\leq T\leq 301.85$ [°C] $20.53\times10^{-9}<P\leq 6.0789\times10^{-6}$ [bar] TSP(P)≤T≤301.85 [°C] $6.0789\times10^{-6}<P\leq 100$ [bar] $-163.15\leq T\leq 301.85$ [°C] $100<P\leq 3424.3$ [bar] $-163.15\leq T\leq 201.85$ [°C] $3424.3\times10^{6}<P\leq 10000$ [bar] TMLP(P)≤T≤201.85 [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$110\leq T\leq 365.57$ [K] $-163.15\leq T\leq 92.42$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$87.89\leq T\leq 365.57$ [K] $-185.26\leq T\leq 92.42$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -95.469×10^{3} [J/kg] Specific Enthalpy P∗: 'A'='P': 4.6646×10^{6} [Pa], 46.646 [bar] Pressure S: 'A'='S': -0.90444×10^{3} [J/(kg·K)] Specific Entropy T∗: 'A'='T': 365.57 [K], 92.42 [°C] Temperature V: 'A'='V': 4.4765×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq P\leq 4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq P\leq 46.646$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\leq P\leq 2.053\times10^{-3}$ [Pa] $90\leq T\leq 575$ [K] $2.053\times10^{-3}<P\leq 0.60789$ [Pa] TSP(P)≤T≤575 [K] $0.60789<P\leq 10\times10^{6}$ [Pa] $110\leq T\leq 575$ [K] $10\times10^{6}<P\leq 342.43\times10^{6}$ [Pa] $110\leq T\leq 475$ [K] $342.43\times10^{6}<P\leq 1000\times10^{6}$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9}\leq P\leq 20.53\times10^{-9}$ [bar] $-183.15\leq T\leq 301.85$ [°C] $20.53\times10^{-9}<P\leq 6.0789\times10^{-6}$ [bar] TSP(P)≤T≤301.85 [°C] $6.0789\times10^{-6}<P\leq 100$ [bar] $-163.15\leq T\leq 301.85$ [°C] $100<P\leq 3424.3$ [bar] $-163.15\leq T\leq 201.85$ [°C] $3424.3\times10^{6}<P\leq 10000$ [bar] TMLP(P)≤T≤201.85 [°C]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$87.89 \le T \le 365.57$ [K] $-185.26 \le T \le 92.42$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 42.0804 Relative Molecular Mass R: 'A'='R': 197.582 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3} \le P \le 4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9} \le P \le 46.646$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3} \le P \le 4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9} \le P \le 46.646$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.95402\times10^{-3} \le P \le 10\times10^{6}$ [Pa] SPT(P,90K)≤S≤ SPT(P,575K) [J/(kg·K)] $10\times10^{6} < P \le 36.9584\times10^{6}$ [Pa] SPT(P,90K)≤S≤ SPT(P,475K) [J/(kg·K)] $36.9584\times10^{6} < P \le 1000\times10^{6}$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,475K) [J/(kg·K)] $9.5402\times10^{-9} \le P \le 100$ [bar] SPT(P,−183.15°C)≤S≤ SPT(P,301.85°C) [J/(kg·K)] 100<P≤369.584 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,201.85°C) [J/(kg·K)] 369.584<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,201.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3} \le P \le 10\times10^{6}$ [Pa] 90≤T≤575 [K] $10\times10^{6} < P \le 36.9584\times10^{6}$ [Pa] 90≤T≤475 [K] $36.9584\times10^{6} < P \le 1000\times10^{6}$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9} \le P \le 100$ [bar] −183.15≤T≤301.85 [°C] 100<P≤369.584 [bar] −183.15≤T≤201.85 [°C] 369.584<P≤10000 [bar] TMLP(P)≤T≤201.85 [°C]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.95402\times10^{-3}\le P\le4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le46.646$ [bar] $0\le X\le1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$87.89\le T\le365.57$ [K] $-185.26\le T\le92.42$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$87.89\le T\le365.57$ [K] $-185.26\le T\le92.42$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$87.89\le T\le365.57$ [K] $-185.26\le T\le92.42$ [°C] $0\le X\le1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C3H6' Molecular Formula S: 'A'='S': 'PROPYLENE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	$87.89\le T\le145$ [K] $-185.26\le T\le-128.15$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$87.89\le T\le365.57$ [K] $-185.26\le T\le92.42$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\le P\le4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le46.646$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\le P\le4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le46.646$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\le P\le10\times10^{6}$ [Pa] $90\le T\le575$ [K] $10\times10^{6}<P\le36.9584\times10^{6}$ [Pa] $90\le T\le475$ [K] $36.9584\times10^{6}<P\le1000\times10^{6}$ [Pa] TMLP(P)$\le T\le475$ [K] $9.5402\times10^{-9}\le P\le100$ [bar] $-183.15\le T\le301.85$ [°C] $100<P\le369.584$ [bar] $-183.15\le T\le201.85$ [°C] $369.584<P\le10000$ [bar] TMLP(P)$\le T\le201.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.95402\times10^{-3}\le P\le4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\le P\le46.646$ [bar] $0\le X\le1.0$ [–]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	0.95402×10^{-3}≤P≤1000×10^{6} [Pa] 9.5402×10^{-9}≤P≤10000 [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	0.95402×10^{-3}≤P≤10×10^{6} [Pa] HPT(P,90K)≤H≤ HPT(P,575K) [J/kg] 10×10^{6}<P≤36.9584×10^{6} [Pa] HPT(P,90K)≤H≤ HPT(P,475K) [J/kg] 36.9584×10^{6}<P≤1000×10^{6} [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,475K) [J/kg] 9.5402×10^{-9}≤P≤100 [bar] HPT(P,−183.15°C)≤H≤ HPT(P,301.85°C) [J/kg] 100<P≤369.584 [bar] HPT(P,−183.15°C)≤H≤ HPT(P,201.85°C) [J/kg] 369.584<P≤10000 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,201.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	0.95402×10^{-3}≤P≤10×10^{6} [Pa] SPT(P,90K)≤S≤ SPT(P,575K) [J/(kg·K)] 10×10^{6}<P≤36.9584×10^{6} [Pa] SPT(P,90K)≤S≤ SPT(P,475K) [J/(kg·K)] 36.9584×10^{6}<P≤1000×10^{6} [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,475K) [J/(kg·K)] 9.5402×10^{-9}≤P≤100 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,301.85°C) [J/(kg·K)] 100<P≤369.584 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,201.85°C) [J/(kg·K)] 369.584<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,201.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point[K], [°C] P∗: Pressure [Pa], [bar]	4.6646×10^{6}<P≤19×10^{6} [Pa] 46.646<P≤190 [bar]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.95402\times10^{-3}\leq P\leq10\times10^6$ [Pa] VPT(P,90K)≤V≤ VPT(P,575K) [m^3/kg] $10\times10^6<P\leq36.9584\times10^6$ [Pa] VPT(P,90K)≤V≤ VPT(P,475K) [m^3/kg] $36.9584\times10^6<P\leq1000\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,475K) [m^3/kg] $9.5402\times10^{-9}\leq P\leq100$ [bar] VPT(P,−183.15°C)≤V≤ VPT(P,301.85°C) [m^3/kg] 100<P≤369.584 [bar] VPT(P,−183.15°C)≤V≤ VPT(P,201.85°C) [m^3/kg] 369.584<P≤10000 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,201.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.95402×10^{-3} [Pa], 9.5402×10^{-9} [bar] Pressure T∗: 'A'='T': 87.89 [K], −185.26 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq P\leq4.6646\times10^6$ [Pa] $9.5402\times10^{-9}\leq P\leq46.646$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq P\leq4.6646\times10^6$ [Pa] $9.5402\times10^{-9}\leq P\leq46.646$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq P\leq4.6646\times10^6$ [Pa] $9.5402\times10^{-9}\leq P\leq46.646$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.95402\times10^{-3}\leq P\leq10\times10^6$ [Pa] SPT(P,90K)≤S≤ SPT(P,575K) [J/(kg·K)] $10\times10^6<P\leq36.9584\times10^6$ [Pa] SPT(P,90K)≤S≤ SPT(P,475K) [J/(kg·K)] $36.9584\times10^6<P\leq1000\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,475K) [J/(kg·K)] $9.5402\times10^{-9}\leq P\leq100$ [bar] SPT(P,−183.15°C)≤S≤ SPT(P,301.85°C) [J/(kg·K)] 100<P≤369.584 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,201.85°C) [J/(kg·K)] 369.584<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,201.85°C) [J/(kg·K)]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\leq$P$\leq10\times10^{6}$ [Pa] 90≤T≤575 [K] $10\times10^{6}<$P$\leq36.9584\times10^{6}$ [Pa] 90≤T≤475 [K] $36.9584\times10^{6}<$P$\leq1000\times10^{6}$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9}\leq$P≤100 [bar] −183.15≤T≤301.85 [°C] 100<P≤369.584 [bar] −183.15≤T≤201.85 [°C] 369.584<P≤10000 [bar] TMLP(P)≤T≤201.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.95402\times10^{-3}\leq$P$\leq10\times10^{6}$ [Pa] SPT(P,90K)≤S≤ SPT(P,575K) [J/(kg·K)] $10\times10^{6}<$P$\leq36.9584\times10^{6}$ [Pa] SPT(P,90K)≤S≤ SPT(P,475K) [J/(kg·K)] $36.9584\times10^{6}<$P$\leq1000\times10^{6}$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,475K) [J/(kg·K)] $9.5402\times10^{-9}\leq$P≤100 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,301.85°C) [J/(kg·K)] 100<P≤369.584 [bar] SPT(P,−183.15°C)≤S≤ SPT(P,201.85°C) [J/(kg·K)] 369.584<P≤10000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,201.85°C) [J/(kg·K)]

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\leq P\leq 10\times10^6$ [Pa] $90\leq T\leq 575$ [K] $10\times10^6<P\leq 36.9584\times10^6$ [Pa] $90\leq T\leq 475$ [K] $36.9584\times10^6<P\leq 1000\times10^6$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9}\leq P\leq 100$ [bar] $-183.15\leq T\leq 301.85$ [°C] $100<P\leq 369.584$ [bar] $-183.15\leq T\leq 201.85$ [°C] $369.584<P\leq 10000$ [bar] TMLP(P)≤T≤201.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.95402\times10^{-3}\leq P\leq 4.6646\times10^6$ [Pa] $9.5402\times10^{-9}\leq P\leq 46.646$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.95402\times10^{-3}\leq P\leq 2.053\times10^{-3}$ [Pa] $90\leq T\leq 575$ [K] $2.053\times10^{-3}<P\leq 0.60789$ [Pa] TSP(P)≤T≤575 [K] $0.60789<P\leq 10\times10^6$ [Pa] $110\leq T\leq 575$ [K] $10\times10^6<P\leq 342.43\times10^6$ [Pa] $110\leq T\leq 475$ [K] $342.43\times10^6<P\leq 1000\times10^6$ [Pa] TMLP(P)≤T≤475 [K] $9.5402\times10^{-9}\leq P\leq 20.53\times10^{-9}$ [bar] $-183.15\leq T\leq 301.85$ [°C] $20.53\times10^{-9}<P\leq 6.0789\times10^{-6}$ [bar] TSP(P)≤T≤301.85 [°C] $6.0789\times10^{-6}<P\leq 100$ [bar] $-163.15\leq T\leq 301.85$ [°C] $100<P\leq 3424.3$ [bar] $-163.15\leq T\leq 201.85$ [°C] $3424.3\times10^6<P\leq 10000$ [bar] TMLP(P)≤T≤201.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.27–1 Propylene Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.95402\times10^{-3}\leq$P$\leq4.6646\times10^{6}$ [Pa] $9.5402\times10^{-9}\leq$P≤46.646 [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	87.89≤T≤365.57 [K] −185.26≤T≤92.42 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.28 Propane

Equations for thermodynamic properties have been cited from Buehner et al.[1] and one for surface tension from Miller et al.[2].

2.28.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.28.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Propane
Library File for UNIX:	libjc3h8.a
Library File for DOS,Windows95/NT:	JC3H8.LIB
Single Shot Program for UNIX:	c3h8-ss
Single Shot Program for DOS,Windows95/NT:	C3H8–SS.EXE

2.28.3 Important Constants and Others

Molecular Formula:	C_3H_8
Relative Molecular Mass:	44.097
Gas Constant:	188.546 J/(kg·K)

Critical Constants:

Critical Pressure:	4.2597×10^6Pa (42.597 bar)
Critical Temperature:	369.9 K (96.75°C)
Critical Specific Volume:	4.5455×10^{-3}m^3/kg

Reference State:

At 1.01325 bar (1 atm) and 25°C(298.15 K), 0 J/(kg·K) is assigned to the specific entropy of the ideal gas. At 25°C(298.15 K), 0 J/kg is assigned to the specific enthalpy of the ideal gas.

2.28.4 Formula

Equation of State:

Equation (1) in a function form of $P = P(\rho, T)$ in reference [1]. Here P= pressure, ρ= density and T= temperature. However,

$$P = \rho T[R + B\rho + C\rho^2 + D\rho^3 + F\rho^4 + E\rho^5 \cdots$$

in equation (1) has been corrected to

$$P = \rho T[R + B\rho + C\rho^2 + D\rho^3 + E\rho^4 + F\rho^5 \cdots$$

Vapor Pressure:

Equation (1) [equation of state] in reference [1] and the Gibbs condition for phase equilibrium.

Properties at Vapor-Liquid Equilibrium:

Equation (1) in reference [1] and the Gibbs condition for phase equlibrium for specific volume. Equations as functions of density and temperature, which have been derived from equation (1) in reference [1] for specific entropy, specific enthalpy and isobaric specific heat, respectively.

The Other Properties:

Surface tension from reference [2].

References

[1] K.Buehner, G.Maurer and E.Bender, Cryogenics, March (1981), pp.157–164.
[2] J.W.Miller Jr. and C.L.Yaws, Chem. Eng., 83–23,(1976), p.127–129.

Table II–2.28–1 Propane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]

Table II–2.28–1 Propane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] $188.15 \leq T \leq 573.15$ [K] $76.71\times10^{-3} \leq P \leq 1000$ [bar] $-85 \leq T \leq 300$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': -491.10×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.2597×10^6 [Pa], 42.597 [bar] Pressure S: 'A'='S': -4.0931×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 369.9 [K], 96.75 [°C] Temperature V: 'A'='V': 4.5455×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] $188.15 \leq T \leq 573.15$ [K] $76.71\times10^{-3} \leq P \leq 1000$ [bar] $-85 \leq T \leq 300$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 44.097 Relative Molecular Mass R: 'A'='R': 188.546 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] $188.15 \leq T \leq 573.15$ [K] $76.71\times10^{-3} \leq P \leq 1000$ [bar] $-85 \leq T \leq 300$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]

Table II–2.28–1 Propane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] SPT(P,188.15K)≤S≤ SPT(P,573.15K) [J/(kg·K)] $76.71\times10^{-3} \le P \le 1000$ [bar] SPT(P,−85°C)≤S≤ SPT(P,300°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C3H8' Molecular Formula S: 'A'='S': 'PROPANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \le P \le 4.251\times10^6$ [Pa] $76.71\times10^{-3} \le P \le 42.51$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671\times10^3 \le P \le 100\times10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71\times10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]

Table II–2.28–1 Propane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$188.15 \leq T \leq 369.6$ [K] $-85 \leq T \leq 96.45$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] HPT(P,188.15K)≤H≤ HPT(P,573.15K) [J/kg] $76.71\times10^{-3} \leq P \leq 1000$ [bar] HPT(P,−85°C)≤H≤ HPT(P,300°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] SPT(P,188.15K)≤S≤ SPT(P,573.15K) [J/(kg·K)] $76.71\times10^{-3} \leq P \leq 1000$ [bar] SPT(P,−85°C)≤S≤ SPT(P,300°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$4.2597\times10^6 < P \leq 20\times10^6$ [Pa] $42.597 < P \leq 200$ [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$7.671\times10^3 \leq P \leq 100\times10^6$ [Pa] VPT(P,188.15K)≤V≤ VPT(P,573.15K) [m^3/kg] $76.71\times10^{-3} \leq P \leq 1000$ [bar] VPT(P,−85°C)≤V≤ VPT(P,300°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.671\times10^3 \leq P \leq 4.251\times10^6$ [Pa] $76.71\times10^{-3} \leq P \leq 42.51$ [bar]

Table II–2.28–1 Propane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.671{\times}10^3 \le P \le 100{\times}10^6$ [Pa] SPT(P,188.15K)≤S≤ SPT(P,573.15K) [J/(kg·K)] $76.71{\times}10^{-3} \le P \le 1000$ [bar] SPT(P,−85°C)≤S≤ SPT(P,300°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671{\times}10^3 \le P \le 100{\times}10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71{\times}10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.671{\times}10^3 \le P \le 4.251{\times}10^6$ [Pa] $76.71{\times}10^{-3} \le P \le 42.51$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$7.671{\times}10^3 \le P \le 4.251{\times}10^6$ [Pa] $76.71{\times}10^{-3} \le P \le 42.51$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$7.671{\times}10^3 \le P \le 4.251{\times}10^6$ [Pa] $76.71{\times}10^{-3} \le P \le 42.51$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.671{\times}10^3 \le P \le 100{\times}10^6$ [Pa] SPT(P,188.15K)≤S≤ SPT(P,573.15K) [J/(kg·K)] $76.71{\times}10^{-3} \le P \le 1000$ [bar] SPT(P,−85°C)≤S≤ SPT(P,300°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671{\times}10^3 \le P \le 100{\times}10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71{\times}10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.671{\times}10^3 \le P \le 4.251{\times}10^6$ [Pa] $76.71{\times}10^{-3} \le P \le 42.51$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$188.15 \le T \le 369.6$ [K] $-85 \le T \le 96.45$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.671{\times}10^3 \le P \le 100{\times}10^6$ [Pa] $188.15 \le T \le 573.15$ [K] $76.71{\times}10^{-3} \le P \le 1000$ [bar] $-85 \le T \le 300$ [°C]
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.28–1 Propane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$7.671\times10^{3}\le P\le 4.251\times10^{6}$ [Pa] $76.71\times10^{-3}\le P\le 42.51$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$7.671\times10^{3}\le P\le 4.251\times10^{6}$ [Pa] $76.71\times10^{-3}\le P\le 42.51$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$7.671\times10^{3}\le P\le 4.251\times10^{6}$ [Pa] $76.71\times10^{-3}\le P\le 42.51$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$7.671\times10^{3}\le P\le 4.251\times10^{6}$ [Pa] $76.71\times10^{-3}\le P\le 42.51$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	188.15≤T≤369.6 [K] −85≤T≤96.45 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	188.15≤T≤369.6 [K] −85≤T≤96.45 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	188.15≤T≤369.6 [K] −85≤T≤96.45 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	188.15≤T≤369.6 [K] −85≤T≤96.45 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.29 n-Butane

Equations for thermodynamic properties have been cited from reference [1].

2.29.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.29.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	n-Butane, Normal Butane
Library File for UNIX:	libjnc4h10.a
Library File for DOS,Windows95/NT:	JNC4H10.LIB
Single Shot Program for UNIX:	nc4h10-ss
Single Shot Program for DOS,Windows95/NT:	NC4H10–SS.EXE

2.29.3 Important Constants and Others

Molecular Formula:	$CH_3CH_2CH_2CH_3$
Relative Molecular Mass:	58.1243
Gas Constant:	143.05 J/(kg·K)

Critical Constants:

Critical Pressure:	3.79612×10^6Pa (37.9612 bar)
Critical Temperature:	425.16 K (152.01°C)
Critical Specific Volume:	4.41×10^{-3}m^3/kg

Triple Point:

Pressure:	0.6738 Pa (6.738×10^{-6} bar)
Temperature:	134.86 K (−138.29°C)

Reference State:
Zero is assigned to the specific internal energy at the triple point.

2.29.4 Formula

Equation of State:
Equation (6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P= pressure, ρ= density and T= temperature.

Vapor Pressure:
Equation (2) in reference [1].

Properties at Vapor-Liquid Equilibrium:
Equation (3) for specific volume of saturated liquid and equation (4) for specific volume of saturated vapor, equations (13) and (17) for specific entropy, equations (14) and (17) for specific enthalpy, and equation (15) for isobaric specific heat, respectively. All of these have been cited from refernce [1].

Pressure and Temperature on Melting Line:
Equation (1) in reference [1].

References

[1] R.D.Goodwin, Normal Butane: Provisional Thermodynamic Functions from 135 to 700K at Pressures to 700 bar, National Bureau of Standards, NBSIR 79-1621 (September 1979)

Table II–2.29–1 n−Butane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \leq P \leq 37.9612$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \leq P \leq 37.9612$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \leq P \leq 37.9612$ [bar]
18	CPPT(P,T)	Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \leq P \leq 70\times10^6$ [Pa] TMLP(P)$\leq T \leq 700$ [K] $6.738\times10^{-6} \leq P \leq 700$ [bar] TMLP(P)$\leq T \leq 426.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 783.5×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.79612×10^6 [Pa], 37.9612 [bar] Pressure S: 'A'='S': 5.129×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 425.16 [K], 152.01 [°C] Temperature V: 'A'='V': 4.41×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.29–1 n−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
77	CVPT(P,T)	Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $6.738 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
7B	CVTD(T)		
78	CVTDD(P)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 58.1243 Relative Molecular Mass R: 'A'='R': 143.05 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
71	HPS(P,S)		
25	HPT(P,T)	Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $6.738 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
26	HPX(P,X)		
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CH3CH2CH2CH3' Molecular Formula S: 'A'='S': 'N-BUTANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	134.86≤T≤146.05 [K] −138.29≤T≤−127.10 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		

Table II–2.29–1 n−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(P)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 37.9612$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 37.9612$ [bar]
35	SPT(P,T)	Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $6.738\times10^{-6} \le P \le 700$ [bar] TMLP(P)≤T≤426.85 [°C]
36	SPX(P,X)		
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	134.86≤T≤425.16 [K] −138.29≤T≤152.01 [°C]
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 70\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 700$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.6738 [Pa], 6.738×10^{-6} [bar] Pressure T∗: 'A'='T': 134.86 [K], −138.29 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 37.9612$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 37.9612$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612\times10^6$ [Pa] $6.738\times10^{-6} \le P \le 37.9612$ [bar]
79	UPS(P,S)		
44	UPT(P,T)	Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \le P \le 70\times10^6$ [Pa] TMLP(P)≤T≤700 [K] $6.738\times10^{-6} \le P \le 700$ [bar] TMLP(P)≤T≤426.85 [°C]

Table II–2.29–1 n−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
45	UPX(P,X)		
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$134.86 \le T \le 425.16$ [K] $-138.29 \le T \le 152.01$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$134.86 \le T \le 425.16$ [K] $-138.29 \le T \le 152.01$ [°C]
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \le P \le 37.9612$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.6738 \le P \le 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \le P \le 37.9612$ [bar]
80	VPS(P,S)		
51	VPT(P,T)	Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \le P \le 70 \times 10^6$ [Pa] TMLP(P)$\le T \le 700$ [K] $6.738 \times 10^{-6} \le P \le 700$ [bar] TMLP(P)$\le T \le 426.85$ [°C]
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$134.86 \le T \le 425.16$ [K] $-138.29 \le T \le 152.01$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$134.86 \le T \le 425.16$ [K] $-138.29 \le T \le 152.01$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.6738 \le P \le 70 \times 10^6$ [Pa] TMLP(P)$\le T \le 700$ [K] $6.738 \times 10^{-6} \le P \le 700$ [bar] TMLP(P)$\le T \le 426.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.30 i-Butane

Equations for thermodynamic properties have been cited from reference [1].

2.30.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.30.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	i-Butane, Isobutane
Library File for UNIX:	libjic4h10.a
Library File for DOS,Windows95/NT:	JIC4H10.LIB
Single Shot Program for UNIX:	ic4h10-ss
Single Shot Program for DOS,Windows95/NT:	IC4H10–SS.EXE

2.30.3 Important Constants and Others

Molecular Formula:	$(CH_3)_2CHCH_3$
Relative Molecular Mass:	58.1243
Gas Constant:	143.05 J/(kg·K)

Critical Constants:

Critical Pressure:	3.65489×10^6Pa (36.5489 bar)
Critical Temperature:	408.00 K (134.85°C)
Critical Specific Volume:	4.46×10^{-3}m^3/kg

Triple Point:

Pressure:	0.018893 Pa (0.18893×10^{-6} bar)
Temperature:	113.55 K (−159.60°C)

Reference State:
Zero is assigned to the specific internal energy at the triple point.

2.30.4 Formula

Equation of State:
Equation (6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P= pressure, ρ= density and T= temperature.

Vapor Pressure:
Equation (2) in reference [1].

Properties at Vapor-Liquid Equilibrium:
Equation (3) for specific volume of saturated liquid and equation (4) for specific volume of saturated vapor, equations (14) and (18) for specific entropy, equations (15) and (18) for specific enthalpy, and equation (16) for isobaric specific heat, respectively. All of these have been cited from refernce [1].

Pressure and Temperature on Melting Line:
Equation (1) in reference [1].

References

[1] R.D.Goodwin, Isobutane: Provisional Thermodynamic Functions from 114 to 700K at Pressures to 700 bar, National Bureau of Standards, NBSIR 79-1612 (September 1979)

Table II–2.30–1 i−Butane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
18	CPPT(P,T)	Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 700$ [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)$\leq T \leq 426.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 752.5×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.65489×10^6 [Pa], 36.5489 [bar] Pressure S: 'A'='S': 4.791×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 408.0 [K], 134.85 [°C] Temperature V: 'A'='V': 4.46×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.30–1 i−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
77	CVPT(P,T)	Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 58.1243 Relative Molecular Mass R: 'A'='R': 143.05 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
71	HPS(P,S)		
25	HPT(P,T)	Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
26	HPX(P,X)		
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': '(CH3)2CHCH3' Molecular Formula S: 'A'='S': 'I-BUTANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	113.55≤T≤133.107 [K] −159.6≤T≤−140.043 [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		

Table II–2.30–1 i−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(P)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
35	SPT(P,T)	Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
36	SPX(P,X)		
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	113.55≤T≤408 [K] −159.6≤T≤134.85 [°C]
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 0.018893 [Pa], 0.18893×10^{-6} [bar] Pressure T∗: 'A'='T': 113.55 [K], −159.60 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
79	UPS(P,S)		
44	UPT(P,T)	Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)≤T≤700 [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)≤T≤426.85 [°C]
45	UPX(P,X)		

Table II–2.30–1 i−Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.018893 \leq P \leq 3.65489 \times 10^6$ [Pa] $0.18893 \times 10^{-6} \leq P \leq 36.5489$ [bar]
80	VPS(P,S)		
51	VPT(P,T)	Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 700$ [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)$\leq T \leq 426.85$ [°C]
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$113.55 \leq T \leq 408$ [K] $-159.6 \leq T \leq 134.85$ [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.018893 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P)$\leq T \leq 700$ [K] $0.18893 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P)$\leq T \leq 426.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		

2.31 FC-14(R14)

All equations for FC-14(R14) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.31.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.31.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	FC-14, R14, Refrigerant 14, Freon 14, Carbontetrafluoride
Library File for UNIX:	libjr14.a
Library File for DOS,Windows95/NT:	JR14.LIB
Single Shot Program for UNIX:	r14-ss
Single Shot Program for DOS,Windows95/NT:	R14-SS.EXE

2.31.3 Important Constants and Others

Molecular Formula:	CF_4
Relative Molecular Mass:	88.010
Gas Constant:	94.4723 J/(kg·K)

Critical Constants:

Critical Pressure:	3.7500×10^6Pa (37.500 bar)
Critical Temperature:	227.51 K (-45.64 °C)
Critical Specific Volume:	1.5982×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.31.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Benderequation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\mathrm{K}) < p < p_{sat}(T_c + 1\mathrm{K})$ and $v'(T_c - 1\mathrm{K}) < v < v''(T_c - 1\mathrm{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T\left(\frac{\partial p}{\partial T}\right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

However, the coefficients of the ideal gas state heat capacity equation (15) ($\mathrm{d}_2 \sim \mathrm{d}_5$) are reviced by kind information from the authors. The correct values are the followings.

$$\mathrm{d}_2 = 8.285805\mathrm{E}-6, \quad \mathrm{d}_3 = 8.405900\mathrm{E}-6, \quad \mathrm{d}_4 = -1.787524\mathrm{E}-8, \quad \mathrm{d}_5 = 1.149856\mathrm{E}-11$$

Transport Properties:
Thermal conductivity from reference[2].

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] Thermophysical Properties of Refrigerants(1976), 22 ASHRAE

Table II–2.31–1 FC-14(R-14) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] $110 \leq T \leq 620$ [K] $6 \leq P \leq 500$ [bar] $-163.15 \leq T \leq 346.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$69.7\times10^3 \leq P \leq 2.1863\times10^6$ [Pa] $0.697 \leq P \leq 21.863$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$93.67\times10^3 \leq P \leq 1.5522\times10^6$ [Pa] $0.9367 \leq P \leq 15.522$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $144 \leq T \leq 278$ [K] $-129.15 \leq T \leq 4.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$140 \leq T \leq 210$ [K] $-133.15 \leq T \leq -63.15$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$144 \leq T \leq 200$ [K] $-129.15 \leq T \leq -73.15$ [°C]
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] $110 \leq T \leq 620$ [K] $6 \leq P \leq 500$ [bar] $-163.15 \leq T \leq 346.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]

Table II–2.31–1 FC-14(R-14) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3266×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.750×10^6 [Pa], 37.50 [bar] Pressure S: 'A'='S': 1.678×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 227.51 [K], −45.64 [°C] Temperature V: 'A'='V': 1.598×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] $110 \leq T \leq 620$ [K] $6 \leq P \leq 500$ [bar] $-163.15 \leq T \leq 346.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 88.010 Relative Molecular Mass R: 'A'='R': 94.472 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,110K)≤S≤ SPT(P,620K) [J/(kg·K)] $6 \leq P \leq 500$ [bar] SPT(P,−163.15°C)≤S≤ SPT(P,346.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] $110 \leq T \leq 620$ [K] $6 \leq P \leq 500$ [bar] $-163.15 \leq T \leq 346.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] $0.0169 \leq P \leq 37.5$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$105 \leq T \leq 227.51$ [K] $-168.15 \leq T \leq -45.64$ [°C]

Table II–2.31–1 FC-14(R-14) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	105≤T≤227.51 [K] −168.15≤T≤−45.64 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C: 'A'='C': 'CF4' Molecular Formula S: 'A'='S': 'FC-14(R-14)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	110≤T≤227.51 [K] −163.15≤T≤−45.64 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(110K)≤P≤3.75×10^6 [Pa] (∼1.55×10^6) PST(−163.15 °C)≤P≤37.5 [bar] (∼15.5)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	110≤T≤227.51 [K] −163.15≤T≤−45.64 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.69×10^3≤P≤3.75×10^6 [Pa] 0.0169≤P≤37.5 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.69×10^3≤P≤3.75×10^6 [Pa] 0.0169≤P≤37.5 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	600×10^3≤P≤50×10^6 [Pa] 110≤T≤620 [K] 6≤P≤500 [bar] −163.15≤T≤346.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	1.69×10^3≤P≤3.75×10^6 [Pa] 0.0169≤P≤37.5 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	105≤T≤227.51 [K] −168.15≤T≤−45.64 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	105≤T≤227.51 [K] −168.15≤T≤−45.64 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	105≤T≤227.51 [K] −168.15≤T≤−45.64 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	600×10^3≤P≤50×10^6 [Pa] HPT(P,110K)≤H≤ HPT(P,620K) [J/kg] 6≤P≤500 [bar] HPT(P,−163.15°C)≤H≤ HPT(P,346.85°C) [J/kg]

Table II–2.31–1 FC-14(R-14) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,110K)≤S≤ SPT(P,620K) [J/(kg·K)] 6≤P≤500 [bar] SPT(P,−163.15°C)≤S≤ SPT(P,346.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] VPT(P,110K)≤V≤ VPT(P,620K) [m^3/kg] 6≤P≤500 [bar] VPT(P,−163.15°C)≤V≤ VPT(P,346.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] 0.0169≤P≤37.5 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] 0.0169≤P≤37.5 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] 0.0169≤P≤37.5 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,110K)≤S≤ SPT(P,620K) [J/(kg·K)] 6≤P≤500 [bar] SPT(P,−163.15°C)≤S≤ SPT(P,346.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \leq P \leq 50\times10^6$ [Pa] 110≤T≤620 [K] 6≤P≤500 [bar] −163.15≤T≤346.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.69\times10^3 \leq P \leq 3.75\times10^6$ [Pa] 0.0169≤P≤37.5 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	110≤T≤227.51 [K] −163.15≤T≤−45.64 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	110≤T≤227.51 [K] −163.15≤T≤−45.64 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	105≤T≤227.51 [K] −168.15≤T≤−45.64 [°C] 0≤X≤1.0 [–]

Table II–2.31–1 FC-14(R-14) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \le P \le 3.75\times10^6$ [Pa] $0.0169 \le P \le 37.5$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.69\times10^3 \le P \le 3.75\times10^6$ [Pa] $0.0169 \le P \le 37.5$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$600\times10^3 \le P \le 50\times10^6$ [Pa] SPT(P,110K)≤S≤ SPT(P,620K) [J/(kg·K)] $6 \le P \le 500$ [bar] SPT(P,−163.15°C)≤S≤ SPT(P,346.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \le P \le 50\times10^6$ [Pa] $110 \le T \le 620$ [K] $6 \le P \le 500$ [bar] $-163.15 \le T \le 346.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.69\times10^3 \le P \le 3.75\times10^6$ [Pa] $0.0169 \le P \le 37.5$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$105 \le T \le 227.51$ [K] $-168.15 \le T \le -45.64$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$105 \le T \le 227.51$ [K] $-168.15 \le T \le -45.64$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$105 \le T \le 227.51$ [K] $-168.15 \le T \le -45.64$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$600\times10^3 \le P \le 50\times10^6$ [Pa] $110 \le T \le 620$ [K] $6 \le P \le 500$ [bar] $-163.15 \le T \le 346.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.69\times10^3 \le P < 3.75\times10^6$ [Pa] $0.0169 \le P < 37.5$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.69\times10^3 \le P < 3.75\times10^6$ [Pa] $0.0169 \le P < 37.5$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.69\times10^3 \le P < 3.75\times10^6$ [Pa] $0.0169 \le P < 37.5$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.69\times10^3 \le P < 3.75\times10^6$ [Pa] $0.0169 \le P < 37.5$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$105 \le T < 227.51$ [K] $-168.15 \le T < -45.64$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$105 \le T < 227.51$ [K] $-168.15 \le T < -45.64$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$105 \le T < 227.51$ [K] $-168.15 \le T < -45.64$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$105 \le T < 227.51$ [K] $-168.15 \le T < -45.64$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.32 FC-C318(RC318)

All equations for FC-C318(RC318) are based on the Table from Thermophysical properties of refrigerants of ASHRAE[1].

2.32.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.32.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	FC-C318, RC318, Refrigerant C318, Freon C318, Octafluorcyclobutan
Library File for UNIX:	libjrc318.a
Library File for DOS,Windows95/NT:	JRC318.LIB
Single Shot Program for UNIX:	rc318-ss
Single Shot Program for DOS,Windows95/NT:	RC318-SS.EXE

2.32.3 Important Constants and Others

Molecular Formula:	C_4F_8
Relative Molecular Mass:	200.040
Gas Constant:	41.5642 J/(kg·K)

Critical Constants:

Critical Pressure:	2.7775×10^6Pa (27.775 bar)
Critical Temperature:	388.38 K (115.23 °C)
Critical Specific Volume:	1.6129×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.32.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\text{K}) < p < p_{sat}(T_c + 1\text{K})$ and $v'(T_c - 1\text{K}) < v < v''(T_c - 1\text{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T, \rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R) dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_\rho - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag

Table II–2.32–1 FC-C318 (RC318) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6\leq P\leq59\times10^6$ [Pa] $238\leq T\leq623$ [K] $2.5\leq P\leq590$ [bar] $-35.15\leq T\leq349.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6\leq P\leq2.7775\times10^6$ [Pa] $2.5\leq P\leq27.775$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$233.35\leq T\leq388.38$ [K] $-39.80\leq T\leq115.23$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.25\times10^6\leq P\leq2.7775\times10^6$ [Pa] $2.5\leq P\leq27.775$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.25\times10^6\leq P\leq2.7775\times10^6$ [Pa] $2.5\leq P\leq27.775$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6\leq P\leq59\times10^6$ [Pa] $238\leq T\leq623$ [K] $2.5\leq P\leq590$ [bar] $-35.15\leq T\leq349.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$233.35\leq T\leq388.38$ [K] $-39.80\leq T\leq115.23$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$233.35\leq T\leq388.38$ [K] $-39.80\leq T\leq115.23$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3586×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 2.7775×10^6 [Pa], 27.775 [bar] Pressure S: 'A'='S': 1.466×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 388.38 [K], 115.23 [°C] Temperature V: 'A'='V': 1.6129×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.32–1 FC-C318 (RC318) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] $2.5 \le P \le 27.775$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] $238 \le T \le 623$ [K] $2.5 \le P \le 590$ [bar] $-35.15 \le T \le 349.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 200.04 Relative Molecular Mass R: 'A'='R': 41.5642 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] $2.5 \le P \le 27.775$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] $2.5 \le P \le 27.775$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] SPT(P,238K)≤S≤ SPT(P,623K) [J/(kg·K)] $2.5 \le P \le 590$ [bar] SPT(P,-35.15°C)≤S≤ SPT(P,349.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] $238 \le T \le 623$ [K] $2.5 \le P \le 590$ [bar] $-35.15 \le T \le 349.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] $2.5 \le P \le 27.775$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C4F8' Molecular Formula S: 'A'='S': 'FC-C318(RC318)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.32–1 FC-C318 (RC318) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST*: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] 238≤T≤623 [K] 2.5≤P≤590 [bar] −35.15≤T≤349.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] HPT(P,238K)≤H≤HPT(P,623K) [J/kg] 2.5≤P≤590 [bar] HPT(P,-35.15°C)≤H≤ HPT(P,349.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] SPT(P,238K)≤S≤ SPT(P,623K) [J/(kg·K)] 2.5≤P≤590 [bar] SPT(P,-35.15°C)≤S≤ SPT(P,349.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		

Table II–2.32–1 FC-C318 (RC318) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.25\times10^6 \leq P \leq 59\times10^6$ [Pa] VPT(P,238K)≤V≤VPT(P,623K) [m^3/kg] 2.5≤P≤590 [bar] VPT(P,-35.15°C)≤V≤ VPT(P,349.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.25\times10^6 \leq P \leq 59\times10^6$ [Pa] SPT(P,238K)≤S≤ SPT(P,623K) [J/(kg·K)] 2.5≤P≤590 [bar] SPT(P,-35.15°C)≤S≤ SPT(P,349.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \leq P \leq 59\times10^6$ [Pa] 238≤T≤623 [K] 2.5≤P≤590 [bar] −35.15≤T≤349.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	233.35≤T≤388.38 [K] −39.80≤T≤115.23 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.25\times10^6 \leq P \leq 2.7775\times10^6$ [Pa] 2.5≤P≤27.775 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.25\times10^6 \leq P \leq 59\times10^6$ [Pa] SPT(P,238K)≤S≤ SPT(P,623K) [J/(kg·K)] 2.5≤P≤590 [bar] SPT(P,-35.15°C)≤S≤ SPT(P,349.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \leq P \leq 59\times10^6$ [Pa] 238≤T≤623 [K] 2.5≤P≤590 [bar] −35.15≤T≤349.85 [°C]

Table II–2.32–1 FC-C318 (RC318) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.25\times10^6 \le P \le 2.7775\times10^6$ [Pa] $2.5 \le P \le 27.775$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$233.35 \le T \le 388.38$ [K] $-39.80 \le T \le 115.23$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.25\times10^6 \le P \le 59\times10^6$ [Pa] $238 \le T \le 623$ [K] $2.5 \le P \le 590$ [bar] $-35.15 \le T \le 349.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.25\times10^6 \le P < 2.7775\times10^6$ [Pa] $2.5 \le P < 27.775$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.25\times10^6 \le P < 2.7775\times10^6$ [Pa] $2.5 \le P < 27.775$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.25\times10^6 \le P < 2.7775\times10^6$ [Pa] $2.5 \le P < 27.775$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.25\times10^6 \le P < 2.7775\times10^6$ [Pa] $2.5 \le P < 27.775$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$233.35 \le T < 388.38$ [K] $-39.80 \le T < 115.23$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$233.35 \le T < 388.38$ [K] $-39.80 \le T < 115.23$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$233.35 \le T < 388.38$ [K] $-39.80 \le T < 115.23$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$233.35 \le T < 388.38$ [K] $-39.80 \le T < 115.23$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.33 CFC-11(R11)

All equations for CFC-11(R11) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.33.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.33.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-11, R11, Refrigerant 11, Freon 11, Trichlorofluoromethane
Library File for UNIX:	libjr11.a
Library File for DOS,Windows95/NT:	JR11.LIB
Single Shot Program for UNIX:	r11-ss
Single Shot Program for DOS,Windows95/NT:	R11-SS.EXE

2.33.3 Important Constants and Others

Molecular Formula:	$CC\ell_3F$
Relative Molecular Mass:	137.380
Gas Constant:	60.520 J/(kg·K)

Critical Constants:

Critical Pressure:	4.4026×10^6Pa (44.026 bar)
Critical Temperature:	471.15 K (198.0 °C)
Critical Specific Volume:	1.7889×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.33.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\mathrm{K}) < p < p_{sat}(T_c + 1\mathrm{K})$ and $v'(T_c - 1\mathrm{K}) < v < v''(T_c - 1\mathrm{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T, \rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^\rho \left[T \left(\frac{\partial p}{\partial T} \right)_\rho - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

However, the coefficients of the ideal gas state heat capacity equation (15) ($\mathrm{d}_2 \sim \mathrm{d}_5$) are reviced by kind information from the authors. The correct values are the followings.

$$\mathrm{d}_2 = 8.285805\mathrm{E}-6, \quad \mathrm{d}_3 = 8.405900\mathrm{E}-6, \quad \mathrm{d}_4 = -1.787524\mathrm{E}-8, \quad \mathrm{d}_5 = 1.149856\mathrm{E}-11$$

Transport Properties:
Equation (2) in reference [2] for thermal conductivity of saturated liquid and gas phase at ordinary pressure. Thermal conductivity of other states and viscosity from refernce [3].

The Other Properties:
Equation (3) in reference [4] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] N.Kitazawa and A.Nagashima, Trans. JSME, 46-406, B(1978-6),p.1127
[3] Thermophysical Properties of Refrigerants(1976), 2 ASHRAE
[4] K.Watanabe and M.Okada, Int. J. Thermophysics, 2-2(1981), p.163

Table II–2.33–1 CFC-11(R-11) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] $230 \le T \le 450$ [K] $1.0 \le P \le 197.5$ [bar] $-43.15 \le T \le 176.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$200 \le T \le 471.15$ [K] $-73.15 \le T \le 198$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 1.1595\times10^6$ [Pa] $0.0298 \le P \le 11.595$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$113.5\times10^3 \le P \le 2.1717\times10^6$ [Pa] $1.135 \le P \le 21.717$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $213 \le T \le 323$ [K] $-60.15 \le T \le 49.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$165 \le T \le 390$ [K] $-108.15 \le T \le 116.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$300 \le T \le 465$ [K] $26.85 \le T \le 191.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 1.1595\times10^6$ [Pa] $0.0298 \le P \le 11.595$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s]	$0.07923\times10^6 \le P \le 4.3132\times10^6$ [Pa] $0.7923 \le P \le 43.132$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$170 \le T \le 390$ [K] $-103.15 \le T \le 116.85$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$290 \le T \le 470$ [K] $16.85 \le T \le 196.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]

Table II–2.33–1 CFC-11(R-11) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] $230 \leq T \leq 450$ [K] $1.0 \leq P \leq 197.5$ [bar] $-43.15 \leq T \leq 176.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4267×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.4026×10^6 [Pa], 44.026 [bar] Pressure S: 'A'='S': 1.589×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 471.15 [K], 198.0 [°C] Temperature V: 'A'='V': 1.789×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] $230 \leq T \leq 450$ [K] $1.0 \leq P \leq 197.5$ [bar] $-43.15 \leq T \leq 176.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 137.38 Relative Molecular Mass R: 'A'='R': 60.522 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] SPT(P,230K)≤S≤ SPT(P,450K) [J/(kg·K)] $1.0 \leq P \leq 197.5$ [bar] SPT(P,−43.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]

Table II–2.33–1 CFC-11(R-11) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] $230 \le T \le 450$ [K] $1.0 \le P \le 197.5$ [bar] $-43.15 \le T \le 176.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C: 'A'='C': 'CCL3F' Molecular Formula S: 'A'='S': 'CFC-11(R-11)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 1.1595\times10^6$ [Pa] $0.0298 \le P \le 11.595$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.1135\times10^6 \le P \le 2.1717\times10^6$ [Pa] $1.135 \le P \le 21.717$ [bar]
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$225 \le T \le 390$ [K] $-48.15 \le T \le 116.85$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$300 \le T \le 425$ [K] $26.85 \le T \le 151.85$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$230 \le T \le 471.15$ [K] $-43.15 \le T \le 198$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(230K)$\le P \le 4.4026\times10^6$ [Pa] ($\sim 4.15\times10^3$) PST(-43.15 °C)$\le P \le 44.026$ [bar] (~ 0.0415)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] $230 \le T \le 450$ [K] $1.0 \le P \le 197.5$ [bar] $-43.15 \le T \le 176.85$ [°C]

Table II–2.33–1 CFC(R-11) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$225 \le T \le 471.15$ [K] $-48.15 \le T \le 198$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] HPT(P,230K)≤H≤ HPT(P,450K) [J/kg] $1.0 \le P \le 197.5$ [bar] HPT(P,−43.15°C)≤H≤ HPT(P,176.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] SPT(P,230K)≤S≤ SPT(P,450K) [J/(kg·K)] $1.0 \le P \le 197.5$ [bar] SPT(P,−43.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] VPT(P,230K)≤V≤ VPT(P,450K) [m^3/kg] $1.0 \le P \le 197.5$ [bar] VPT(P,−43.15°C)≤V≤ VPT(P,176.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \le P \le 4.4026\times10^6$ [Pa] $0.0298 \le P \le 44.026$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \le P \le 19.75\times10^6$ [Pa] SPT(P,230K)≤S≤ SPT(P,450K) [J/(kg·K)] $1.0 \le P \le 197.5$ [bar] SPT(P,−43.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]

Table II–2.33–1 CFC-11(R-11) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal [J/kg] P: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] $230 \leq T \leq 450$ [K] $1.0 \leq P \leq 197.5$ [bar] $-43.15 \leq T \leq 176.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$230 \leq T \leq 471.15$ [K] $-43.15 \leq T \leq 198$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$230 \leq T \leq 471.15$ [K] $-43.15 \leq T \leq 198$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] SPT(P,230K)≤S≤ SPT(P,450K) [J/(kg·K)] $1.0 \leq P \leq 197.5$ [bar] SPT(P,−43.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] $230 \leq T \leq 450$ [K] $1.0 \leq P \leq 197.5$ [bar] $-43.15 \leq T \leq 176.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.98\times10^3 \leq P \leq 4.4026\times10^6$ [Pa] $0.0298 \leq P \leq 44.026$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$225 \leq T \leq 471.15$ [K] $-48.15 \leq T \leq 198$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 19.75\times10^6$ [Pa] $230 \leq T \leq 450$ [K] $1.0 \leq P \leq 197.5$ [bar] $-43.15 \leq T \leq 176.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		

Table II–2.33–1 CFC-11(R-11) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$2.98\times10^3 \leq P < 4.4026\times10^6$ [Pa] $0.0298 \leq P < 44.026$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$2.98\times10^3 \leq P < 4.4026\times10^6$ [Pa] $0.0298 \leq P < 44.026$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$2.98\times10^3 \leq P < 4.4026\times10^6$ [Pa] $0.0298 \leq P < 44.026$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$2.98\times10^3 \leq P < 4.4026\times10^6$ [Pa] $0.0298 \leq P < 44.026$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$225 \leq T < 471.15$ [K] $-48.15 \leq T < 198$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$225 \leq T < 471.15$ [K] $-48.15 \leq T < 198$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$225 \leq T < 471.15$ [K] $-48.15 \leq T < 198$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$225 \leq T < 471.15$ [K] $-48.15 \leq T < 198$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.34 CFC-12(R12)

All equations for CFC-12(R12) are based on the Table from Japanese Association of Refrigeration [1].

2.34.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.34.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-12, R12, Refrigerant 12, Freon 12, Dichlorodifluoromethane
Library File for UNIX:	libjr12.a
Library File for DOS,Windows95/NT:	JR12.LIB
Single Shot Program for UNIX:	r12-ss
Single Shot Program for DOS,Windows95/NT:	R12–SS.EXE

2.34.3 Important Constants and Others

Molecular Formula:	$CC\ell_2F_2$
Relative Molecular Mass:	120.9138
Gas Constant:	68.7625 J/(kg·K)

Critical Constants:

Critical Pressure:	4.125×10^6Pa (41.25 bar)
Critical Temperature:	384.95 K (111.80°C)
Critical Specific Volume:	1.7921×10^{-3}m^3/kg

Reference State:
At 0°C, 1.0000 kcal(thermochemical)/(kg·K), i.e. 4184.0 J/(kg·K) and 100.00 kcal(thermochemical)/kg, i.e. 0.4184 $\times10^6$J/kg are assigned to the specific entropy and the specific enthalpy, respectively.

2.34.4 Formula

Equation of State:
Equation (II·2·1) in a function form of $Z = Z(\rho, T)$ in reference [1]. Here Z=compressibility, ρ=density and T= temperature. However the temperature scale IPTS-1948 used in the reference has been replaced with terms of IPTS-1968.

Vapor Pressure:
Equation (II·2·3) in reference [1].

Properties at Vapor-Liquid Equilibrium:
saturated liquid: Equations (II·2·3), (II·2·9), (II·2·15) and (II·2·17) for specific volume, specific enthalpy, specific entropy and isobaric specific heat, respectively. However the factor -2.1953×10^{-6} in the 3rd term in right hand side of (II·2·17) has been corrected as -2.1593×10^{-6}.
saturated vapor: Equations (II·2·16) and (II·2·1) for specific volume, (II·2·16) and (II·2·6) for specific enthalpy, and (II·2·16) and (II·2·12) for specific volume. Equations (II·2·16) and (II·2·21) for isobaric specific heat. Equations (II·2·16) and (II·2·26) for isochoric specific heat.
All of these equations have been cited from reference [1].

Transport Properties:
Equations (II·3·8) and (II·3·1) in reference [1] for thermal conductivity and dynamic viscosity of saturated liquid, respectively. However the right hand side of (II·3·1) has been corrected as

$$21.08203 - 2.450974 \times 10^4/T + 9.430266 \times 10^6/T^2 - 1.549714 \times 10^9/T^3 + 9.433612 \times 10^{10}/T^4$$

Equations (II.3.10) and (II.3.3) in reference [1] for thermal conductivity of vapor at the atmospheric pressure and dynamic viscosity of the superheated vapor, respectively.

The Other Properties:
Equation (II·2·37) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration, Thermophysical Properties of Refrigerants (R12, Dichlorodifluoromethane), (1981).

Table II–2.34–1 CFC-12 (R12) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \leq P \leq 8.0\times10^6$ [Pa] $183.15 \leq T \leq 473.15$ [K] $0.02 \leq P \leq 80$ [bar] $-90 \leq T \leq 200$ [°C] see Fig.II-2.34-1
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$22.59\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.2259 \leq P \leq 40.2$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$213.15 \leq T \leq 383.15$ [K] $-60 \leq T \leq 110$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(333.15K) [Pa] ($\sim1.17\times10^3$) ($\sim1.52\times10^6$) PST(−100°C)≤P≤PST(60°C) [bar] (∼0.0117) (∼15.2)
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $253.15 \leq T \leq 363.15$ [K] $-20 \leq T \leq 90$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 333.15$ [K] $-100 \leq T \leq 60$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	PST(203.15K)≤P≤PST(311.15K) [Pa] ($\sim12.2\times10^3$) ($\sim0.913\times10^6$) PST(−70°C)≤P≤PST(38°C) [bar] (∼0.122) (∼9.13)
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \leq P \leq 4.0\times10^6$ [Pa] $298.15 \leq T \leq 398.15$ [K] $1.0 \leq P \leq 40$ [bar] $25 \leq T \leq 125$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$203.15 \leq T \leq 311.15$ [K] $-70 \leq T \leq 38$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		

Table II–2.34–1 CFC-12 (R12) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(363.15K) [Pa] (∼1.17×10^3) (∼2.77×10^6) PST(−100°C)≤P≤PST(90°C) [bar] (∼0.0117) (∼27.7)
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(363.15K) [Pa] (∼1.17×10^3) (∼2.77×10^6) PST(−100°C)≤P≤PST(90°C) [bar] (∼0.0117) (∼27.7)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.0×10^3≤P≤8.0×10^6 [Pa] 183.15≤T≤473.15 [K] 0.02≤P≤80 [bar] −90≤T≤200 [°C] see Fig.II-2.34-1
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤363.15 [K] −100≤T≤90 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤363.15 [K] −100≤T≤90 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.56681×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.125×10^6 [Pa], 41.25 [bar] Pressure S: 'A'='S': 4.6140×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 384.95 [K], 111.80 [°C] Temperature V: 'A'='V': 1.7921×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(363.15K) [Pa] (∼1.17×10^3) (∼2.77×10^6) PST(−100°C)≤P≤PST(90°C) [bar] (∼0.0117) (∼27.7)
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.0×10^3≤P≤8.0×10^6 [Pa] 183.15≤T≤473.15 [K] 0.02≤P≤80 [bar] −90≤T≤200 [°C] see Fig.II-2.34-1
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤363.15 [K] −100≤T≤90 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 120.9138 Relative Molecular Mass R: 'A'='R': 68.7625 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	1.2×10^3≤P≤4.02×10^6 [Pa] 0.012≤P≤40.2 [bar]

Table II–2.34–1 CFC-12 (R12) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.2\times10^3 \leq P \leq 8.0\times10^6$ [Pa] $0.012 \leq P \leq 80$ [bar] see Fig.II-2.34-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \leq P \leq 8.0\times10^6$ [Pa] $183.15 \leq T \leq 473.15$ [K] $0.02 \leq P \leq 80$ [bar] $-90 \leq T \leq 200$ [°C] see Fig.II-2.34-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CCL2F2' Molecular Formula S: 'A'='S': 'CFC-12(R12)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $253.15 \leq T \leq 363.15$ [K] $-20 \leq T \leq 90$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 384.95$ [K] $-100 \leq T \leq 111.8$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(213.15K)$\leq P \leq 4.125\times10^6$ [Pa] ($\sim 22.59\times10^3$) PST(-60°C)$\leq P \leq 41.25$ [bar] ($\sim$0.2259)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$213.15 \leq T \leq 384.95$ [K] $-60 \leq T \leq 111.8$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar]

Table II–2.34–1 CFC-12 (R12) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 8.0\times10^6$ [Pa] $183.15 \le T \le 473.15$ [K] $0.02 \le P \le 80$ [bar] $-90 \le T \le 200$ [°C] see Fig.II-2.34-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.2\times10^3 \le P \le 4.02\times10^6$ [Pa] $0.012 \le P \le 40.2$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \le T \le 383.15$ [K] $-100 \le T \le 110$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \le T \le 383.15$ [K] $-100 \le T \le 110$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \le T \le 383.15$ [K] $-100 \le T \le 110$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$1.2\times10^3 \le P \le 8.0\times10^6$ [Pa] $0.012 \le P \le 80$ [bar] see Fig.II-2.34-2 for H
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.2\times10^3 \le P \le 8.0\times10^6$ [Pa] $0.012 \le P \le 80$ [bar] see Fig.II-2.34-3 for S
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$1.2\times10^3 \le P \le 4.125\times10^6$ [Pa] VPD(P)≤V≤ VPT(P,473.15K) [m^3/kg] $4.125\times10^6 < P \le 8.0\times10^6$ [Pa] 0.0017921≤V≤ VPT(P,473.15K) [m^3/kg] $0.012 \le P \le 41.25$ [bar] VPD(P)≤V≤ VPT(P,200°C) [m^3/kg] $41.25 < P \le 80$ [bar] 0.0017921≤V≤ VPT(P,200°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \le P \le 4.125\times10^6$ [Pa] $0.012 \le P \le 41.25$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \le P \le 4.02\times10^6$ [Pa] $0.012 \le P \le 40.2$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3 \le P \le 4.02\times10^6$ [Pa] $0.012 \le P \le 40.2$ [bar]

Table II–2.34–1 CFC-12 (R12) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.2\times10^3\leq P\leq 8.0\times10^6$ [Pa] $0.012\leq P\leq 80$ [bar] see Fig.II-2.34-3 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq 8.0\times10^6$ [Pa] $183.15\leq T\leq 473.15$ [K] $0.02\leq P\leq 80$ [bar] $-90\leq T\leq 200$ [°C] see Fig.II-2.34-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.2\times10^3\leq P\leq 4.02\times10^6$ [Pa] $0.012\leq P\leq 40.2$ [bar] $0\leq X\leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C] $0\leq X\leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3\leq P\leq 4.02\times10^6$ [Pa] $0.012\leq P\leq 40.2$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.2\times10^3\leq P\leq 4.02\times10^6$ [Pa] $0.012\leq P\leq 40.2$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.2\times10^3\leq P\leq 8.0\times10^6$ [Pa] $0.012\leq P\leq 80$ [bar] see Fig.II-2.34-3 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq 8.0\times10^6$ [Pa] $183.15\leq T\leq 473.15$ [K] $0.02\leq P\leq 80$ [bar] $-90\leq T\leq 200$ [°C] see Fig.II-2.34-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.2\times10^3\leq P\leq 4.02\times10^6$ [Pa] $0.012\leq P\leq 40.2$ [bar] $0\leq X\leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15\leq T\leq 383.15$ [K] $-100\leq T\leq 110$ [°C] $0\leq X\leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq 8.0\times10^6$ [Pa] $183.15\leq T\leq 473.15$ [K] $0.02\leq P\leq 80$ [bar] $-90\leq T\leq 200$ [°C] see Fig.II-2.34-1
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.2\times10^3\leq P\leq 4.02\times10^6$ [Pa] $0.012\leq P\leq 40.2$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]

Table II–2.34–1 CFC-12 (R12) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.2\times10^3 \leq P \leq 4.02\times10^6$ [Pa] $0.012 \leq P \leq 40.2$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$173.15 \leq T \leq 383.15$ [K] $-100 \leq T \leq 110$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

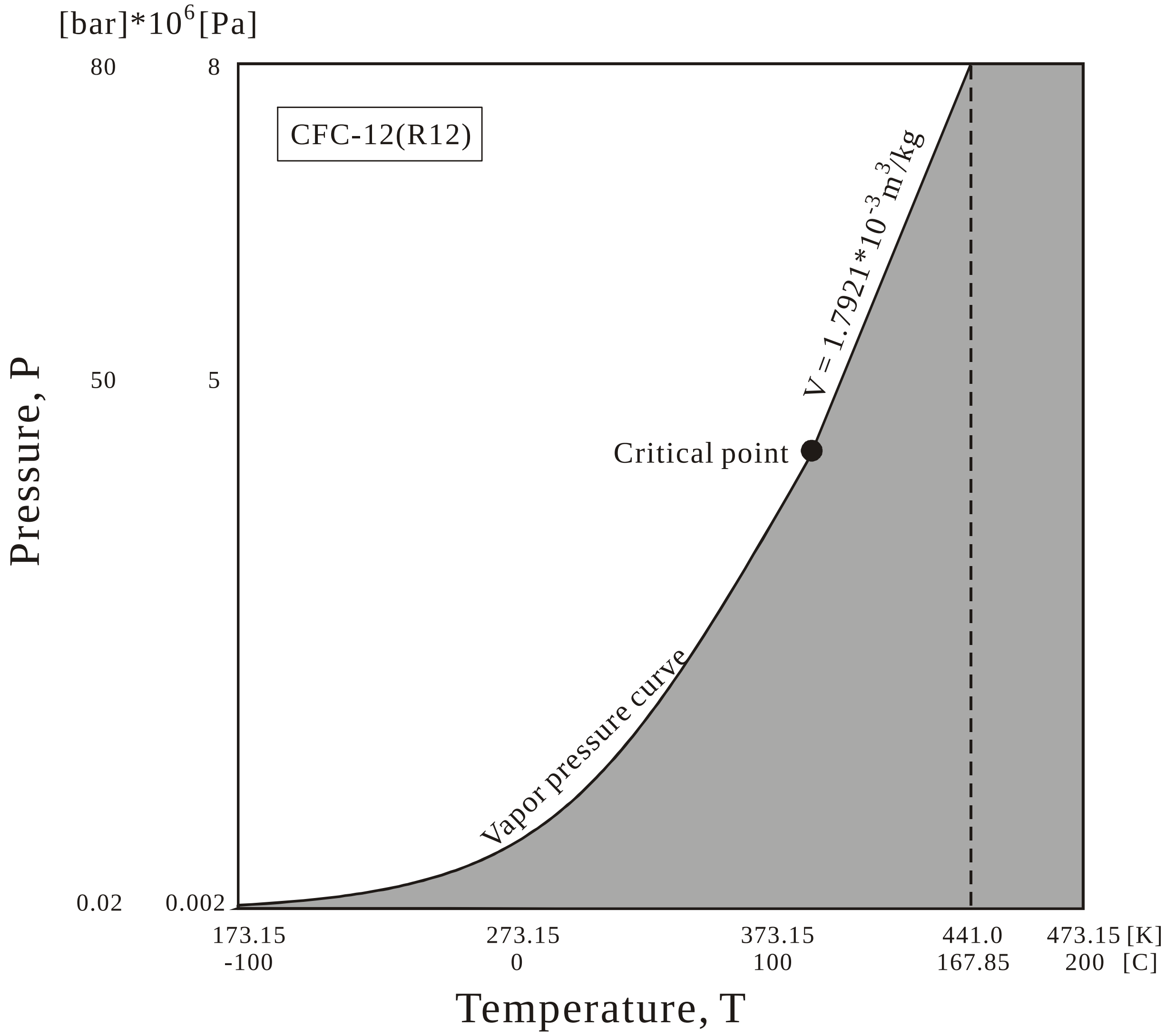


Fig.II–2.34–1 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T),VPT(P,T) and WPT(P,T).

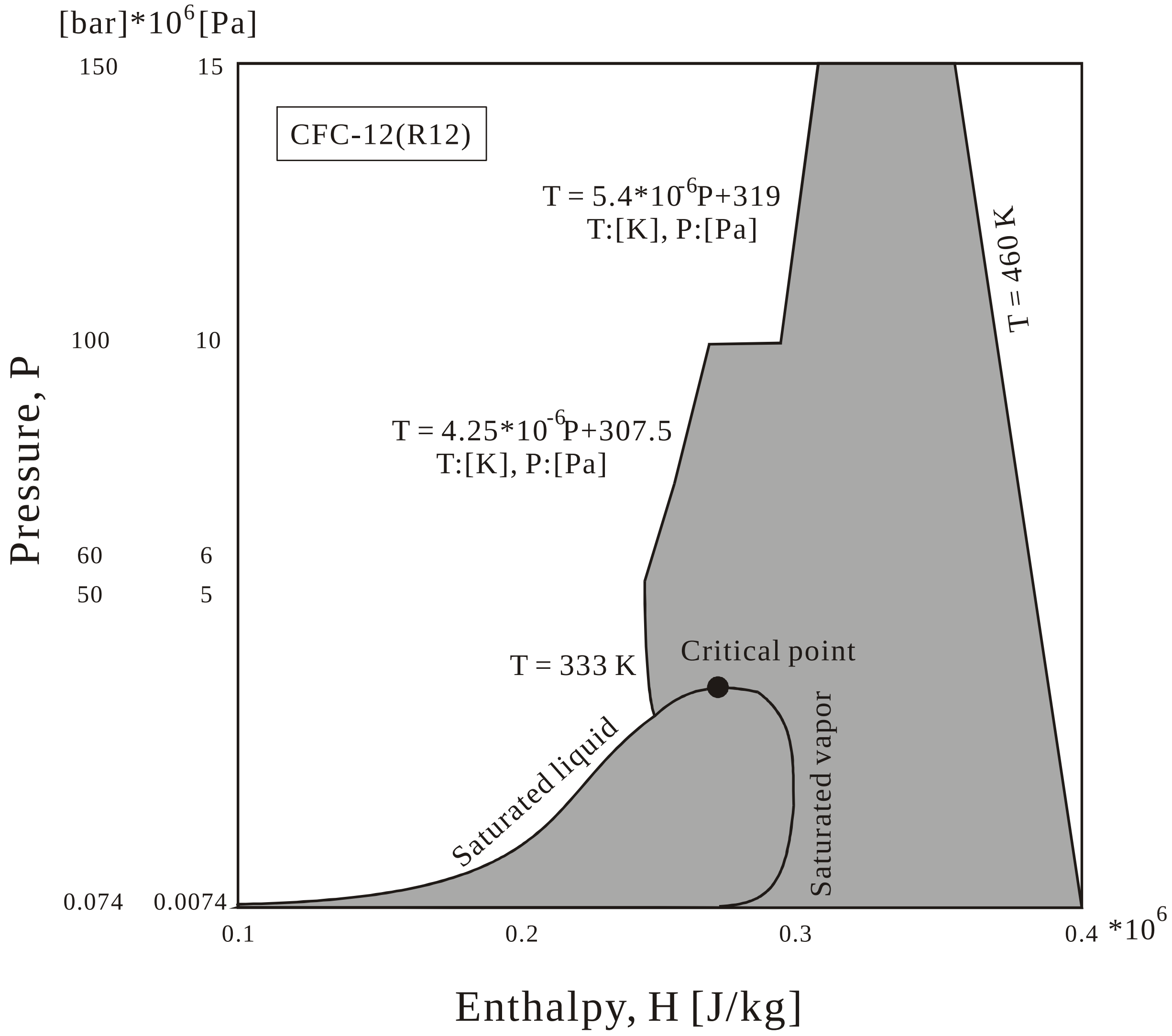


Fig.II–2.34–2 Range of Arguments(P,H) for TPH(P,H).

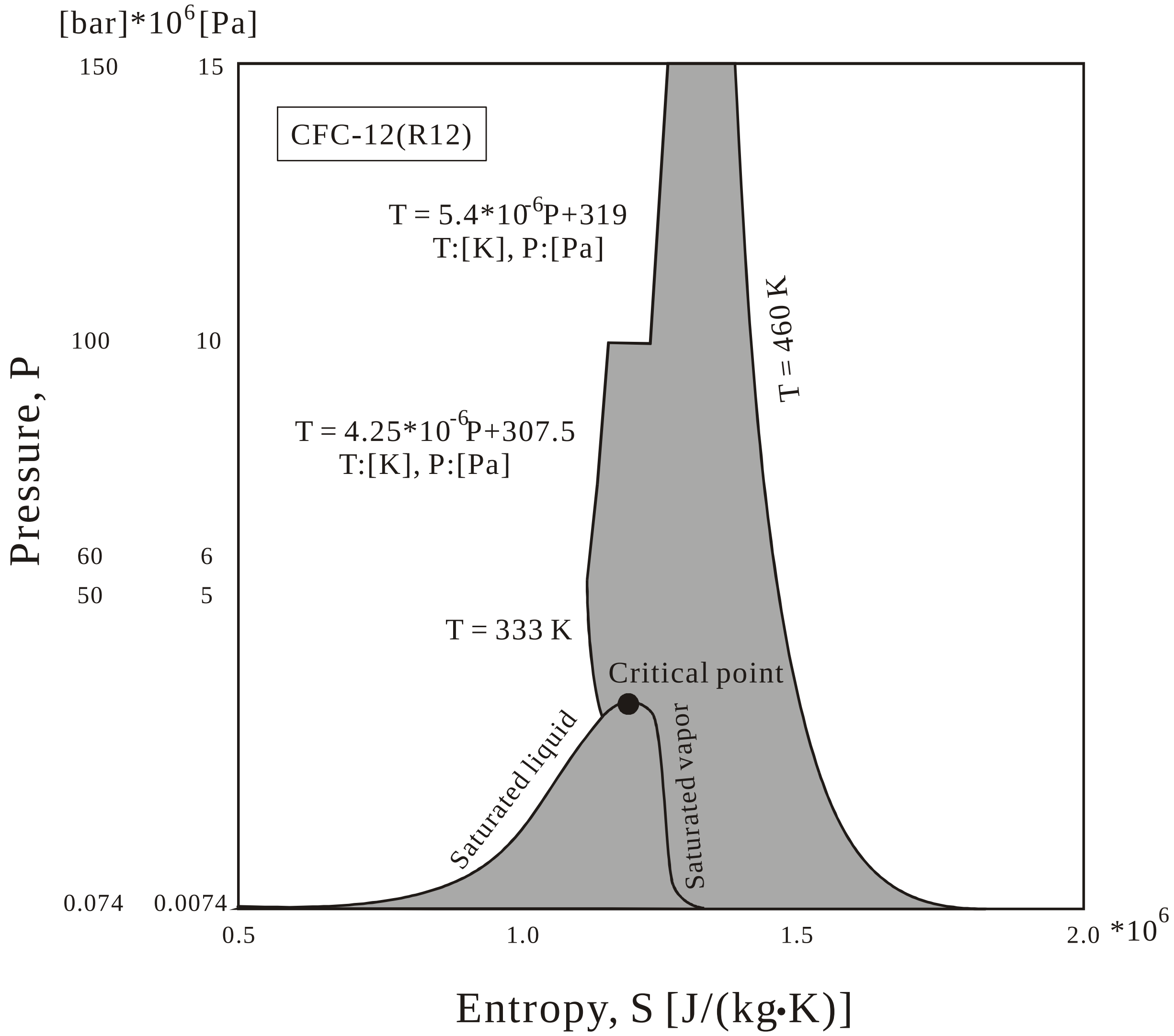


Fig.II–2.34–3 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.35 CFC-13(R13)

All equations for CFC-13(R13) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.35.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.35.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-13, R13, Refrigerant 13, Freon 13, Chlorotrifluoromethane
Library File for UNIX:	libjr13.a
Library File for DOS,Windows95/NT:	JR13.LIB
Single Shot Program for UNIX:	r13-ss
Single Shot Program for DOS,Windows95/NT:	R13-SS.EXE

2.35.3 Important Constants and Others

Molecular Formula:	$CC\ell F_3$
Relative Molecular Mass:	104.470
Gas Constant:	79.5875 J/(kg·K)

Critical Constants:

Critical Pressure:	3.8770×10^6Pa (38.770 bar)
Critical Temperature:	301.88 K (28.73 °C)
Critical Specific Volume:	1.7182×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.35.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\text{K}) < p < p_{sat}(T_c + 1\text{K})$ and $v'(T_c - 1\text{K}) < v < v''(T_c - 1\text{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_\rho - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

Transport Properties:
Thermal conductivity and viscosity from reference [2].

The Other Properties:
Equation (3) in reference [3] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] Thermophysical Properties of Refrigerants(1976), 13 ASHRAE
[3] K.Watanabe and M.Okada, Int. J. Thermophysics, 2-2(1981), p.163

Table II–2.35–1 CFC-13(R-13) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3 \le P \le 50\times10^6$ [Pa] $150 \le T \le 450$ [K] $5 \le P \le 500$ [bar] $-123.15 \le T \le 176.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \le P \le 3.877\times10^6$ [Pa] $0.031 \le P \le 38.77$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$140 \le T \le 301.88$ [K] $-133.15 \le T \le 28.73$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \le P \le 3.877\times10^6$ [Pa] $0.031 \le P \le 38.77$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$144.63 \le T \le 301.88$ [K] $-128.52 \le T \le 28.73$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \le P \le 1.8178\times10^6$ [Pa] $0.031 \le P \le 18.178$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$400.5\times10^3 \le P \le 2.225\times10^6$ [Pa] $4.005 \le P \le 22.25$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $222 \le T \le 533$ [K] $-51.15 \le T \le 259.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$94 \le T \le 270$ [K] $-179.15 \le T \le -3.15$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$222 \le T \le 278$ [K] $-51.15 \le T \le 4.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$154.4\times10^3 \le P \le 3.7114\times10^6$ [Pa] $1.544 \le P \le 37.114$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$92.23\times10^3 \le P \le 2.9604\times10^6$ [Pa] $0.9223 \le P \le 29.604$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$200 \le T \le 300$ [K] $-73.15 \le T \le 26.85$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$190 \le T \le 290$ [K] $-83.15 \le T \le 16.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \le P \le 3.877\times10^6$ [Pa] $0.031 \le P \le 38.77$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \le P \le 3.877\times10^6$ [Pa] $0.031 \le P \le 38.77$ [bar]

Table II–2.35–1 CFC-13(R-13) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3 \leq P \leq 50\times10^6$ [Pa] $150 \leq T \leq 450$ [K] $5 \leq P \leq 500$ [bar] $-123.15 \leq T \leq 176.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$144.63 \leq T \leq 301.88$ [K] $-128.52 \leq T \leq 28.73$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$144.63 \leq T \leq 301.88$ [K] $-128.52 \leq T \leq 28.73$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.2596×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.877×10^6 [Pa], 38.77 [bar] Pressure S: 'A'='S': 1.197×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 301.88 [K], 28.73 [°C] Temperature V: 'A'='V': 1.718×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \leq P \leq 3.877\times10^6$ [Pa] $0.031 \leq P \leq 38.77$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3 \leq P \leq 50\times10^6$ [Pa] $150 \leq T \leq 450$ [K] $5 \leq P \leq 500$ [bar] $-123.15 \leq T \leq 176.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$144.63 \leq T \leq 301.88$ [K] $-128.52 \leq T \leq 28.73$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 104.47 Relative Molecular Mass R: 'A'='R': 79.588 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \leq P \leq 3.877\times10^6$ [Pa] $0.031 \leq P \leq 38.77$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$3.1\times10^3 \leq P \leq 3.877\times10^6$ [Pa] $0.031 \leq P \leq 38.77$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$500\times10^3 \leq P \leq 50\times10^6$ [Pa] SPT(P,150K)≤S≤ SPT(P,450K) [J/(kg·K)] $5 \leq P \leq 500$ [bar] SPT(P,−123.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]

Table II–2.35–1 CFC-13(R-13) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3\leq P\leq 50\times10^6$ [Pa] $150\leq T\leq 450$ [K] $5\leq P\leq 500$ [bar] $-123.15\leq T\leq 176.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$3.1\times10^3\leq P\leq 3.877\times10^6$ [Pa] $0.031\leq P\leq 38.77$ [bar] $0\leq X\leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$144.63\leq T\leq 301.88$ [K] $-128.52\leq T\leq 28.73$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor[J/kg] T∗: Temperature [K], [°C]	$144.63\leq T\leq 301.88$ [K] $-128.52\leq T\leq 28.73$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$144.63\leq T\leq 301.88$ [K] $-128.52\leq T\leq 28.73$ [°C] $0\leq X\leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C: 'A'='C': 'CCLF3 ' Molecular Formula S: 'A'='S': 'CFC-13(R-13)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$154.4\times10^3\leq P\leq 1.8178\times10^6$ [Pa] $1.544\leq P\leq 18.178$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$400.5\times10^3\leq P\leq 2.225\times10^6$ [Pa] $4.005\leq P\leq 22.25$ [bar]
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$200\leq T\leq 270$ [K] $-73.15\leq T\leq -3.15$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$222\leq T\leq 278$ [K] $-51.15\leq T\leq 4.85$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$150\leq T\leq 301.88$ [K] $-123.15\leq T\leq 28.73$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(150K)$\leq P\leq 3.877\times10^6$ [Pa] ($\sim 5.25\times10^3$) PST(−123.15 °C)$\leq P\leq 38.77$ [bar] ($\sim$0.0525)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$150\leq T\leq 301.88$ [K] $-123.15\leq T\leq 28.73$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3\leq P\leq 3.877\times10^6$ [Pa] $0.031\leq P\leq 38.77$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$3.1\times10^3\leq P\leq 3.877\times10^6$ [Pa] $0.031\leq P\leq 38.77$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3\leq P\leq 50\times10^6$ [Pa] $150\leq T\leq 450$ [K] $5\leq P\leq 500$ [bar] $-123.15\leq T\leq 176.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$3.1\times10^3\leq P\leq 3.877\times10^6$ [Pa] $0.031\leq P\leq 38.77$ [bar] $0\leq X\leq 1.0$ [–]

Table II–2.35–1 CFC-13(R-13) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	144.63≤T≤301.88 [K] −128.52≤T≤28.73 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	144.63≤T≤301.88 [K] −128.52≤T≤28.73 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	144.63≤T≤301.88 [K] −128.52≤T≤28.73 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	500×10^3≤P≤50×10^6 [Pa] HPT(P,150K)≤H≤ HPT(P,450K) [J/kg] 5≤P≤500 [bar] HPT(P,−123.15°C)≤H≤ HPT(P,176.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	500×10^3≤P≤50×10^6 [Pa] SPT(P,150K)≤S≤ SPT(P,450K) [J/(kg·K)] 5≤P≤500 [bar] SPT(P,−123.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	500×10^3≤P≤50×10^6 [Pa] VPT(P,210K)≤V≤ VPT(P,450K) [m^3/kg] 5≤P≤500 [bar] VPT(P,−123.15°C)≤V≤ VPT(P,176.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	3.1×10^3≤P≤3.877×10^6 [Pa] 0.031≤P≤38.77 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	3.1×10^3≤P≤3.877×10^6 [Pa] 0.031≤P≤38.77 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	3.1×10^3≤P≤3.877×10^6 [Pa] 0.031≤P≤38.77 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	500×10^3≤P≤50×10^6 [Pa] SPT(P,150K)≤S≤ SPT(P,450K) [J/(kg·K)] 5≤P≤500 [bar] SPT(P,−123.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	500×10^3≤P≤50×10^6 [Pa] 150≤T≤450 [K] 5≤P≤500 [bar] −123.15≤T≤176.85 [°C]

Table II–2.35–1 CFC-13(R-13) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$3.1\times10^3\leq P\leq3.877\times10^6$ [Pa] $0.031\leq P\leq38.77$ [bar] $0\leq X\leq1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$150\leq T\leq301.88$ [K] $-123.15\leq T\leq28.73$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$150\leq T\leq301.88$ [K] $-123.15\leq T\leq28.73$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$144.63\leq T\leq301.88$ [K] $-128.52\leq T\leq28.73$ [°C] $0\leq X\leq1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$3.1\times10^3\leq P\leq3.877\times10^6$ [Pa] $0.031\leq P\leq38.77$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$3.1\times10^3\leq P\leq3.877\times10^6$ [Pa] $0.031\leq P\leq38.77$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$500\times10^3\leq P\leq50\times10^6$ [Pa] SPT(P,150K)≤S≤ SPT(P,450K) [J/(kg·K)] $5\leq P\leq500$ [bar] SPT(P,−123.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3\leq P\leq50\times10^6$ [Pa] $150\leq T\leq450$ [K] $5\leq P\leq500$ [bar] $-123.15\leq T\leq176.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$3.1\times10^3\leq P\leq3.877\times10^6$ [Pa] $0.031\leq P\leq38.77$ [bar] $0\leq X\leq1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$144.63\leq T\leq301.88$ [K] $-128.52\leq T\leq28.73$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$144.63\leq T\leq301.88$ [K] $-128.52\leq T\leq28.73$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$144.63\leq T\leq301.88$ [K] $-128.52\leq T\leq28.73$ [°C] $0\leq X\leq1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$500\times10^3\leq P\leq50\times10^6$ [Pa] $150\leq T\leq450$ [K] $5\leq P\leq500$ [bar] $-123.15\leq T\leq176.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$3.1\times10^3\leq P<3.877\times10^6$ [Pa] $0.031\leq P<38.77$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$3.1\times10^3\leq P<3.877\times10^6$ [Pa] $0.031\leq P<38.77$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$3.1\times10^3\leq P<3.877\times10^6$ [Pa] $0.031\leq P<38.77$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$3.1\times10^3\leq P<3.877\times10^6$ [Pa] $0.031\leq P<38.77$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.35–1 CFC-13(R-13) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T$*$: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$144.63 \le T < 301.88$ [K] $-128.52 \le T < 28.73$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T$*$: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$144.63 \le T < 301.88$ [K] $-128.52 \le T < 28.73$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T$*$: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$144.63 \le T < 301.88$ [K] $-128.52 \le T < 28.73$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T$*$: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$144.63 \le T < 301.88$ [K] $-128.52 \le T < 28.73$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.36 CFC-113(R113)

All equations for CFC-113(R113) are based on the Table from Thermophysical properties of refrigerants of ASHRAE[1].

2.36.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.36.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-113, R113, Refrigerant 113, Freon 113, 1,1,2-Trichloro-1,2,2-Trifluoroethane
Library File for UNIX:	libjr113.a
Library File for DOS,Windows95/NT:	JR113.LIB
Single Shot Program for UNIX:	r113-ss
Single Shot Program for DOS,Windows95/NT:	R113–SS.EXE

2.36.3 Important Constants and Others

Molecular Formula:	$CC\ell_2F{\cdot}CC\ell F_2$
Relative Molecular Mass:	187.390
Gas Constant:	44.3710 J/(kg·K)

Critical Constants:

Critical Pressure:	$3.4100{\times}10^6$Pa (34.100 bar)
Critical Temperature:	487.25 K (214.10 °C)
Critical Specific Volume:	$1.7361{\times}10^{-3}$m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.36.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\ K) < p < p_{sat}(T_c + 1\ K)$ and $v'(T_c - 1\ K) < v < v''(T_c - 1\ K)$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat respectively. However, the sign of the last integration term in u including in Equation (2) has been corrected to −.

Transport Properties:

Equation (2) in reference [2] and Eq.(3.24) in reference [3] for thermal conductivity of saturated liquid and dynamic viscosity at the atmospheric pressure respectivery.

The Other Properties:
Equation (3) in reference [5] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), ASHRAE
[2] N.Kitazawa and A.Nagashima, Trans. ASME, 46-406, B(1978-6), 1127
[3] JSME Data Book: Thermophysical Properties of Fluids, JSME (1983), 527
[4] Thermophysical Properties of Refrigerants (1976), 57 ASHRAE
[5] K.Watanabe and M.Okada, Int. J. Thermophysics, 2-2(1981), 163

Table II–2.36–1 CFC-113 (R113) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] $257.97 \le T \le 538.19$ [K] $0.4 \le P \le 243.2$ [bar] $-15.18 \le T \le 265.04$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$5.858\times10^3 \le P < 3.41\times10^6$ [Pa] $0.05858 \le P < 34.1$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$170 \le T < 487.25$ [K] $-103.15 \le T < 214.1$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] $0.4 \le P \le 34.1$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$257.97 \le T \le 487.25$ [K] $-15.18 \le T \le 214.1$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(160K)$\le P \le 2.635\times10^6$ [Pa] PST(−113.15°C)$\le P \le 26.35$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.015\times10^6 \le P \le 3.052\times10^6$ [Pa] $0.15 \le P \le 30.52$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity at Ordinary Pressure [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $273.15 \le T \le 480$ [K] PST(T)$\le P \le 100$ [bar] $0 \le T \le 206.85$ [°C]
14	AMUTD(T)		
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$320 \le T \le 480$ [K] $46.85 \le T \le 206.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] $0.4 \le P \le 34.1$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] $0.4 \le P \le 34.1$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] $257.97 \le T \le 538.19$ [K] $0.4 \le P \le 243.2$ [bar] $-15.18 \le T \le 265.04$ [°C]

Table II–2.36–1 CFC-113 (R113) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4457×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.410×10^6 [Pa], 34.10 [bar] Pressure S: 'A'='S': 1.633×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 487.25[K], 214.10 [°C] Temperature V: 'A'='V': 1.7361×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40\times10^3\leq P\leq3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40\times10^3\leq P\leq24.32\times10^6$ [Pa] 257.97≤T≤538.19 [K] 0.4≤P≤243.2 [bar] −15.18≤T≤265.04 [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 187.39 Relative Molecular Mass R: 'A'='R': 44.3701 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3\leq P\leq3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3\leq P\leq3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$40\times10^3\leq P\leq24.32\times10^6$ [Pa] SPT(P,257.97K)≤S≤ SPT(P,538.19K) [J/(kg·K)] 0.4≤P≤243.2 [bar] SPT(P,−15.18°C)≤S≤ SPT(P,265.04°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40\times10^3\leq P\leq24.32\times10^6$ [Pa] 257.97≤T≤538.19 [K] 0.4≤P≤243.2 [bar] −15.18≤T≤265.04 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3\leq P\leq3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar] 0≤X≤1.0 [–]

Table II–2.36–1 CFC-113 (R113) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CCL2F CCLF2' Molecular Formula S: 'A'='S': 'CFC-113(R113)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$PST(160K) \leq P \leq 3.41 \times 10^6$ [Pa] ($\sim 40 \times 10^3$) $PST(-113.15°C) \leq P \leq 34.1$ [bar] (~ 0.4)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$160 \leq T \leq 487.25$ [K] $-113.15 \leq T \leq 214.1$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40 \times 10^3 \leq P \leq 3.41 \times 10^6$ [Pa] $0.4 \leq P \leq 34.1$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$40 \times 10^3 \leq P \leq 3.41 \times 10^6$ [Pa] $0.4 \leq P \leq 34.1$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40 \times 10^3 \leq P \leq 24.32 \times 10^6$ [Pa] $257.97 \leq T \leq 538.19$ [K] $0.4 \leq P \leq 243.2$ [bar] $-15.18 \leq T \leq 265.04$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40 \times 10^3 \leq P \leq 3.41 \times 10^6$ [Pa] $0.4 \leq P \leq 34.1$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$257.97 \leq T \leq 487.25$ [K] $-15.18 \leq T \leq 214.1$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		

Table II–2.36–1 CFC-113 (R113) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] HPT(P,257.97K)≤H≤ HPT(P,538.19K) [J/kg] 0.4≤P≤243.2 [bar] HPT(P,−15.18°C)≤H≤ HPT(P,265.04°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] SPT(P,257.97K)≤S≤ SPT(P,538.19K) [J/(kg·K)] 0.4≤P≤243.2 [bar] SPT(P,−15.18°C)≤S≤ SPT(P,265.04°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] VPT(P,257.97K)≤V≤ VPT(P,538.19K) [m^3/kg] 0.4≤P≤243.2 [bar] VPT(P,−15.18°C)≤V≤ VPT(P,265.04°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] SPT(P,257.97K)≤S≤ SPT(P,538.19K) [J/(kg·K)] 0.4≤P≤243.2 [bar] SPT(P,−15.18°C)≤S≤ SPT(P,265.04°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$40\times10^3 \le P \le 24.32\times10^6$ [Pa] 257.97≤T≤538.19 [K] 0.4≤P≤243.2 [bar] −15.18≤T≤265.04 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$40\times10^3 \le P \le 3.41\times10^6$ [Pa] 0.4≤P≤34.1 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]

Table II–2.36–1 CFC-113 (R113) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	40×10^3≤P≤3.41×10^6 [Pa] 0.4≤P≤34.1 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	40×10^3≤P≤3.41×10^6 [Pa] 0.4≤P≤34.1 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	40×10^3≤P≤24.32×10^6 [Pa] SPT(P,257.97K)≤S≤ SPT(P,538.19K) [J/(kg·K)] 0.4≤P≤243.2 [bar] SPT(P,−15.18°C)≤S≤ SPT(P,265.04°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	40×10^3≤P≤24.32×10^6 [Pa] 257.97≤T≤538.19 [K] 0.4≤P≤243.2 [bar] −15.18≤T≤265.04 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	40×10^3≤P≤3.41×10^6 [Pa] 0.4≤P≤34.1 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	257.97≤T≤487.25 [K] −15.18≤T≤214.1 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	40×10^3≤P≤24.32×10^6 [Pa] 257.97≤T≤538.19 [K] 0.4≤P≤243.2 [bar] −15.18≤T≤265.04 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	40×10^3≤P<3.41×10^6 [Pa] 0.4≤P<34.1 [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	40×10^3≤P<3.41×10^6 [Pa] 0.4≤P<34.1 [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	40×10^3≤P<3.41×10^6 [Pa] 0.4≤P<34.1 [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	40×10^3≤P<3.41×10^6 [Pa] 0.4≤P<34.1 [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	257.97≤T<487.25 [K] −15.18≤T<214.1 [°C] HTD(T)≤H≤HTDD(T) [J/kg]

Table II–2.36–1 CFC-113 (R113) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$257.97 \leq T < 487.25$ [K] $-15.18 \leq T < 214.1$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$257.97 \leq T < 487.25$ [K] $-15.18 \leq T < 214.1$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$257.97 \leq T < 487.25$ [K] $-15.18 \leq T < 214.1$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.37 CFC-114(R114)

All equations for CFC-114(R114) are based on the Table from Japanese Association of Refrigeration [1].

2.37.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.37.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-114, R114, Refrigerant 114, Freon 114, 1,2-Dichlorotetrafluoroethane
Library File for UNIX:	libjr114.a
Library File for DOS,Windows95/NT:	JR114.LIB
Single Shot Program for UNIX:	r114-ss
Single Shot Program for DOS,Windows95/NT:	R114–SS.EXE

2.37.3 Important Constants and Others

Molecular Formula:	$CC\ell F_2CC\ell F_2$
Relative Molecular Mass:	170.922
Gas Constant:	48.6445 J/(kg·K)

Critical Constants:

Critical Pressure:	3.248×10^6Pa (32.48 bar)
Critical Temperature:	418.78 K (145.63 °C)
Critical Specific Volume:	1.7361×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.37.4 Formula

Equation of State:

Equation (II·2·1) in a function from of $Z = Z(\rho, T)$ in reference [1]. Here Z=compressibility, ρ=density and T= temperature.

Vapor Pressure:

Equation (II·2·18) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated liquid: Equations (II·2·3), (II·2·8), (II·2·15) and (II·2·19) for specific volume, specific enthalpy, specific entropy and isobaric specific heat, respectively.

saturated vapor: Equations (II·2·18) and (II·2·1) for specific volume (II·2·18) and (II·2·6) for specific enthalpy and (II·2·25) for isobaric specific heat. Equation (II·2·30) for isochoric specific heat.

All of these equations have been cited from reference [1].

Transport Properties:

Equations (II·3·6) and (II·3·1) in reference [1] for thermal conductivity and dynamic viscosity of saturated liquid, respectively. However the 1st term in the right hand side of (II·3·1) has been corrected as $635392/T^2$. Equations (II·3·8) and (II·3·3) in reference [1] for thermal conductivity of vapor and dynamic viscosity at the atmospheric pressure, respectively. Equations (II·3·4) in reference [1] for dynamic viscosity of superheated vapor.

The Other Properties:
Equation (II·2·38) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration, Thermophysical Properties of Refrigerants (R114, 1,2-Dichlorotetrafluoroethane), (1986).

Table II–2.37–1 CFC-114 (R114) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3 \le P \le PST(310K)$ [Pa] $TSP(P) \le T \le 510$ [K] $PST(310K) < P \le 11\times10^6$ [Pa] $TPV(P,0.7\times10^{-3} m^3/kg)$ $\le T \le 510$ [K] $0.01369 \le P \le PST(36.85°C)$ [bar] $TSP(P) \le T \le 236.85$ [°C] $PST(36.85°C) < P \le 110$ [bar] $TPV(P,0.7\times10^{-3} m^3/kg)$ $\le T \le 236.85$ [°C] see Fig.II-2.37-1
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \le P < 3.248\times10^6$ [Pa] $0.01369 \le P < 32.48$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$200 \le T < 418.78$ [K] $-73.15 \le T < 145.63$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \le P \le 3.248\times10^6$ [Pa] $0.01369 \le P \le 32.48$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$200 \le T \le 418.78$ [K] $-73.15 \le T \le 145.63$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \le P \le 1.889\times10^6$ [Pa] $0.01369 \le P \le 18.89$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$1.637\times105 \le P \le 2.111\times10^6$ [Pa] $1.637 \le P \le 21.11$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $290 \le T \le 394$ [K] $0.85 \le T \le 120.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$180 \le T \le 388$ [K] $-53.15 \le T \le 114.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$290 \le T \le 394$ [K] $16.85 \le T \le 120.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$PST(210K) \le P \le PST(398K)$ [Pa] $(\sim2.96\times10^3)$ $(\sim2.269\times10^6)$ $PST(-63.15°C) \le P \le PST(124.85°C)$ (~0.0296) (~22.69) [bar]
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 4.4\times10^6$ [Pa] $298.15 \le T \le 473.15$ [K] $3.3333\times10^{-3} < V(P,T)$ [m^3/kg] $1.0 \le P \le 44$ [bar] $25 \le T \le 200$ [°C]

Table II–2.37–1 CFC-114 (R114) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$210 \leq T \leq 398$ [K] $-63.15 \leq T \leq 124.85$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \leq P \leq 0.2\times10^6$ [Pa] $0.01369 \leq P \leq 2$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \leq P < 3.248\times10^6$ [Pa] $0.01369 \leq P < 32.48$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3 \leq P \leq$ PST(310K) [Pa] TSP(P)$\leq T \leq 510$ [K] PST(310K)$< P \leq 11\times10^6$ [Pa] TPV(P,0.7×10^{-3}m^3/kg) $\leq T \leq 510$ [K] $0.01369 \leq P \leq$ PST(36.85°C) [bar] TSP(P)$\leq T \leq 236.85$ [°C] PST(36.85°C)$< P \leq 110$ [bar] TPV(P,0.7×10^{-3}m^3/kg) $\leq T \leq 236.85$ [°C] see Fig.II-2.37-1
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$182 \leq T \leq 296$ [K] $-91.15 \leq T \leq 22.85$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$200 \leq T \leq 418.78$ [K] $-73.15 \leq T \leq 145.63$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3829×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.248×10^6 [Pa], 32.48 [bar] Pressure S: 'A'='S': 1.512×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 418.78[K], 145.63 [°C] Temperature V: 'A'='V': 1.7361×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.369\times10^3 \leq P \leq 3.248\times10^6$ [Pa] $0.01369 \leq P \leq 32.48$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3 \leq P \leq$ PST(310K) [Pa] TSP(P)$\leq T \leq 510$ [K] PST(310K)$< P \leq 11\times10^6$ [Pa] TPV(P,0.7×10^{-3}m^3/kg) $\leq T \leq 510$ [K] $0.01369 \leq P \leq$ PST(36.85°C) [bar] TSP(P)$\leq T \leq 236.85$ [°C] PST(36.85°C)$< P \leq 110$ [bar] TPV(P,0.7×10^{-3}m^3/kg) $\leq T \leq 236.85$ [°C] see Fig.II-2.37-1
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$200 \leq T \leq 418.78$ [K] $-73.15 \leq T \leq 145.63$ [°C]

Table II–2.37–1 CFC-114 (R114) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 170.922 Relative Molecular Mass R: 'A'='R': 48.6445 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.369\times10^3\leq P\leq11\times10^6$ [Pa] $0.01369\leq P\leq110$ [bar] see Fig.II-2.37-4 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3\leq P\leq11\times10^6$ [Pa] $200\leq T\leq510$ [K] $0.01369\leq P\leq110$ [bar] $-73.15\leq T\leq236.85$ [°C] see Fig.II-2.37-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C] $0\leq X\leq1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CCLF2CCLF2' Molecular Formula S: 'A'='S': 'CFC-114(R114)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$2.96\times10^3\leq P\leq1.889\times10^6$ [Pa] $0.0296\leq P\leq18.89$ [bar]
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $290\leq T\leq394$ [K] $0.85\leq T\leq120.85$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$210\leq T\leq388$ [K] $-63.15\leq T\leq114.85$ [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]

Table II–2.37–1 CFC-114 (R114) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(180K)≤P≤3.248×10^6 [Pa] (∼1.0×10^3) PST(−93.15 °C)≤P≤32.48 [bar] (∼0.01)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	180≤T≤418.78 [K] −93.15≤T≤145.63 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.369×10^3≤P≤3.248×10^6 [Pa] 0.01369≤P≤32.48 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.369×10^3≤P≤3.248×10^6 [Pa] 0.01369≤P≤32.48 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	1.369×10^3≤P≤11×10^6 [Pa] 200≤T≤510 [K] 0.01369≤P≤110 [bar] −73.15≤T≤236.85 [°C] see Fig.II-2.37-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	1.369×10^3≤P≤3.248×10^6 [Pa] 0.01369≤P≤32.48 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	200≤T≤418.78 [K] −73.15≤T≤145.63 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	200≤T≤418.78 [K] −73.15≤T≤145.63 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	200≤T≤418.78 [K] −73.15≤T≤145.63 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	1.369×10^3≤P≤11×10^6 [Pa] 0.01369≤P≤110 [bar] see Fig.II-2.37-3 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	1.369×10^3≤P≤11×10^6 [Pa] 0.01369≤P≤110 [bar] see Fig.II-2.37-4 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	1.369×10^3≤P≤PST(310K) [Pa] VPD(P)≤V≤VPT(P,510 K) [m^3/kg] PST(310K)<P≤11×10^6 [Pa] 0.705×10^{-3}≤V≤VPT(P,510K) [m^3/kg] 11×10^6<P≤21×10^6 [Pa] 0.705×10^{-3}≤V≤VPT(P,430K) [m^3/kg] 0.01369≤P≤PST(36.85°C) [bar] VPD(P)≤V≤VPT(P,236.85°C) [m^3/kg] PST(36.85°C)<P≤110 [bar] 0.705×10^{-3}≤V≤ VPT(P,236.85°C) [m^3/kg] 110<P≤210 [bar] 0.705×10^{-3}≤V≤ VPT(P,156.85°C) [m^3/kg]
41	TRPL('A')		

Table II–2.37–1 CFC-114 (R114) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.369\times10^3\leq P\leq11\times10^6$ [Pa] $0.01369\leq P\leq110$ [bar] see Fig.II-2.37-4 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3\leq P\leq11\times10^6$ [Pa] $200\leq T\leq510$ [K] $0.01369\leq P\leq110$ [bar] $-73.15\leq T\leq236.85$ [°C] see Fig.II-2.37-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar] $0\leq X\leq1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C] $0\leq X\leq1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.369\times10^3\leq P\leq11\times10^6$ [Pa] $0.01369\leq P\leq110$ [bar] see Fig.II-2.37-4 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3\leq P\leq21\times10^6$ [Pa] $200\leq T\leq510$ [K] $0.01369\leq P\leq210$ [bar] $-73.15\leq T\leq236.85$ [°C] see Fig.II-2.37-2
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.369\times10^3\leq P\leq3.248\times10^6$ [Pa] $0.01369\leq P\leq32.48$ [bar] $0\leq X\leq1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$200\leq T\leq418.78$ [K] $-73.15\leq T\leq145.63$ [°C] $0\leq X\leq1.0$ [–]

Table II–2.37–1 CFC-114 (R114) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$1.369\times10^3 \le P \le$ PST(310K) [Pa] TSP(P)$\le T \le 510$ [K] PST(310K)$< P \le 11\times10^6$ [Pa] TPV(P,0.7×10^{-3}m^3/kg) $\le T \le 510$ [K] $0.01369 \le P \le$ PST(36.85°C) [bar] TSP(P)$\le T \le 236.85$ [°C] PST(36.85°C)$< P \le 110$ [bar] TPV(P,0.7×10^{-3}m^3/kg) $\le T \le 236.85$ [°C] see Fig.II-2.37-1
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.369\times10^3 \le P < 3.248\times10^6$ [Pa] $0.01369 \le P < 32.48$ [bar] HPD(P)$\le H \le$HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.369\times10^3 \le P < 3.248\times10^6$ [Pa] $0.01369 \le P < 32.48$ [bar] SPD(P)$\le S \le$SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.369\times10^3 \le P < 3.248\times10^6$ [Pa] $0.01369 \le P < 32.48$ [bar] UPD(P)$\le U \le$UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.369\times10^3 \le P < 3.248\times10^6$ [Pa] $0.01369 \le P < 32.48$ [bar] VPD(P)$\le V \le$VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$200 \le T < 418.78$ [K] $-73.15 \le T < 145.63$ [°C] HTD(T)$\le H \le$HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$200 \le T < 418.78$ [K] $-73.15 \le T < 145.63$ [°C] STD(T)$\le S \le$STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$200 \le T < 418.78$ [K] $-73.15 \le T < 145.63$ [°C] UTD(T)$\le U \le$UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$200 \le T < 418.78$ [K] $-73.15 \le T < 145.63$ [°C] VTD(T)$\le V \le$VTDD(T) [m^3/kg]

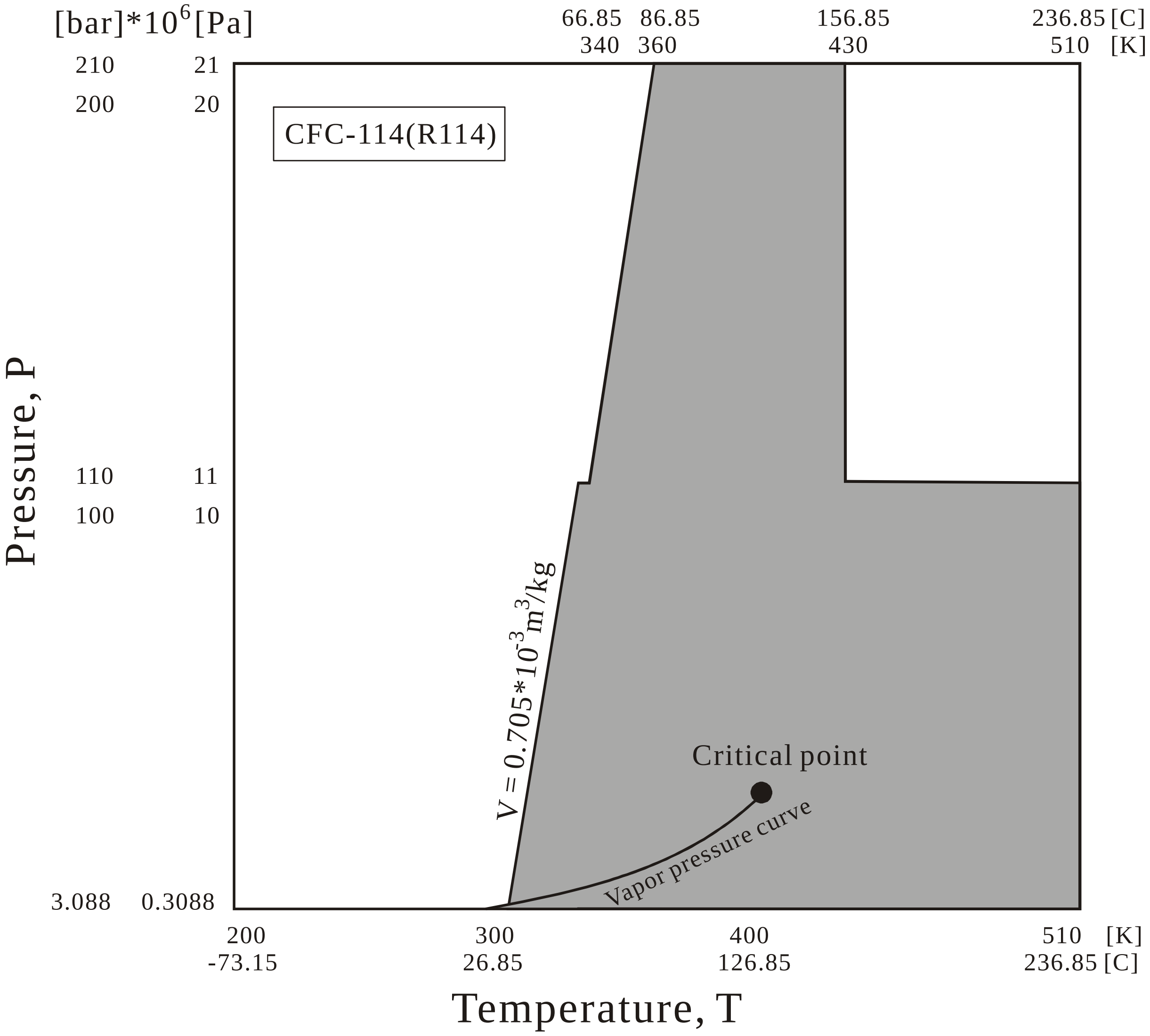


Fig.II–2.37–2 Range of Arguments(P,T) for VPT(P,T).

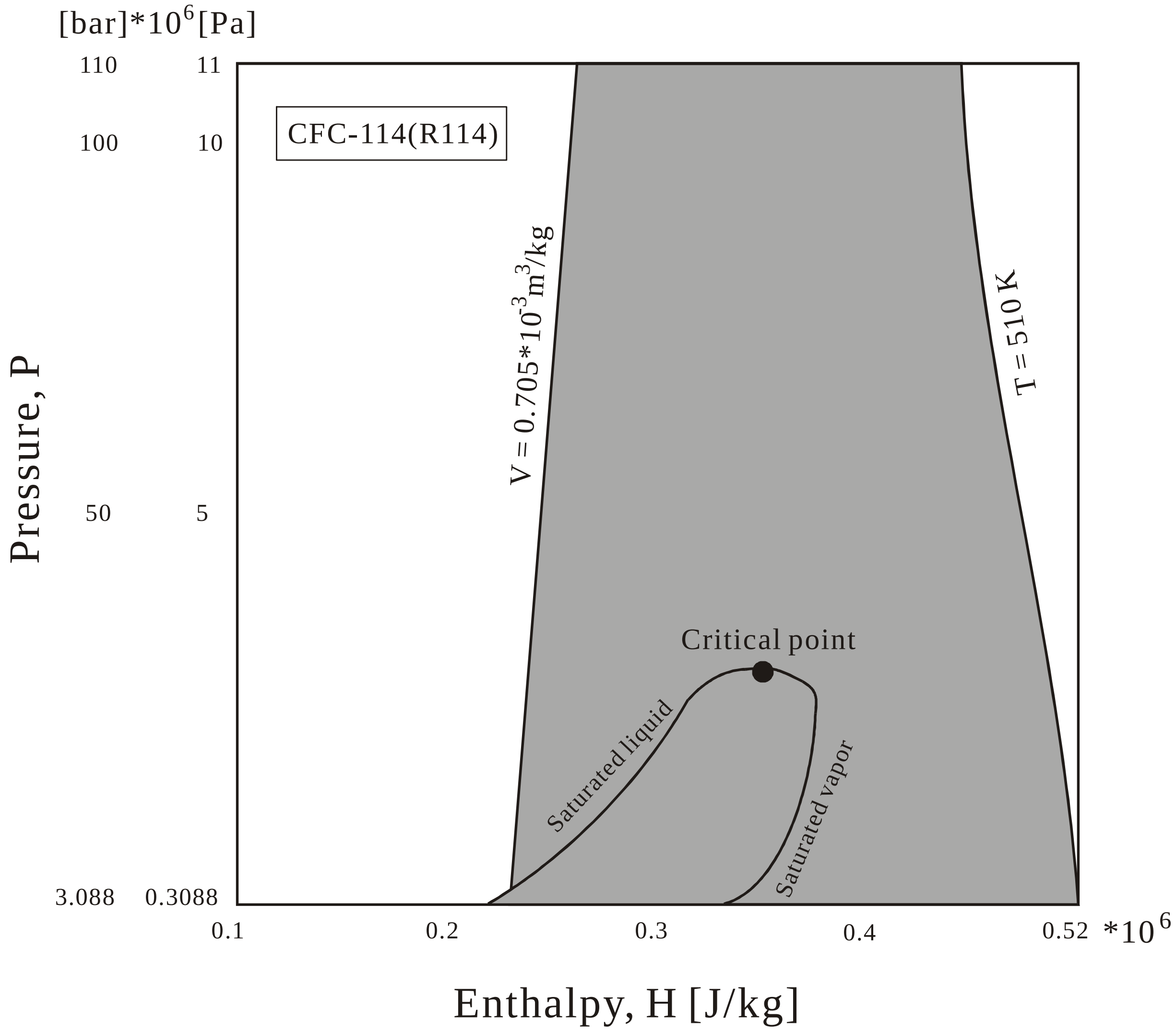


Fig.II–2.37–3 Range of Arguments(P,H) for TPH(P,H).

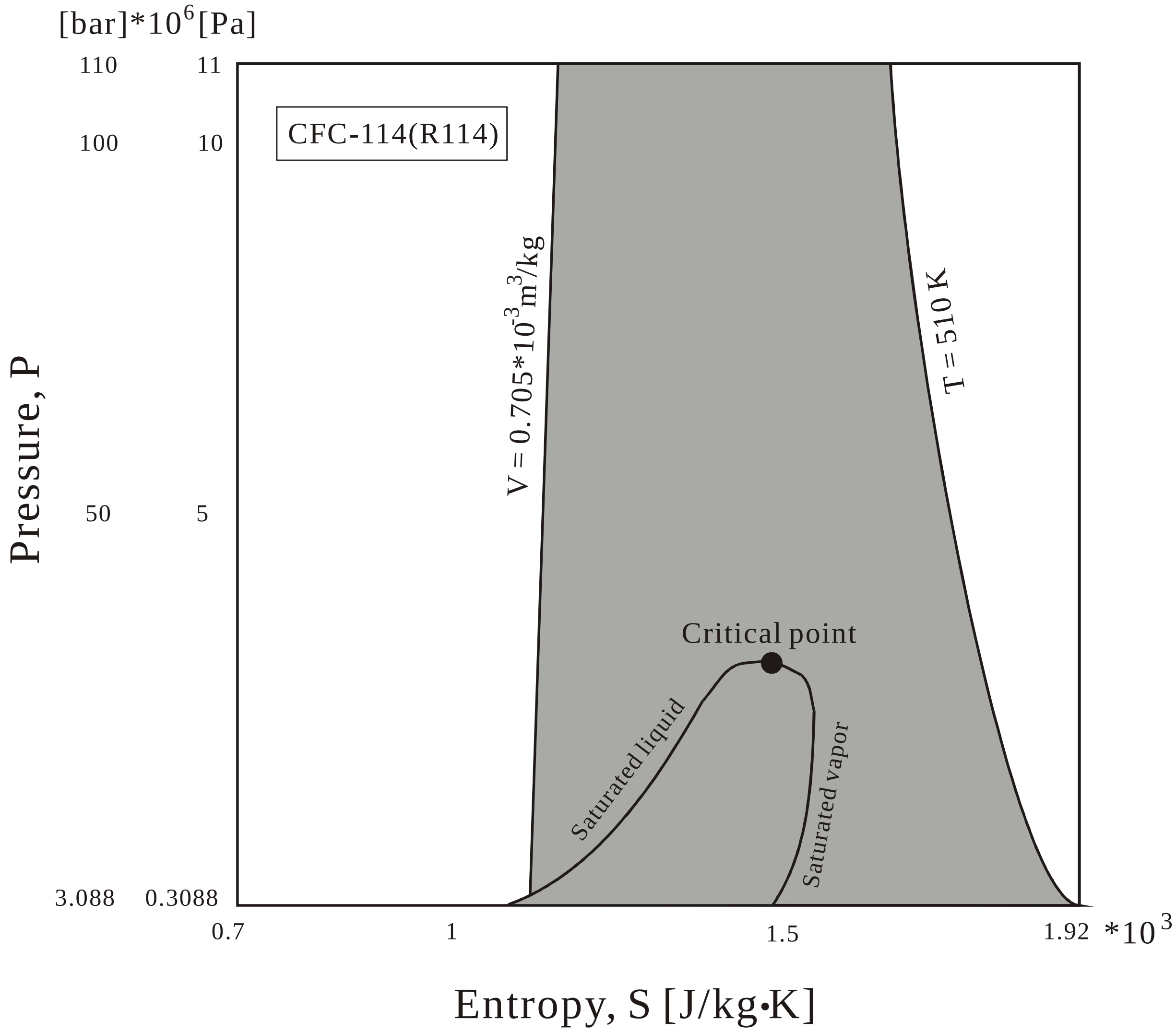


Fig.II–2.37–4 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.38 CFC-115(R115)

All equations for CFC-115(R115) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.38.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.38.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-115, R115, Refrigerant 115, Freon 115, Chlorofluoroethane
Library File for UNIX:	libjr115.a
Library File for DOS,Windows95/NT:	JR115.LIB
Single Shot Program for UNIX:	r115-ss
Single Shot Program for DOS,Windows95/NT:	R115-SS.EXE

2.38.3 Important Constants and Others

Molecular Formula:	$C_2C\ell F_5$
Relative Molecular Mass:	154.480
Gas Constant:	53.997 J/(kg·K)

Critical Constants:

Critical Pressure:	3.1600×10^{6}Pa (31.600 bar)
Critical Temperature:	353.10 K (79.95 °C)
Critical Specific Volume:	1.6300×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.38.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\text{K}) < p < p_{sat}(T_c + 1\text{K})$ and $v'(T_c - 1\text{K}) < v < v''(T_c - 1\text{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T, \rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_\rho - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

However, the coefficients of Bender equation of state ($a_{01} \sim a_{19}$) are revised. The correct values are the followings.

$a_{01} = 2.3366423320E-02$	$a_{08} = 5.8910342990E+04$	$a_{15} = 4.3630653440E+09$
$a_{02} = 3.6254298340E+01$	$a_{09} = -4.1131369640E-01$	$a_{16} = -4.8300903530E+11$
$a_{03} = -8.9222216730E+03$	$a_{10} = 1.8247777160E+02$	$a_{17} = 1.7669793250E+07$
$a_{04} = 3.7757690770E+06$	$a_{11} = 4.5099307060E-01$	$a_{18} = -1.9335704800E+10$
$a_{05} = 2.3826225750E+08$	$a_{12} = -2.8676585670E+02$	$a_{19} = 3.8905495630E+12$
$a_{06} = 4.1067070490E-01$	$a_{13} = 7.2142477090E+01$	
$a_{07} = -2.6810832280E+02$	$a_{14} = -1.1555632860E+07$	

Transport Properties:
Thermal conductivity and viscosity from reference [2].

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] Thermophysical Properties of Refrigerants(1976), 65 ASHRAE

Table II–2.38–1 CFC-115(R-115) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3\leq P\leq7.0\times10^6$ [Pa] $210\leq T\leq450$ [K] $0.3\leq P\leq70$ [bar] $-63.15\leq T\leq176.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$200\leq T\leq353.1$ [K] $-73.15\leq T\leq79.95$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq0.9569\times10^6$ [Pa] $0.1625\leq P\leq9.569$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $240\leq T\leq380$ [K] $-33.15\leq T\leq106.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$176\leq T\leq300$ [K] $-97.15\leq T\leq26.85$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq0.7306\times10^6$ [Pa] $0.1625\leq P\leq7.306$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$84.26\times10^3\leq P\leq2.9365\times10^6$ [Pa] $0.8426\leq P\leq29.635$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$190\leq T\leq290$ [K] $-83.15\leq T\leq16.85$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$230\leq T\leq350$ [K] $-43.15\leq T\leq76.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]

Table II–2.38–1 CFC-115(R-115) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3\leq P\leq7.0\times10^6$ [Pa] $210\leq T\leq450$ [K] $0.3\leq P\leq70$ [bar] $-63.15\leq T\leq176.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$200\leq T\leq353.1$ [K] $-73.15\leq T\leq79.95$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$200\leq T\leq353.1$ [K] $-73.15\leq T\leq79.95$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3125×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.16×10^6 [Pa], 31.6 [bar] Pressure S: 'A'='S': 1.345×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 353.10 [K], 79.95 [°C] Temperature V: 'A'='V': 1.630×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3\leq P\leq7.0\times10^6$ [Pa] $210\leq T\leq450$ [K] $0.3\leq P\leq70$ [bar] $-63.15\leq T\leq176.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$200\leq T\leq353.1$ [K] $-73.15\leq T\leq79.95$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 154.48 Relative Molecular Mass R: 'A'='R': 53.997 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq P\leq3.16\times10^6$ [Pa] $0.1625\leq P\leq31.6$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$30\times10^3\leq P\leq7.0\times10^6$ [Pa] SPT(P,210K)≤S≤ SPT(P,450K) [J/(kg·K)] $0.3\leq P\leq70$ [bar] SPT(P,−63.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]

Table II–2.38–1 CFC-115(R-115) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3\leq$P$\leq7.0\times10^6$ [Pa] 210≤T≤450 [K] 0.3≤P≤70 [bar] −63.15≤T≤176.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$16.25\times10^3\leq$P$\leq3.16\times10^6$ [Pa] 0.1625≤P≤31.6 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C: 'A'='C':'CCLF2CF3' Molecular Formula S: 'A'='S':'CFC-115(R-115)' Name of Substance V: 'A'='V':'10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq$P$\leq0.7306\times10^6$ [Pa] 0.1625≤P≤7.306 [bar]
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	200≤T≤290 [K] −73.15≤T≤16.85 [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	210≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(200K)≤P$\leq3.16\times10^6$ [Pa] ($\sim20\times10^3$) PST(−73.15°C)≤P≤31.6 [bar] (∼0.2)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq$P$\leq3.16\times10^6$ [Pa] 0.1625≤P≤31.6 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$16.25\times10^3\leq$P$\leq3.16\times10^6$ [Pa] 0.1625≤P≤31.6 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3\leq$P$\leq7.0\times10^6$ [Pa] 210≤T≤450 [K] 0.3≤P≤70 [bar] −63.15≤T≤176.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$16.25\times10^3\leq$P$\leq3.16\times10^6$ [Pa] 0.1625≤P≤31.6 [bar] 0≤X≤1.0 [–]

Table II–2.38–1 CFC-115(R-115) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	200≤T≤353.1 [K] −73.15≤T≤79.95 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	30×10^3≤P≤7.0×10^6 [Pa] HPT(P,210K)≤H≤ HPT(P,450K) [J/kg] 0.3≤P≤70 [bar] HPT(P,−63.15°C)≤H≤ HPT(P,176.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	30×10^3≤P≤7.0×10^6 [Pa] SPT(P,210K)≤S≤ SPT(P,450K) [J/(kg·K)] 0.3≤P≤70 [bar] SPT(P,−63.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	30×10^3≤P≤7.0×10^6 [Pa] VPT(P,210K)≤V≤ VPT(P,450K) [m^3/kg] 0.3≤P≤70 [bar] VPT(P,−63.15°C)≤V≤ VPT(P,176.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	16.25×10^3≤P≤3.16×10^6 [Pa] 0.1625≤P≤31.6 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	16.25×10^3≤P≤3.16×10^6 [Pa] 0.1625≤P≤31.6 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	16.25×10^3≤P≤3.16×10^6 [Pa] 0.1625≤P≤31.6 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	16.25×10^3≤P≤10.0×10^6 [Pa] SPT(P,210K)≤S≤ SPT(P,450K) [J/(kg·K)] 0.3≤P≤70 [bar] SPT(P,−63.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	30×10^3≤P≤7.0×10^6 [Pa] 210≤T≤450 [K] 0.3≤P≤70 [bar] −63.15≤T≤176.85 [°C]

Table II–2.38–1 CFC-115(R-115) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$16.25\times10^3 \leq P \leq 3.16\times10^6$ [Pa] $0.1625 \leq P \leq 31.6$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$16.25\times10^3 \leq P \leq 3.16\times10^6$ [Pa] $0.1625 \leq P \leq 31.6$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$16.25\times10^3 \leq P \leq 3.16\times10^6$ [Pa] $0.1625 \leq P \leq 31.6$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$30\times10^3 \leq P \leq 7.0\times10^6$ [Pa] SPT(P,210K)≤S≤ SPT(P,450K) [J/(kg·K)] $0.3 \leq P \leq 70$ [bar] SPT(P,−63.15°C)≤S≤ SPT(P,176.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3 \leq P \leq 7.0\times10^6$ [Pa] $210 \leq T \leq 450$ [K] $0.3 \leq P \leq 70$ [bar] $-63.15 \leq T \leq 176.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$16.25\times10^3 \leq P \leq 3.16\times10^6$ [Pa] $0.1625 \leq P \leq 31.6$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$200 \leq T \leq 353.1$ [K] $-73.15 \leq T \leq 79.95$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$30\times10^3 \leq P \leq 7.0\times10^6$ [Pa] $210 \leq T \leq 450$ [K] $0.3 \leq P \leq 70$ [bar] $-63.15 \leq T \leq 176.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$16.25\times10^3 \leq P < 3.16\times10^6$ [Pa] $0.1625 \leq P < 31.6$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$16.25\times10^3 \leq P < 3.16\times10^6$ [Pa] $0.1625 \leq P < 31.6$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]

Table II–2.38–1 CFC-115(R-115) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$16.25\times10^3 \leq P < 3.16\times10^6$ [Pa] $0.1625 \leq P < 31.6$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$16.25\times10^3 \leq P < 3.16\times10^6$ [Pa] $0.1625 \leq P < 31.6$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$200 \leq T < 353.1$ [K] $-73.15 \leq T < 79.95$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$200 \leq T < 353.1$ [K] $-73.15 \leq T < 79.95$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$200 \leq T < 353.1$ [K] $-73.15 \leq T < 79.95$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$200 \leq T < 353.1$ [K] $-73.15 \leq T < 79.95$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.39 CFC-152a(R152a)

All equations for CFC-152a(R152a) are based on the Table from Thermodynamic properties of refrigerants of ASHRAE[1],[2].

2.39.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.39.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	CFC-152a, R152a, Refrigerant 152a, Difluoroethane
Library File for UNIX:	libjr152a.a
Library File for DOS,Windows95/NT:	JR152A.LIB
Single Shot Program for UNIX:	r152a-ss
Single Shot Program for DOS,Windows95/NT:	R152A–SS.EXE

2.39.3 Important Constants and Others

Molecular Formula:	$C_2H_4F_2$
Relative Molecular Mass:	66.050
Gas Constant:	125.882 J/(kg·K)

Critical Constants:

Critical Pressure:	4.495×10^{6}Pa (44.95 bar)
Critical Temperature:	386.65 K (113.50 °C)
Critical Specific Volume:	2.7397×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.39.4 Formula

Equation of State:

The Martin-Hou equation in reference [1] is used.

Vapor Pressure:

Equation (2.2.2) in reference [1].

Properties at Vapor-Liquid Equilibrium:

The saturated liquid density equation is obtained from Equation (2.2.4.d) in reference [1]. The saturated vapor density is obtained by the compatibility of the equation of state and vapor pressure equation. Isobaric specific heat c_p is obtained from individual in reference [2].

Transport Properties:

Thermal conductivity and viscosity from reference [2].

The Other Properties:

Surface tension from reference [5].

References

[1] Thermodynamic Properties of Refrigerants (1986), 33, ASHRAE
[2] Thermophysical Properties of Refrigerants (Inch-Pound Edition), (1993), 113, ASHRAE

Table II–2.39–1 R152a Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$1.033\times10^3 \leq P \leq 0.22189\times10^6$ [Pa] $0.01033 \leq P \leq 2.2189$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 268$ [K] $-100 \leq T \leq -5.15$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.033\times10^3 \leq P \leq 3.3832\times10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$9.71\times10^3 \leq P \leq 1.899\times10^6$ [Pa] $0.0971 \leq P \leq 18.99$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $273 \leq T \leq 473$ [K] $-0.15 \leq T \leq 199.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$203.15 \leq T \leq 343.15$ [K] $-70 \leq T \leq 70$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$9.62\times10^3 \leq P \leq 0.6885\times10^6$ [Pa] $0.0962 \leq P \leq 6.885$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.12486\times10^3 \leq P \leq 1.509\times10^6$ [Pa] $1.2486 \leq P \leq 15.09$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity at Ordinary Pressure [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $248 \leq T \leq 423$ [K] $-25.15 \leq T \leq 149.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$203 \leq T \leq 303$ [K] $-70.15 \leq T \leq 29.85$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$253.15 \leq T \leq 333.15$ [K] $-20 \leq T \leq 60$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$9.71\times10^3 \leq P \leq 1.899\times10^6$ [Pa] $0.0971 \leq P \leq 18.99$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$17.81\times10^3 \leq P \leq 0.912\times10^6$ [Pa] $0.1781 \leq P \leq 9.12$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat at Ordinary Pressure [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $248.15 \leq T \leq 473.15$ [K] $-25 \leq T \leq 200$ [°C]

Table II–2.39–1 R152a Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	203.15≤T≤343.15 [K] −70≤T≤70 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	213.15≤T≤313.15 [K] −60≤T≤40 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4679×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.495×10^6 [Pa], 44.95 [bar] Pressure S: 'A'='S': 1.7970×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 386.65 [K], 113.50 [°C] Temperature V: 'A'='V': 2.7397×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 66.050 Relative Molecular Mass R: 'A'='R': 125.882 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	1.033×10^3≤P≤3.3832×10^6 [Pa] 0.01033≤P≤33.832 [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	1.033×10^3≤P≤3.3832×10^6 [Pa] 0.01033≤P≤33.832 [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	10×10^3≤P≤3.0×10^6 [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤30 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.39-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	10×10^3≤P≤3.0×10^6 [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤30 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.39-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	1.033×10^3≤P≤3.3832×10^6 [Pa] 0.01033≤P≤33.832 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	173.15≤T≤371.15 [K] −100≤T≤98 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	173.15≤T≤371.15 [K] −100≤T≤98 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	173.15≤T≤371.15 [K] −100≤T≤98 [°C] 0≤X≤1.0 [–]

Table II–2.39–1 R152a Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C2H4F2' Molecular Formula S: 'A'='S': 'R152A' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$9.71 \leq P \leq 0.6885$ [Pa] $0.0971 \leq P \leq 6.885$ [bar]
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $273 \leq T \leq 423$ [K] $-0.15 \leq T \leq 149.85$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$203.15 \leq T \leq 303$ [K] $-70 \leq T \leq 29.85$ [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$1.033 \times 10^3 \leq P \leq 0.22189 \times 10^6$ [Pa] $0.01033 \leq P \leq 2.2189$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 268$ [K] $-1000 \leq T \leq -5.15$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10 \times 10^3 \leq P \leq 3.0 \times 10^6$ [Pa] $TSP(P) \leq T \leq 453.15$ [K] $0.1 \leq P \leq 30$ [bar] $TSP(P) \leq T \leq 180$ [°C] see Fig.II-2.39-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		

Table II–2.39–1 R152a Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$10\times10^3 \leq P \leq 3.0\times10^6$ [Pa] HPDD(P)≤H≤ HPT(P,453.15K) [J/kg] 0.1≤P≤30 [bar] HPDD(P)≤H≤ HPT(P,180°C) [J/kg] see Fig.II-2.39-2 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\times10^3 \leq P \leq 3.0\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤30 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.39-3 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$10\times10^3 \leq P \leq 3.0\times10^6$ [Pa] VPDD(P)≤V≤ VPT(P,453.15K) [m^3/kg] 0.1≤P≤30 [bar] VPDD(P)≤V≤ VPT(P,180°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.033\times10^3 \leq P \leq 3.3832\times10^6$ [Pa] 0.01033≤P≤33.832 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.033\times10^3 \leq P \leq 3.3832\times10^6$ [Pa] 0.01033≤P≤33.832 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.033\times10^3 \leq P \leq 3.3832\times10^6$ [Pa] 0.01033≤P≤33.832 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\times10^3 \leq P \leq 3.0\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤30 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.39-3 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10\times10^3 \leq P \leq 3.0\times10^6$ [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤30 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.39-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.033\times10^3 \leq P \leq 3.3832\times10^6$ [Pa] 0.01033≤P≤33.832 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	173.15≤T≤371.15 [K] −100≤T≤98 [°C]

Table II–2.39–1 R152a Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy[J/(kg·K)]	$10 \times 10^3 \leq P \leq 3.0 \times 10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] $0.1 \leq P \leq 30$ [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.39-3 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10 \times 10^3 \leq P \leq 3.0 \times 10^6$ [Pa] TSP(P)≤T≤453.15 [K] $0.1 \leq P \leq 30$ [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.39-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.033 \times 10^3 \leq P \leq 3.3832 \times 10^6$ [Pa] $0.01033 \leq P \leq 33.832$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \leq T \leq 371.15$ [K] $-100 \leq T \leq 98$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.033 \times 10^3 \leq P < 3.3832 \times 10^6$ [Pa] $0.01033 \leq P < 33.832$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.033 \times 10^3 \leq P < 3.3832 \times 10^6$ [Pa] $0.01033 \leq P < 33.832$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.033 \times 10^3 \leq P < 3.3832 \times 10^6$ [Pa] $0.01033 \leq P < 33.832$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.033 \times 10^3 \leq P < 3.3832 \times 10^6$ [Pa] $0.01033 \leq P < 33.832$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.39–1 R152a Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$173.15 \le T < 371.15$ [K] $-100 \le T < 98$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$173.15 \le T < 371.15$ [K] $-100 \le T < 98$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$173.15 \le T < 371.15$ [K] $-100 \le T < 98$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$173.15 \le T < 371.15$ [K] $-100 \le T < 98$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

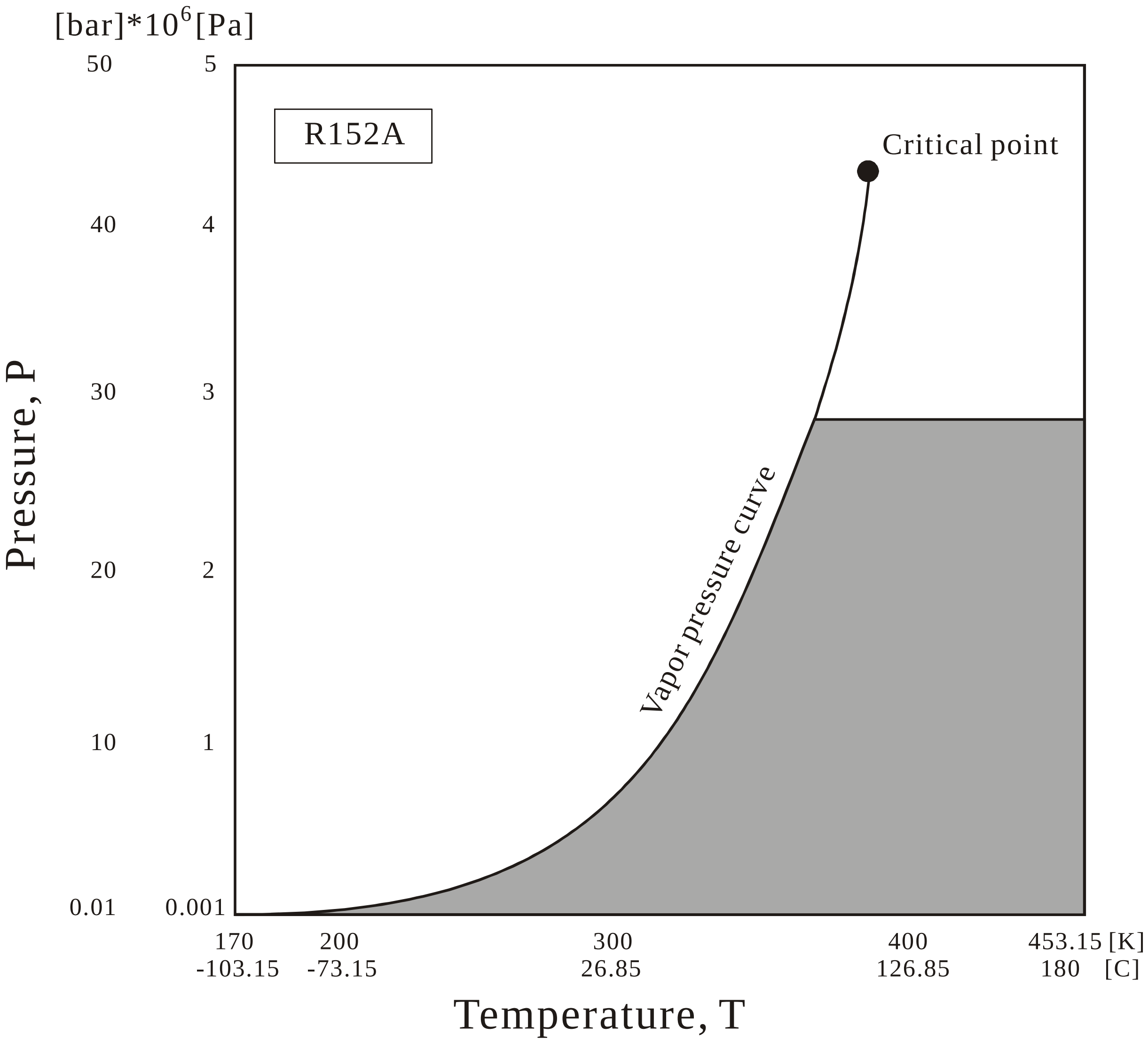


Fig.II–2.39–1 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T) and VPT(P,T).

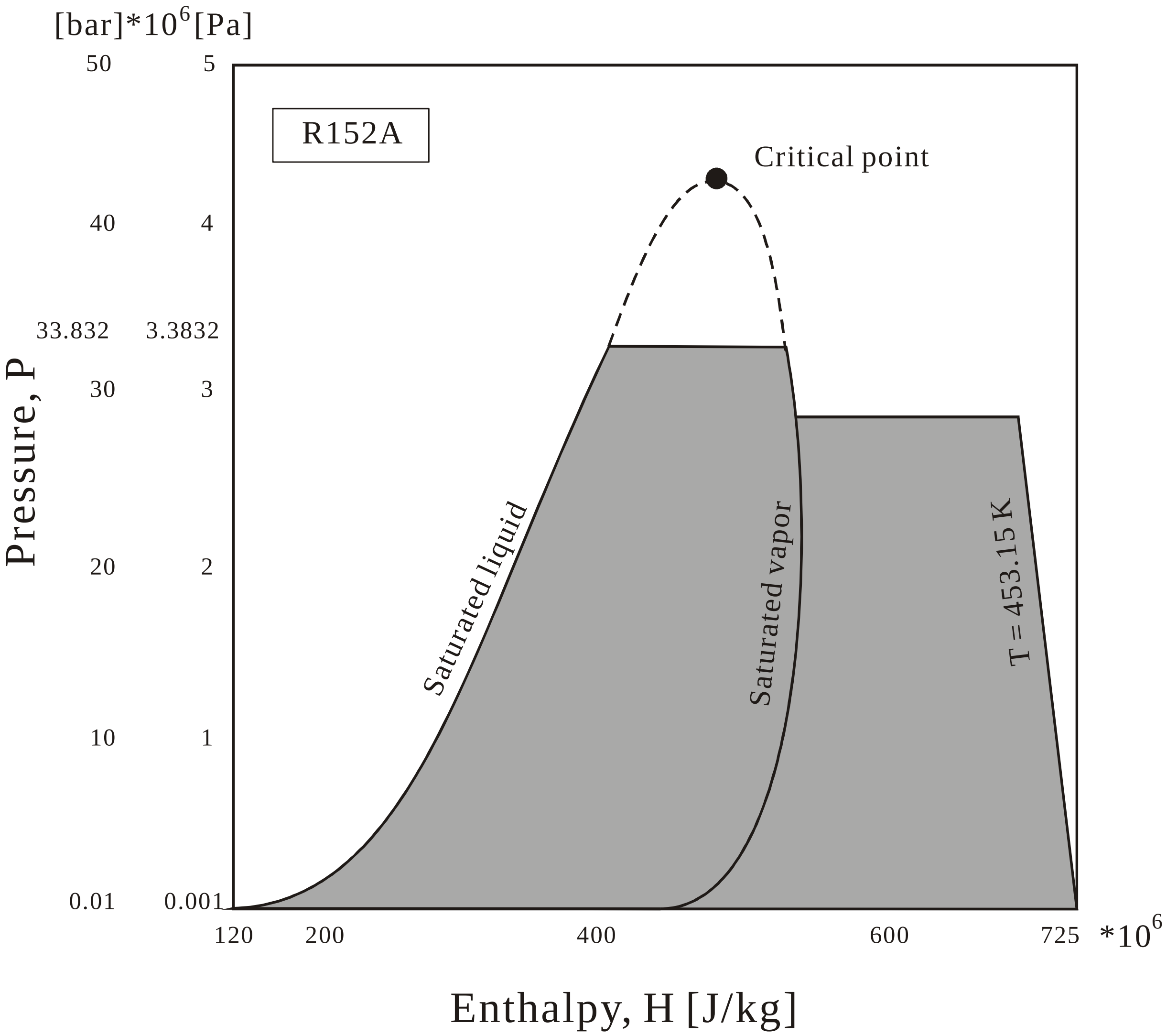


Fig.II–2.39–2 Range of Arguments(P,H) for TPH(P,H).

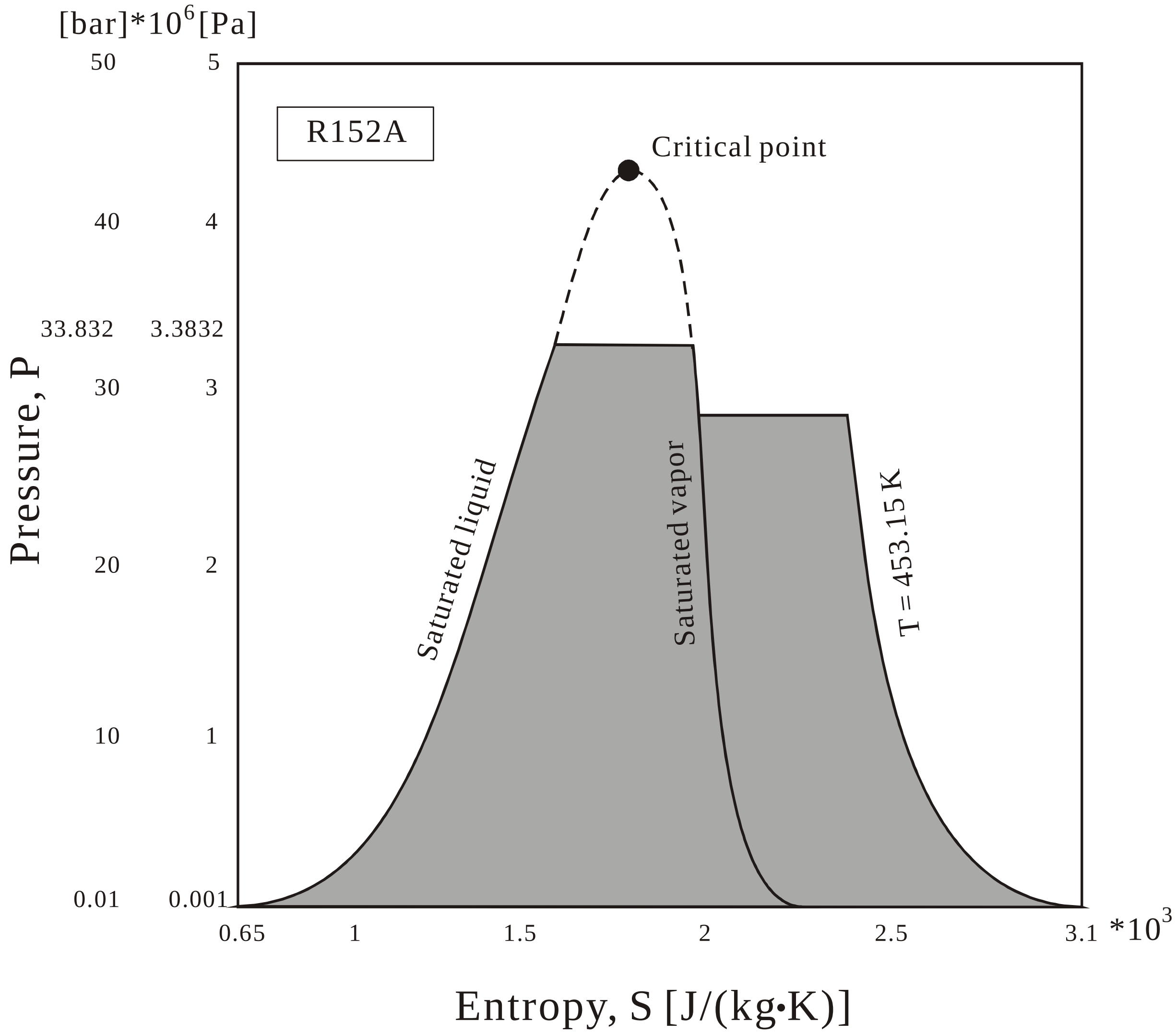


Fig.II–2.39–3 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.40 HCFC-21(R21)

All equations for HCFC-21(R21) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.40.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.40.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HCFC-21, R21, Refrigerant 21, Freon 21, Dichlorofluoromethane
Library File for UNIX:	libjr21.a
Library File for DOS,Windows95/NT:	JR21.LIB
Single Shot Program for UNIX:	r21-ss
Single Shot Program for DOS,Windows95/NT:	R21-SS.EXE

2.40.3 Important Constants and Others

Molecular Formula:	$CHC\ell_2F$
Relative Molecular Mass:	102.920
Gas Constant:	80.7614 J/(kg·K)

Critical Constants:

Critical Pressure:	5.1812×10^6Pa (51.812 bar)
Critical Temperature:	451.48 K (178.33 °C)
Critical Specific Volume:	1.9011×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.40.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\text{K}) < p < p_{sat}(T_c + 1\text{K})$ and $v'(T_c - 1\text{K}) < v < v''(T_c - 1\text{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T, \rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

Transport Properties:
Thermal conductivity and viscosity from reference [2].

The Other Properties:
Equation (3) in reference [3] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] Thermophysical Properties of Refrigerants(1976), 65 ASHRAE
[3] K.Watanabe and M.Okada, Int. J. Thermophysics, 2-2(1981), 163

Table II–2.40–1 HCFC-21(R-21) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \leq P \leq 90\times10^6$ [Pa] $220 \leq T \leq 470$ [K] $2.5 \leq P \leq 900$ [bar] $-53.15 \leq T \leq 196.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 5.1812\times10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$240 \leq T \leq 451.48$ [K] $-33.15 \leq T \leq 178.33$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 5.1812\times10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$215 \leq T \leq 451.48$ [K] $-58.15 \leq T \leq 178.33$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 3.4191\times10^6$ [Pa] $0.0286 \leq P \leq 34.191$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$93.64\times10^3 \leq P \leq 2.2309\times10^6$ [Pa] $0.9364 \leq P \leq 22.309$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $233 \leq T \leq 695$ [K] $-40.15 \leq T \leq 421.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$139 \leq T \leq 425$ [K] $-134.15 \leq T \leq 151.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$280 \leq T \leq 400$ [K] $6.85 \leq T \leq 126.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 1.8547\times10^6$ [Pa] $0.0286 \leq P \leq 18.547$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$194\times10^3 \leq P \leq 3.7059\times10^6$ [Pa] $1.940 \leq P \leq 37.059$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$170 \leq T \leq 400$ [K] $-103.15 \leq T \leq 126.85$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$300 \leq T \leq 430$ [K] $26.85 \leq T \leq 156.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 5.1812\times10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \leq P \leq 5.1812\times10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]

Table II–2.40–1 HCFC-21(R-21) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \le P \le 90\times10^6$ [Pa] $220 \le T \le 470$ [K] $2.5 \le P \le 900$ [bar] $-53.15 \le T \le 196.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4479×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 5.1812×10^6 [Pa], 51.812 [bar] Pressure S: 'A'='S': 1.656×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 451.48 [K], 178.33 [°C] Temperature V: 'A'='V': 1.901×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \le P \le 90\times10^6$ [Pa] $220 \le T \le 470$ [K] $2.5 \le P \le 900$ [bar] $-53.15 \le T \le 196.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 102.92 Relative Molecular Mass R: 'A'='R': 80.786 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$250\times10^3 \le P \le 90\times10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,470K) [J/(kg·K)] $2.5 \le P \le 900$ [bar] SPT(P,−53.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]

Table II–2.40–1 HCFC-21(R-21) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3\le P\le 90\times10^6$ [Pa] $220\le T\le 470$ [K] $2.5\le P\le 900$ [bar] $-53.15\le T\le 196.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.86\times10^3\le P\le 5.1812\times10^6$ [Pa] $0.0286\le P\le 51.812$ [bar] $0\le X\le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$215\le T\le 451.48$ [K] $-58.15\le T\le 178.33$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$215\le T\le 451.48$ [K] $-58.15\le T\le 178.33$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$215\le T\le 451.48$ [K] $-58.15\le T\le 178.33$ [°C] $0\le X\le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C:'A'='C': ' CHCL2F' Molecular Formula S:'A'='S': 'HCFC-21(R-21)' Name of Substance V:'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$2.86\times10^3\le P\le 1.8547\times10^6$ [Pa] $0.0286\le P\le 18.547$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$93.64\times10^3\le P\le 2.2309\times10^6$ [Pa] $0.9364\le P\le 22.309$ [bar]
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$215\le T\le 400$ [K] $-58.15\le T\le 126.85$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$280\le T\le 400$ [K] $6.85\le T\le 126.85$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$220\le T\le 451.48$ [K] $-53.15\le T\le 178.33$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(220K)$\le P\le 5.1812\times10^6$ [Pa] ($\sim4.1\times10^3$) PST(-53.15 °C)$\le P\le 51.812$ [bar] (~0.041)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$220\le T\le 451.48$ [K] $-53.15\le T\le 178.33$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3\le P\le 5.1812\times10^6$ [Pa] $0.0286\le P\le 51.812$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.86\times10^3\le P\le 5.1812\times10^6$ [Pa] $0.0286\le P\le 51.812$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3\le P\le 90\times10^6$ [Pa] $220\le T\le 470$ [K] $2.5\le P\le 900$ [bar] $-53.15\le T\le 196.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.86\times10^3\le P\le 5.1812\times10^6$ [Pa] $0.0286\le P\le 51.812$ [bar] $0\le X\le 1.0$ [–]

Table II–2.40–1 HCFC-21(R-21) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$215 \leq T \leq 451.48$ [K] $-58.15 \leq T \leq 178.33$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$215 \leq T \leq 451.48$ [K] $-58.15 \leq T \leq 178.33$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$215 \leq T \leq 451.48$ [K] $-58.15 \leq T \leq 178.33$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$250 \times 10^3 \leq P \leq 90 \times 10^6$ [Pa] HPT(P,220K)≤H≤ HPT(P,470K) [J/kg] $2.5 \leq P \leq 900$ [bar] HPT(P,−53.15°C)≤H≤ HPT(P,196.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$250 \times 10^3 \leq P \leq 90 \times 10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,470K) [J/(kg·K)] $2.5 \leq P \leq 900$ [bar] SPT(P,−53.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$250 \times 10^3 \leq P \leq 90 \times 10^6$ [Pa] VPT(P,220K)≤V≤ VPT(P,470K) [m^3/kg] $2.5 \leq P \leq 900$ [bar] VPT(P,−53.15°C)≤V≤ VPT(P,196.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$2.86 \times 10^3 \leq P \leq 5.1812 \times 10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.86 \times 10^3 \leq P \leq 5.1812 \times 10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.86 \times 10^3 \leq P \leq 5.1812 \times 10^6$ [Pa] $0.0286 \leq P \leq 51.812$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$250 \times 10^3 \leq P \leq 90 \times 10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,470K) [J/(kg·K)] $2.5 \leq P \leq 900$ [bar] SPT(P,−53.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]

Table II–2.40–1 HCF-21(R-21) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \le P \le 90\times10^6$ [Pa] $220 \le T \le 470$ [K] $2.5 \le P \le 900$ [bar] $-53.15 \le T \le 196.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$220 \le T \le 451.48$ [K] $-53.15 \le T \le 178.33$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$220 \le T \le 451.48$ [K] $-53.15 \le T \le 178.33$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$250\times10^3 \le P \le 90\times10^6$ [Pa] SPT(P,220K)≤S≤ SPT(P,470K) [J/(kg·K)] $2.5 \le P \le 900$ [bar] SPT(P,−53.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \le P \le 90\times10^6$ [Pa] $220 \le T \le 470$ [K] $2.5 \le P \le 900$ [bar] $-53.15 \le T \le 196.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.86\times10^3 \le P \le 5.1812\times10^6$ [Pa] $0.0286 \le P \le 51.812$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$215 \le T \le 451.48$ [K] $-58.15 \le T \le 178.33$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$250\times10^3 \le P \le 90\times10^6$ [Pa] $220 \le T \le 470$ [K] $2.5 \le P \le 900$ [bar] $-53.15 \le T \le 196.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$2.86\times10^3 \le P < 5.1812\times10^6$ [Pa] $0.0286 \le P < 51.812$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]

Table II–2.40–1 HCF-21(R-21) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$2.86\times10^3 \leq P < 5.1812\times10^6$ [Pa] $0.0286 \leq P < 51.812$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$2.86\times10^3 \leq P < 5.1812\times10^6$ [Pa] $0.0286 \leq P < 51.812$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$2.86\times10^3 \leq P < 5.1812\times10^6$ [Pa] $0.0286 \leq P < 51.812$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$215 \leq T < 451.48$ [K] $-58.15 \leq T < 178.33$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$215 \leq T < 451.48$ [K] $-58.15 \leq T < 178.33$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$215 \leq T < 451.48$ [K] $-58.15 \leq T < 178.33$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$215 \leq T < 451.48$ [K] $-58.15 \leq T < 178.33$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.41 HCFC-22(R22)

All equations for HCFC-22(R22) are based on the Table from Japanese Association of Refrigeration [1].

2.41.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.41.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HCFC-22, R22, Refrigerant 22, Freon 22, Chlorodifluoromethane
Library File for UNIX:	libjr22.a
Library File for DOS,Windows95/NT:	JR22.LIB
Single Shot Program for UNIX:	r22-ss
Single Shot Program for DOS,Windows95/NT:	R22–SS.EXE

2.41.3 Important Constants and Others

Molecular Formula:	$CHC\ell F_2$
Relative Molecular Mass:	86.469
Gas Constant:	96.15469 J/(kg·K)

Critical Constants:

Critical Pressure:	4.988×10^6Pa (49.88 bar)
Critical Temperature:	369.30 K (96.15°C)
Critical Specific Volume:	1.9493×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kcal(thermochemical)/(kg·K), i.e. 4184.0 J/(kg·K) and 100.00 kcal(thermochemical)/kg, i.e. 0.4184 $\times10^6$J/kg are assigned to the specific entropy and the specific enthalpy, respectively.

2.41.4 Formula

Equation of State:

Equation (II·2·1) in a function form of $Z = Z(\rho, T)$ in reference [1]. Here Z=compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (II·2·20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated liquid: Equations (II·2·3), (II·2·9), (II·2·17) and (II·2·21) for specific volume, specific enthalpy, specific entropy and isobaric specific heat, respectively. However the 5th term in right hand side of (II·2·17) has been corrected as $B_5(1 + 4T_r)(1 - T_r)^4$.

saturated vapor: Equations (II·2·20) and (II·2·21) for specific volume, (II·2·20) and (II·2·6) for specific enthalpy and (II·2·20) and (II·2·25) for isobaric specific heat. However $\ln(T_r/T_0)$ the 12th term in right hand side of (II·2·14) has been deleted. Equations (II·2·16) and (II·2·26) for isochoric specific heat.

All of these equations have been cited from reference [1].

Transport Properties:

Equations (II·3·9) and (II·3·1) in reference [1] for thermal conductivity and dynamic viscosity of saturated liquid, respectively. Equations (II·3·10) and (II·3·5) in reference [1] for thermal conductivity of vapor at the atmospheric pressure and dynamic viscosity of the superheated vapor, respectively.

The Other Properties:

Equation (II·2·37) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration, Thermophysical Properties of Refrigerants (R22, Chlorodifluoromethane), (1975).

Table II–2.41–1 HCFC-22 (R22) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq10\times10^6$ [Pa] $183.15\leq T\leq473.15$ [K] $0.02\leq P\leq100$ [bar] $-90\leq T\leq200$ [°C] see Fig.II-2.41-1
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$64.54\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.6454\leq P\leq49.7$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$223.15\leq T\leq369.15$ [K] $-50\leq T\leq96$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(343.15K) [Pa] ($\sim1.95\times10^3$) ($\sim2.99\times10^6$) PST(−100°C)≤P≤PST(70°C) [bar] (∼0.0195) (∼29.9)
7	ALMPDD(P)		
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $233.15\leq T\leq473.15$ [K] $-40\leq T\leq200$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$173.15\leq T\leq343.15$ [K] $-100\leq T\leq70$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(313.15K) [Pa] ($\sim1.95\times10^3$) ($\sim1.53\times10^6$) PST(−100°C)≤P≤PST(40°C) [bar] (∼0.0195) (∼15.3)
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq P\leq6.0\times10^6$ [Pa] $273.15\leq T\leq398.15$ [K] $1.0\leq P\leq60$ [bar] $0\leq T\leq125$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$173.15\leq T\leq313.15$ [K] $-100\leq T\leq40$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(298.15K) [Pa] ($\sim1.95\times10^3$) ($\sim1.04\times10^6$) PST(−100°C)≤P≤PST(25°C) [bar] (∼0.0195) (∼10.4)

Table II–2.41–1 HCFC-22 (R22) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(353.15K) [Pa] (∼1.95×10^3) (∼3.66×10^6) PST(−100°C)≤P≤PST(80°C) [bar] (∼0.0195) (∼36.6)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.0×10^3≤P≤10×10^6 [Pa] 183.15≤T≤473.15 [K] 0.02≤P≤100 [bar] −90≤T≤200 [°C] see Fig.II-2.41-1
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤298.15 [K] −100≤T≤25 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤353.15 [K] −100≤T≤80 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.58654×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.988×10^6 [Pa], 49.88 [bar] Pressure S: 'A'='S': 4.6799×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 369.3 [K], 96.15 [°C] Temperature V: 'A'='V': 1.9493×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	PST(173.15K)≤P≤PST(353.15K) (∼1.95×10^3) (∼3.66×10^6) [Pa] PST(−100°C)≤P≤PST(80°C) (∼0.0195) (∼36.6) [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.0×10^3≤P≤10×10^6 [Pa] 183.15≤T≤473.15 [K] 0.02≤P≤100 [bar] −90≤T≤200 [°C] see Fig.II-2.41-1
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	173.15≤T≤353.15 [K] −100≤T≤80 [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 86.469 Relative Molecular Mass R: 'A'='R': 96.15469 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		

Table II–2.41–1 HCFC-22 (R22) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq 4.97\times10^6$ [Pa] $0.019\leq P\leq 49.7$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq 4.97\times10^6$ [Pa] $0.019\leq P\leq 49.7$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.9\times10^3\leq P\leq 15\times10^6$ [Pa] $0.019\leq P\leq 150$ [bar] see Fig.II-2.41-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq 15\times10^6$ [Pa] $178.15\leq T\leq 473.15$ [K] $0.02\leq P\leq 150$ [bar] $-95\leq T\leq 200$ [°C] see Fig.II-2.41-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.9\times10^3\leq P\leq 4.97\times10^6$ [Pa] $0.019\leq P\leq 49.7$ [bar] $0\leq X\leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 369.15$ [K] $-100\leq T\leq 96$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq 369.15$ [K] $-100\leq T\leq 96$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15\leq T\leq 369.15$ [K] $-100\leq T\leq 96$ [°C] $0\leq X\leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CHCLF2' Molecular Formula S: 'A'='S': 'HCFC-22 (R22)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $233.15\leq T\leq 423.15$ [K] $-40\leq T\leq 150$ [°C]
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$173.15\leq T\leq 369.3$ [K] $-100\leq T\leq 96.15$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(223.15K)$\leq P\leq 4.988\times10^6$ [Pa] ($\sim 64.54\times10^3$) PST(−50°C)$\leq P\leq 49.88$ [bar] ($\sim$0.6454)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$223.15\leq T\leq 369.3$ [K] $-50\leq T\leq 96.15$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq 4.97\times10^6$ [Pa] $0.019\leq P\leq 49.7$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq 4.97\times10^6$ [Pa] $0.019\leq P\leq 49.7$ [bar]

Table II–2.41–1 HCFC-22 (R22) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 15\times10^6$ [Pa] $178.15 \le T \le 473.15$ [K] $0.02 \le P \le 150$ [bar] $-95.0 \le T \le 200$ [°C] see Fig.II-2.41-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.9\times10^3 \le P \le 4.97\times10^6$ [Pa] $0.019 \le P \le 49.7$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \le T \le 369.15$ [K] $-100 \le T \le 96$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173.15 \le T \le 369.15$ [K] $-100 \le T \le 96$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15 \le T \le 369.15$ [K] $-100 \le T \le 96$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$1.9\times10^3 \le P \le 15\times10^6$ [Pa] $0.019 \le P \le 150$ [bar] see Fig.II-2.41-2 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.9\times10^3 \le P \le 15\times10^6$ [Pa] $0.019 \le P \le 150$ [bar] see Fig.II-2.41-3 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$1.9\times10^3 \le P \le 0.66214\times10^6$ [Pa] VPD(P)≤V≤ VPT(P,473.15K) [m^3/kg] $0.66214\times10^6 \le P \le 15\times10^6$ [Pa] 0.0008≤V≤VPT(P,473.15K) [m^3/kg] $0.019 \le P \le 6.6214$ [bar] VPD(P)≤V≤VPT(P,200°C) [m^3/kg] $6.6214 \le P \le 150$ [bar] 0.0008≤V≤VPT(P,200°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.9\times10^3 \le P \le 4.988\times10^6$ [Pa] $0.019 \le P \le 49.88$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3 \le P \le 4.97\times10^6$ [Pa] $0.019 \le P \le 49.7$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3 \le P \le 4.97\times10^6$ [Pa] $0.019 \le P \le 49.7$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.9\times10^3 \le P \le 15\times10^6$ [Pa] $0.019 \le P \le 150$ [bar] see Fig.II-2.41-3 for S

Table II–2.41–1 HCFC-22 (R22) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq15\times10^6$ [Pa] $178.15\leq T\leq473.15$ [K] $0.02\leq P\leq150$ [bar] $-95\leq T\leq200$ [°C] see Fig.II-2.41-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar] $0\leq X\leq1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C] $0\leq X\leq1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar]
80	VPS(P,S)	VPS: Specific Volume P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$1.9\times10^3\leq P\leq15\times10^6$ [Pa] $0.019\leq P\leq150$ [bar] see Fig.II-2.41-3 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq15\times10^6$ [Pa] $178.15\leq T\leq473.15$ [K] $0.02\leq P\leq150$ [bar] $-95\leq T\leq200$ [°C] see Fig.II-2.41-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar] $0\leq X\leq1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173.15\leq T\leq369.15$ [K] $-100\leq T\leq96$ [°C] $0\leq X\leq1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3\leq P\leq10\times10^6$ [Pa] $183.15\leq T\leq473.15$ [K] $0.02\leq P\leq100$ [bar] $-90\leq T\leq200$ [°C] see Fig.II-2.41-1
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.9\times10^3\leq P\leq4.97\times10^6$ [Pa] $0.019\leq P\leq49.7$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]

Table II–2.41–1 HCFC-22 (R22) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.9\times10^3 \leq P \leq 4.97\times10^6$ [Pa] $0.019 \leq P \leq 49.7$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.9\times10^3 \leq P \leq 4.97\times10^6$ [Pa] $0.019 \leq P \leq 49.7$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$173.15 \leq T \leq 369.15$ [K] $-100 \leq T \leq 96$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$173.15 \leq T \leq 369.15$ [K] $-100 \leq T \leq 96$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$173.15 \leq T \leq 369.15$ [K] $-100 \leq T \leq 96$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$173.15 \leq T \leq 369.15$ [K] $-100 \leq T \leq 96$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

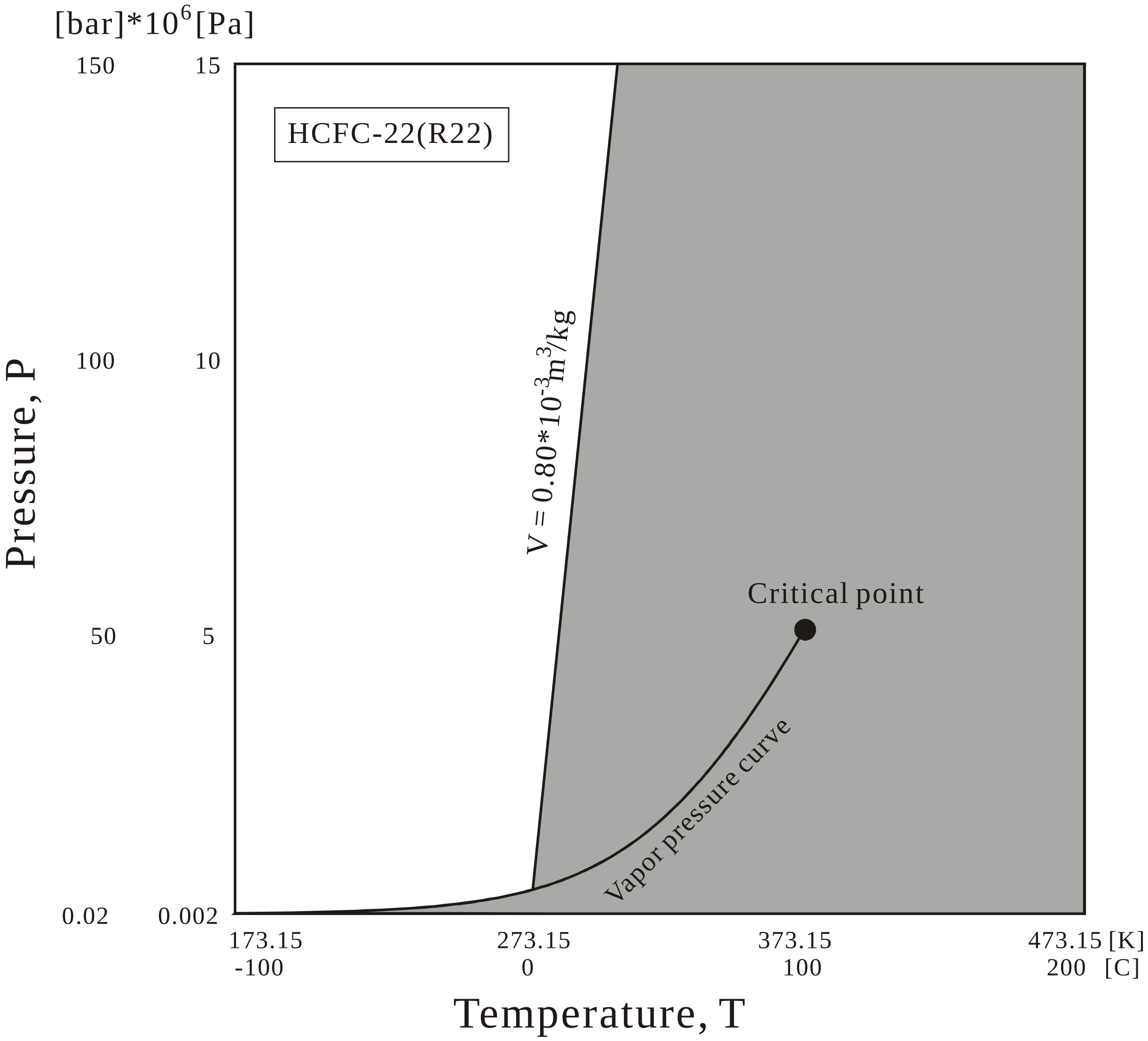


Fig.II–2.41–1 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T),VPT(P,T) and WPT(P,T).

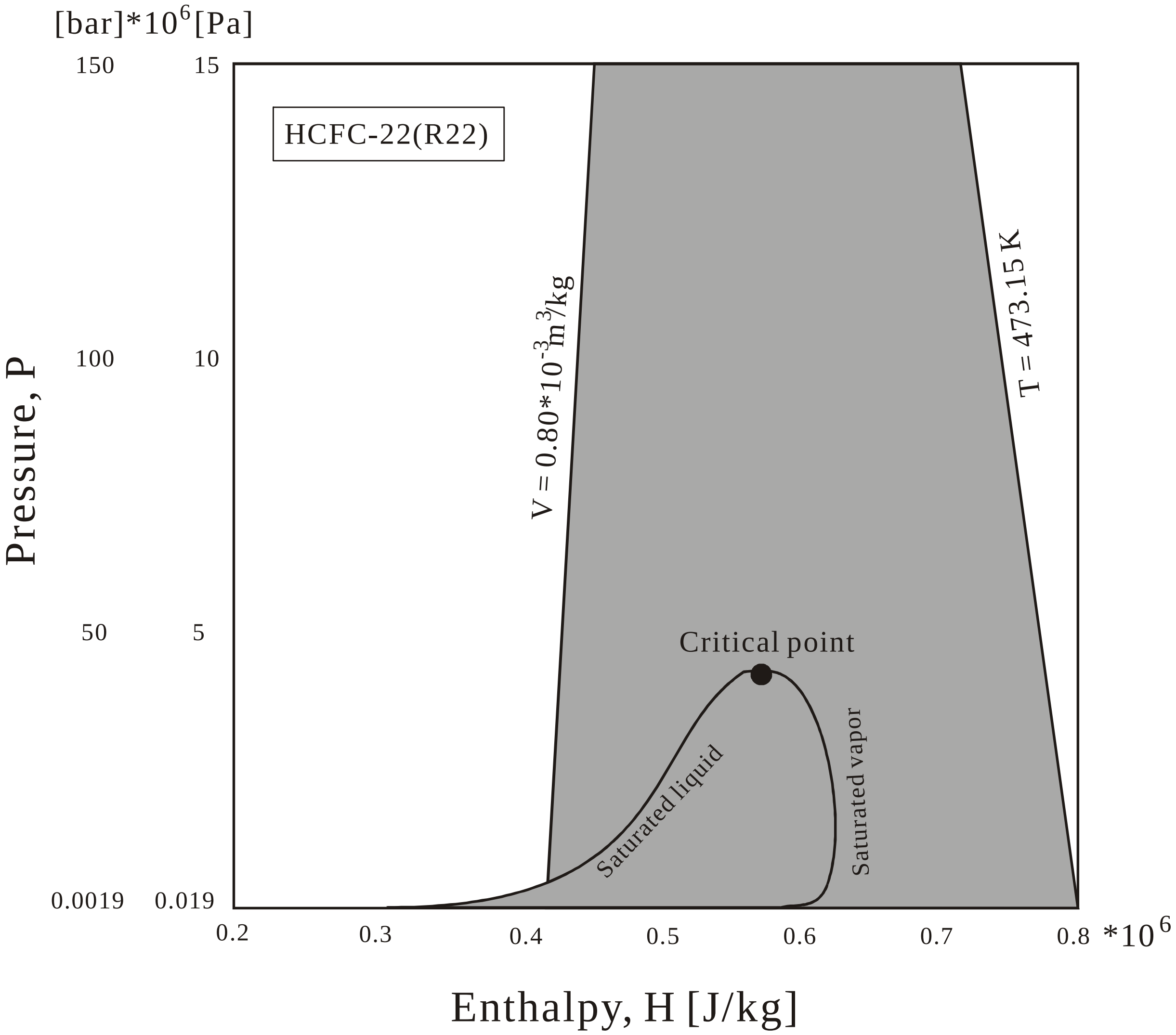


Fig.II–2.41–2 Range of Arguments(P,H) for TPH(P,H).

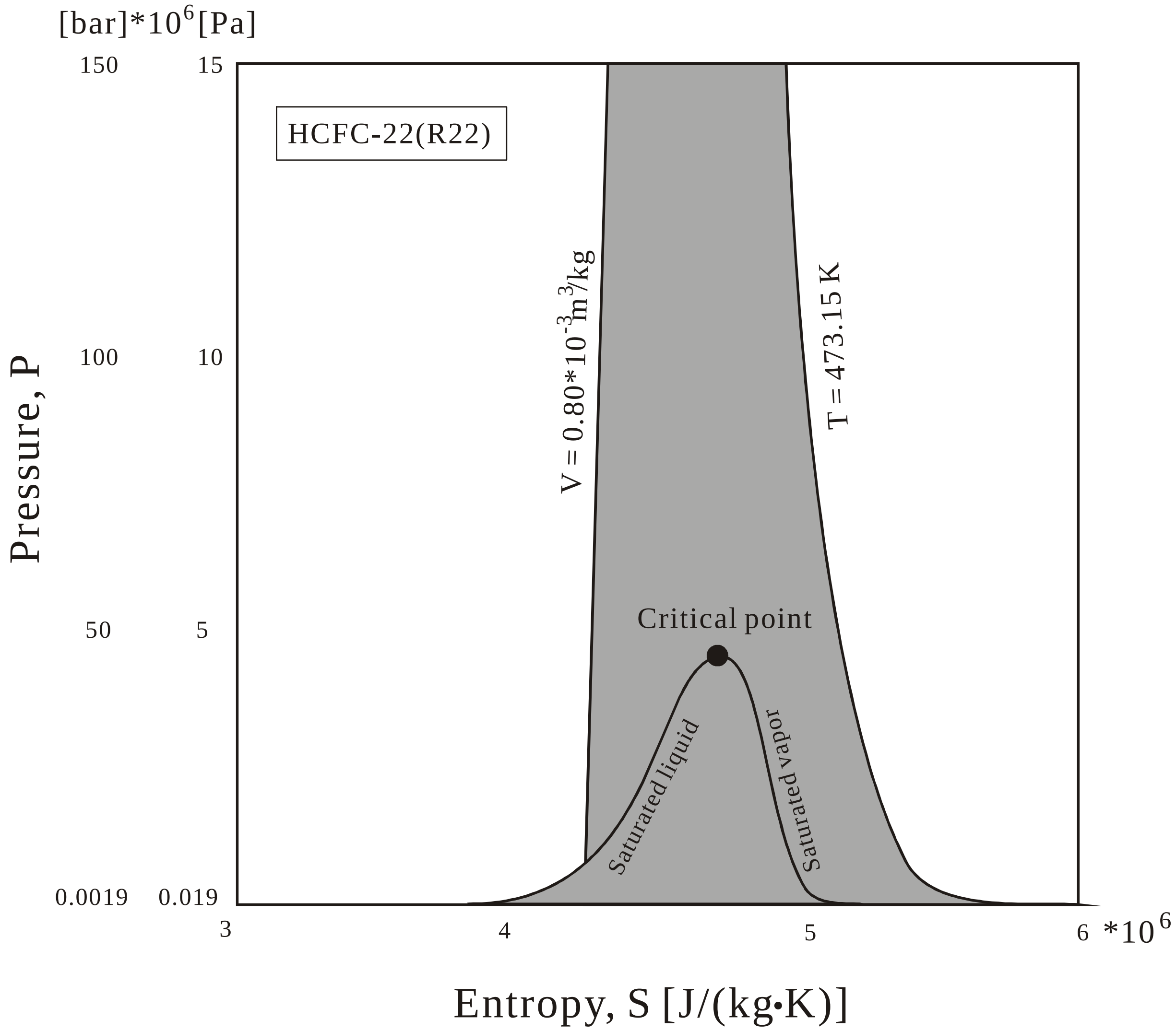


Fig.II–2.41–3 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.42 HCFC-123(R123)

All equations for HCFC-123(R123) are based on the Table from Japanese Association of Refrigeration and Japan Flon Gas Association[1].

2.42.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.42.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HCFC-123, R123, Refrigerant 123, 1,1-Dichloro-2,2,2-Trifluoroethane
Library File for UNIX:	libjr123.a
Library File for DOS,Windows95/NT:	JR123.LIB
Single Shot Program for UNIX:	r123-ss
Single Shot Program for DOS,Windows95/NT:	R123–SS.EXE

2.42.3 Important Constants and Others

Molecular Formula:	$CHC\ell_2CF_3$
Relative Molecular Mass:	152.931
Gas Constant:	54.36769 J/(kg·K)

Critical Constants:

Critical Pressure:	3.666×10^6Pa (36.66 bar)
Critical Temperature:	456.86 K (183.71 °C)
Critical Specific Volume:	1.8018×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.42.4 Formula

Equation of State:

Equation (IIIA·2·3·2) in a function from of $f = f(\rho, T)$ in reference [1]. Here f=Helmholtz function, ρ=density and T= temperature.

Vapor Pressure:

Equation (IIIA·2·1·1) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (IIIA·2·4·1) for specific volume of saturated liquid. Equation of state, Eq.(IIIA·2·3·1), together with the vapor pressure curve for specific volume of saturated vapor. Equations (IIIA·2·6·3), (IIIA·2·6·6) and (IIIA·2·6·8), and Eqs.(IIIA·2·5·3), (IIIA·2·5·6) and (IIIA·2·5·8), and Eqs.(IIIA·2·7·4) and (IIIA·2·7·10) together with these specific volumes for specific entropy, specific enthalpy, isobaric specific heat and isochoric specific heat, respectively. All these equations have been cited from reference [1].

Transport Properties:

Equations (IIIA·3·1·1)∼ (IIIA·3·1·3) in reference [1] for viscosity. Equations (IIIA·3·3·1)∼ (IIIA·3·1·4) in reference [1] for thermal conductivity.

The Other Properties:

Equation (IIIA·2·10·1) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration·Japan Flon Gas Association, Thermophysical Properties of Environmentally Acceptable Fluorocarbons (HFC-134a, HCFC-123), (1986).

Table II–2.42–1 HCFC-123 (R123) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 10\times 10^6$ [Pa] $273.15\leq T\leq 500$ [K] $0<P\leq 100$ [bar] $0\leq T\leq 226.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 10\times 10^6$ [Pa] $273.15\leq T\leq 500$ [K] $0<P\leq 100$ [bar] $0\leq T\leq 226.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$20\times 10^3\leq P\leq 3.666\times 10^6$ [Pa] $0.2\leq P\leq 36.66$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$260\leq T\leq 456.86$ [K] $-13.15\leq T\leq 183.71$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$20\times 10^3\leq P\leq 3.666\times 10^6$ [Pa] $0.2\leq P\leq 36.66$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$260\leq T\leq 456.86$ [K] $-13.15\leq T\leq 183.71$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$10.66\times 10^3<P<0.916\times 10^6$ [Pa] $0.1066<P<9.16$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$67.4\times 10^3<P<0.734\times 10^6$ [Pa] $0.674<P<7.34$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$P=0.101325\times 10^6$ [Pa] $305\leq T\leq 370$ [K] $0.1\times 10^6\leq P\leq 3.666\times 10^6$ [Pa] $250\leq T\leq TSP(P)$ [K] $3.666\times 10^6<P\leq 20\times 10^6$ [Pa] $250\leq T\leq 380$ [K] $P=1.01325$ [bar] $31.85\leq T\leq 96.85$ [°C] $1.0\leq P\leq 36.66$ [bar] $-23.15\leq T\leq TSP(P)$ [°C] $36.66<P\leq 200$ [bar] $-23.15\leq T\leq 106.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$250\leq T\leq 380$ [K] $-23.15\leq T\leq 106.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$290\leq T\leq 370$ [K] $16.85\leq T\leq 96.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$28.9\times 10^3\leq P\leq 0.476\times 10^6$ [Pa] $0.289\leq P\leq 4.76$ [bar]

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6\leq P\leq0.2256\times10^6$ [Pa] $325\leq T\leq420$ [K] $0.2256\times10^6<P\leq1.8\times10^6$ [Pa] TSP(P)≤T≤420 [K] $1.0\leq P\leq2.256$ [bar] $51.85\leq T\leq146.85$ [°C] $2.256<P\leq18$ [bar] TSP(P)≤T≤146.85 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$270\leq T\leq352$ [K] $-3.15\leq T\leq78.85$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$33.3\times10^3\leq P\leq3.5\times10^6$ [Pa] $0.333\leq P\leq35$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$33.3\times10^3\leq P\leq3.5\times10^6$ [Pa] $0.333\leq P\leq35$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15\leq T\leq454$ [K] $0\leq T\leq180.85$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15\leq T\leq454$ [K] $0\leq T\leq180.85$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4333×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 3.666×10^6 [Pa], 36.66 [bar] Pressure S: 'A'='S': 1.619×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 456.86 [K], 183.71 [°C] Temperature V: 'A'='V': 1.8018×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$33.3\times10^3\leq P\leq3.5\times10^6$ [Pa] $0.333\leq P\leq35$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$273.15\leq T\leq454$ [K] $0\leq T\leq180.85$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 152.931 Relative Molecular Mass R: 'A'='R': 54.36769 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$33.3\times10^3\leq P\leq3.5\times10^6$ [Pa] $0.333\leq P\leq35$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0<P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.15\leq T\leq454$ [K] $0\leq T\leq180.85$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$20\times10^3\leq P\leq3.666\times10^6$ [Pa] $0.2\leq P\leq36.66$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$20\times10^3\leq P\leq3.666\times10^6$ [Pa] $0.2\leq P\leq36.66$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$20\times10^3\leq P\leq10\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,500K) [J/(kg·K)] $0.2\leq P\leq100$ [bar] SPT(P,0°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$20\times10^3\leq P\leq10\times10^6$ [Pa] $273.15\leq T\leq500$ [K] $0.2\leq P\leq100$ [bar] $0\leq T\leq226.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$20\times10^3\leq P\leq3.666\times10^6$ [Pa] $0.2\leq P\leq36.66$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$260\leq T\leq456.86$ [K] $-13.15\leq T\leq183.71$ [°C]

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CHCL2-CF3' Molecular Formula S: 'A'='S': 'HCFC-123(R123)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$33.3{\times}10^3{\le}P{\le}0.476{\times}10^6$ [Pa] 0.333≤P≤4.76 [bar]
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$P{=}0.101325{\times}10^6$ [Pa] 325≤T≤370 [K] P=1.01325 [bar] 51.85≤T≤95.85 [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	273.15≤T≤352 [K] 0≤T≤78.85 [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$4.46{\times}10^3{\le}P{\le}3.666{\times}10^6$ [Pa] 0466≤P≤36.66 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	235≤T≤456.86 [K] −38.15≤T≤183.71 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$20{\times}10^3{\le}P{\le}3.666{\times}10^6$ [Pa] 0.2≤P≤36.66 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$20{\times}10^3{\le}P{\le}3.666{\times}10^6$ [Pa] 0.2≤P≤36.66 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$20{\times}10^3{\le}P{\le}10{\times}10^6$ [Pa] 273.15≤T≤500 [K] 0.2≤P≤100 [bar] 0≤T≤226.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$20{\times}10^3{\le}P{\le}3.666{\times}10^6$ [Pa] 0.2≤P≤36.66 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] HPT(P,273.15K)≤H≤ HPT(P,500K) [J/kg] 0.2≤P≤100 [bar] HPT(P,0°C)≤H≤ HPT(P,226.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.2≤P≤100 [bar] SPT(P,0°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$3.666\times10^6 \leq P < 7.12\times10^6$ [Pa] 36.66≤P<71.2 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] VPT(P,273.15K)≤V≤ VPT(P,500K) [m^3/kg] 0.2≤P≤100 [bar] VPT(P,0°C)≤V≤ VPT(P,226.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] 0.2≤P≤36.66 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] 0.2≤P≤36.66 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] 0.2≤P≤36.66 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.2≤P≤100 [bar] SPT(P,0°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] 273.15≤T≤500 [K] 0.2≤P≤100 [bar] 0≤T≤226.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] 0.2≤P≤36.66 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C]

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$260 \leq T \leq 456.86$ [K] $-13.15 \leq T \leq 183.71$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$260 \leq T \leq 456.86$ [K] $-13.15 \leq T \leq 183.71$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] SPT(P,273.15K)≤S≤ SPT(P,500K) [J/(kg·K)] $0.2 \leq P \leq 100$ [bar] SPT(P,0°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$20\times10^3 \leq P \leq 10\times10^6$ [Pa] $273.15 \leq T \leq 500$ [K] $0.2 \leq P \leq 100$ [bar] $0 \leq T \leq 226.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$260 \leq T \leq 456.86$ [K] $-13.15 \leq T \leq 183.71$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$260 \leq T \leq 456.86$ [K] $-13.15 \leq T \leq 183.71$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$260 \leq T \leq 456.86$ [K] $-13.15 \leq T \leq 183.71$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \leq 10\times10^6$ [Pa] $273.15 \leq T \leq 500$ [K] $0 < P \leq 100$ [bar] $0 \leq T \leq 226.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$20\times10^3 \leq P \leq 3.666\times10^6$ [Pa] $0.2 \leq P \leq 36.66$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.42–1 HCFC-123 (R123) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	260≤T≤456.86 [K] −13.15≤T≤183.71 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.43 HCFC-142b(R142b)

All equations for HCFC-142b(R142b) are based on the Table from Thermodynamic properties of refrigerants by ASHRAE[1],[2].

2.43.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.43.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HCFC-142b, R142b, Refrigerant 142b, Freon 142b, Chlorodifluoroethane
Library File for UNIX:	libjr142b.a
Library File for DOS,Windows95/NT:	JR142B.LIB
Single Shot Program for UNIX:	r142b-ss
Single Shot Program for DOS,Windows95/NT:	R142B-SS.EXE

2.43.3 Important Constants and Others

Molecular Formula:	$C_2H_3C\ell F_2$
Relative Molecular Mass:	100.496
Gas Constant:	82.7347 J/(kg·K)

Critical Constants:

Critical Pressure:	4.123×10^6Pa (41.23 bar)
Critical Temperature:	410.25 K (137.10 °C)
Critical Specific Volume:	2.2988×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.43.4 Formula

Equation of State:

The Martin-Hou equation in reference [1] is used.

Vapor Pressure:

Equation (2.2.2) in reference [1].

Properties at Vapor-Liquid Equilibrium:

The saturated liquid density equation is obtained from Equation (2.2.4.d) in reference [1]. The saturated vapor density is obtained by the compatibility of the equation of state and vapor pressure equation. Isobaric specific heat c_P is obtained from individual in reference [2].

Transport Properties:

Thermal conductivity and viscosity from reference [2].

The Other Properties:

Surface tension from reference [2].

References

[1] Thermodynamic Properties of Refrigerants(1986), 32 ASHRAE
[2] Thermophysical Properties of Refrigerants (Inch-Pound Edition), (1993), 105 ASHRAE

Table II–2.43–1 R142b Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$4.697\times10^3\leq P\leq0.2453\times10^6$ [Pa] $0.04697\leq P\leq2.453$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$203.15\leq T\leq288$ [K] $-70\leq T\leq14.85$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3\leq P\leq3.3691\times10^6$ [Pa] $0.04697\leq P\leq33.691$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$203.15\leq T\leq398.15$ [K] $-70\leq T\leq125$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$15.65\times10^3\leq P\leq1.7409\times10^6$ [Pa] $0.1565\leq P\leq17.409$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$39.37\times10^3\leq P\leq1.7409\times10^6$ [Pa] $0.3937\leq P\leq17.409$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $273\leq T\leq473$ [K] $-0.15\leq T\leq199.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$223.15\leq T\leq363.15$ [K] $-50\leq T\leq90$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$303.15\leq T\leq363.15$ [K] $30\leq T\leq90$ [°C]
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$15.65\times10^3\leq P\leq1.7409\times10^6$ [Pa] $0.1565\leq P\leq17.409$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$15.65\times10^3\leq P\leq1.7409\times10^6$ [Pa] $0.1565\leq P\leq17.409$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat at Ordinary Pressure [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $263.15\leq T\leq473.15$ [K] $-10\leq T\leq200$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$223.15\leq T\leq363.15$ [K] $-50\leq T\leq90$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$223.15\leq T\leq363.15$ [K] $-50\leq T\leq90$ [°C]

Table II–2.43–1 R142b Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.4309×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.123×10^6 [Pa], 41.23 [bar] Pressure S: 'A'='S': 1.6464×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 410.25 [K], 137.10 [°C] Temperature V: 'A'='V': 2.2988×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 100.496 Relative Molecular Mass R: 'A'='R': 82.7347 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3\leq P\leq3.3691\times10^6$ [Pa] $0.04697\leq P\leq33.691$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3\leq P\leq3.3691\times10^6$ [Pa] $0.04697\leq P\leq33.691$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\times10^3\leq P\leq3.50\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤35 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.43-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10\times10^3\leq P\leq3.50\times10^6$ [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤35 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.43-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$4.697\times10^3\leq P\leq3.3691\times10^6$ [Pa] $0.04697\leq P\leq33.691$ [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	203.15≤T≤398.15 [K] −70≤T≤125 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'C2H3ClF2' Molecular Formula S: 'A'='S': 'R142B' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.43–1 R142b Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	4.697×10^3≤P≤0.2453×10^6 [Pa] 0.04697≤P≤2.543 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	203.15≤T≤288 [K] −70≤T≤14.85 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	4.697×10^3≤P≤3.3691×10^6 [Pa] 0.04697≤P≤33.691 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	4.697×10^3≤P≤3.3691×10^6 [Pa] 0.04697≤P≤33.691 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	10×10^3≤P≤3.50×10^6 [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤35 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.43-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	4.697×10^3≤P≤3.3691×10^6 [Pa] 0.04697≤P≤33.691 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	203.15≤T≤398.15 [K] −70≤T≤125 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	10×10^3≤P≤3.50×10^6 [Pa] HPDD(P)≤H≤ HPT(P,453.15K) [J/kg] 0.1≤P≤35 [bar] HPDD(P)≤H≤ HPT(P,180°C) [J/kg] see Fig.II-2.43-2 for H

Table II–2.43–1 R142b Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤35 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.43-3 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] VPDD(P)≤V≤ VPT(P,453.15K) [m^3/kg] 0.1≤P≤35 [bar] VPDD(P)≤V≤ VPT(P,180°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] 0.04697≤P≤33.691 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] 0.04697≤P≤33.691 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] 0.04697≤P≤33.691 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤35 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.43-3 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤35 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.43-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] 0.04697≤P≤33.691 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	203.15≤T≤398.15 [K] −70≤T≤125 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] 0.04697≤P≤33.691 [bar]

Table II–2.43–1 R142b Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] $0.04697 \le P \le 33.691$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy[J/(kg·K)]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] SPDD(P)≤S≤ SPT(P,453.15K) [J/(kg·K)] 0.1≤P≤35 [bar] SPDD(P)≤S≤ SPT(P,180°C) [J/(kg·K)] see Fig.II-2.43-3 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$10\times10^3 \le P \le 3.50\times10^6$ [Pa] TSP(P)≤T≤453.15 [K] 0.1≤P≤35 [bar] TSP(P)≤T≤180 [°C] see Fig.II-2.43-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$4.697\times10^3 \le P \le 3.3691\times10^6$ [Pa] $0.04697 \le P \le 33.691$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	203.15≤T≤398.15 [K] −70≤T≤125 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	203.15≤T≤398.15 [K] −70≤T≤125 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$4.697\times10^3 \le P < 3.3691\times10^6$ [Pa] $0.04697 \le P < 33.691$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$4.697\times10^3 \le P < 3.3691\times10^6$ [Pa] $0.04697 \le P < 33.691$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$4.697\times10^3 \le P < 3.3691\times10^6$ [Pa] $0.04697 \le P < 33.691$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$4.697\times10^3 \le P < 3.3691\times10^6$ [Pa] $0.04697 \le P < 33.691$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	203.15≤T<398.15 [K] −70≤T<125 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	203.15≤T<398.15 [K] −70≤T<125 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	203.15≤T<398.15 [K] −70≤T<125 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	203.15≤T<398.15 [K] −70≤T<125 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

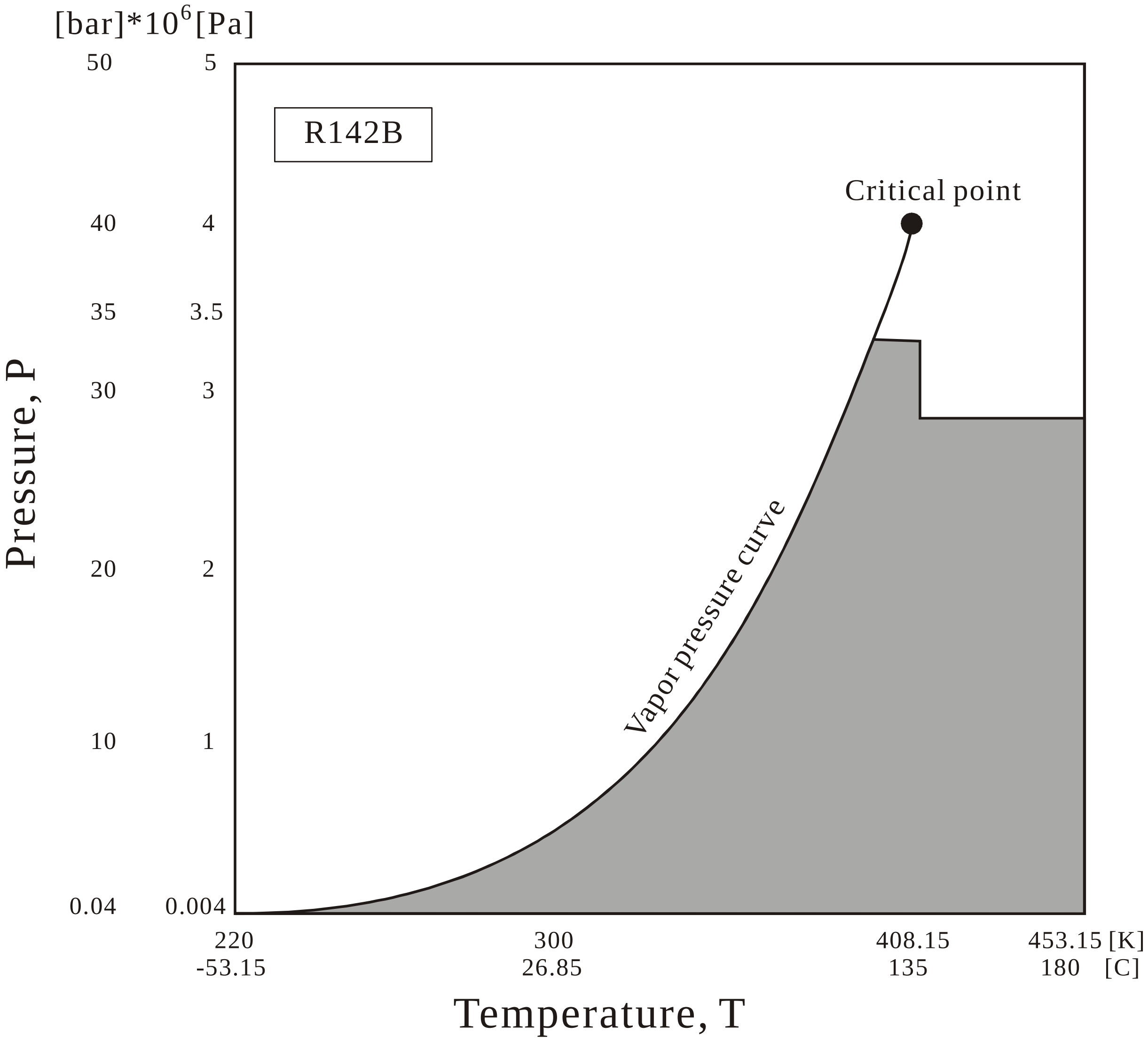


Fig.II–2.43–1 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T) and VPT(P,T).

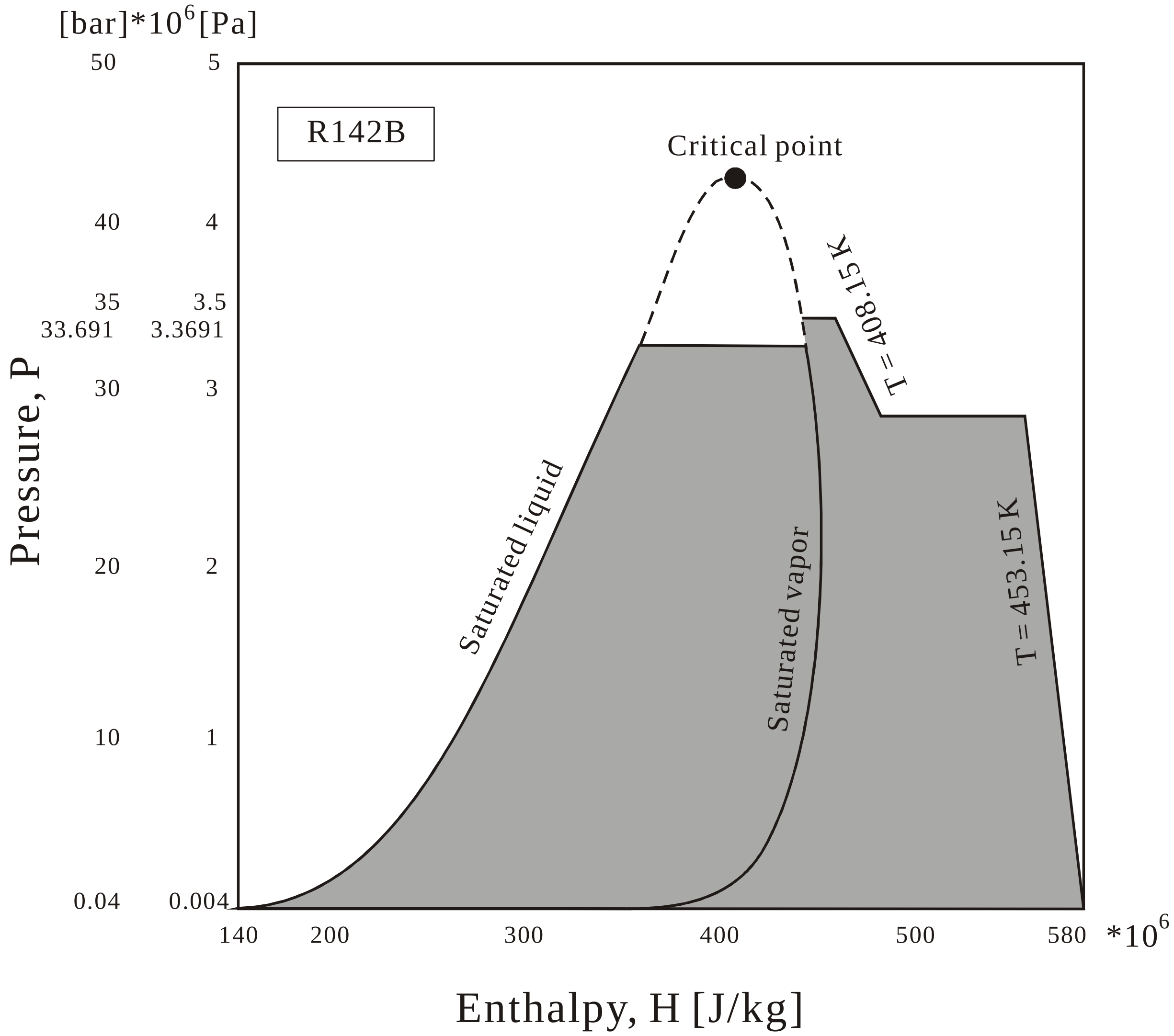


Fig.II–2.43–2 Range of Arguments(P,H) for TPH(P,H).

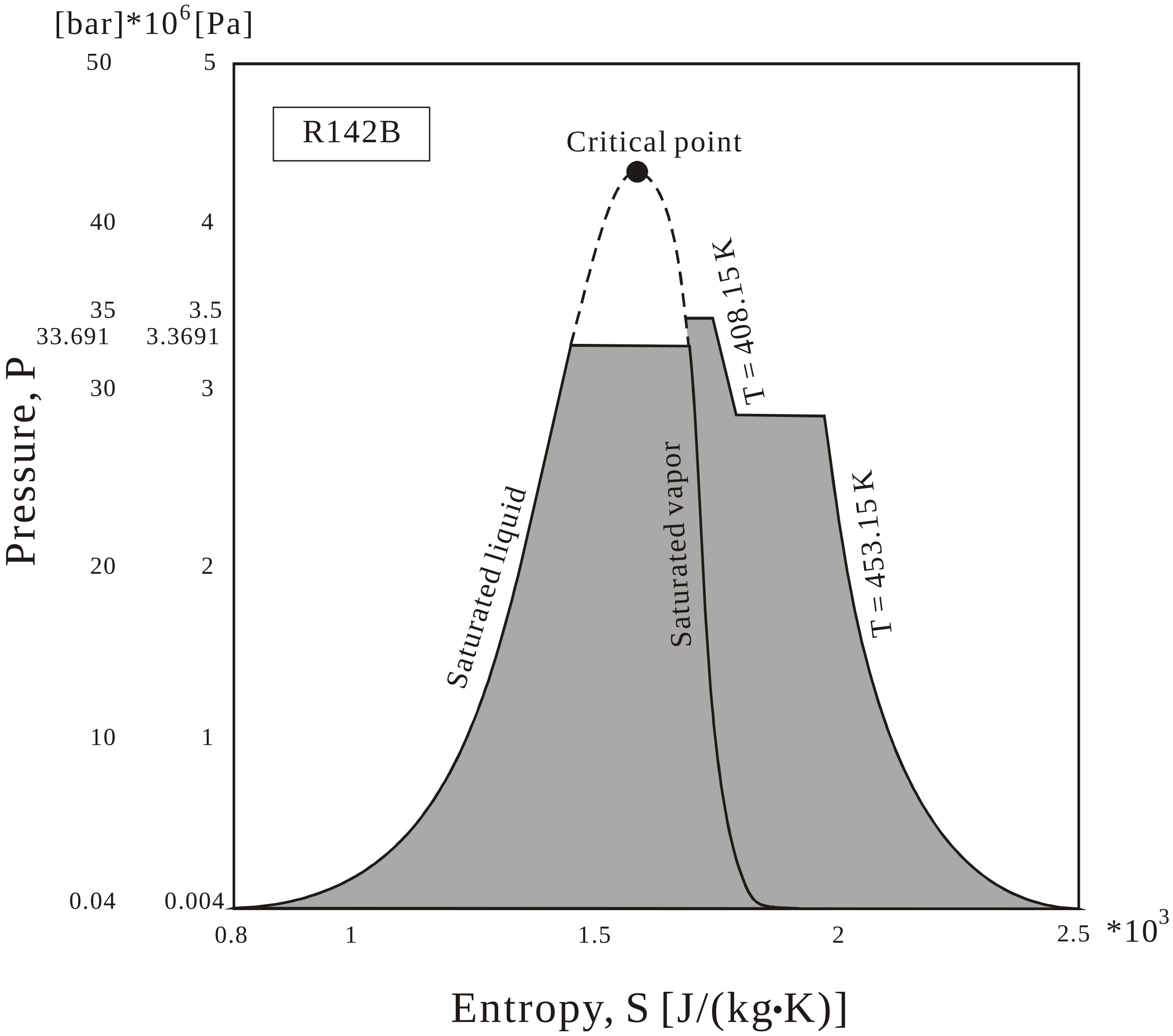


Fig.II–2.43–3 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.44 HFC-23(R23)

All equations for HFC-23(R23) are based on the Table from Thermophysical properties of refrigerants by Platzer *et al.*[1].

2.44.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.44.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HFC-23, R23, Refrigerant 23, Freon 23, Fluoroform, Trifluoromethane
Library File for UNIX:	libjr23.a
Library File for DOS,Windows95/NT:	JR23.LIB
Single Shot Program for UNIX:	r23-ss
Single Shot Program for DOS,Windows95/NT:	R23-SS.EXE

2.44.3 Important Constants and Others

Molecular Formula:	CHF_3
Relative Molecular Mass:	70.019
Gas Constant:	118.75 J/(kg·K)

Critical Constants:

Critical Pressure:	4.8162×10^6Pa (48.162 bar)
Critical Temperature:	299.01 K (25.86 °C)
Critical Specific Volume:	1.9231×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.44.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of Maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\text{K}) < p < p_{sat}(T_c + 1\text{K})$ and $v'(T_c - 1\text{K}) < v < v''(T_c - 1\text{K})$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat, respectively. However, the sign of the last integration term in Equation (2) for u

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT + \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}$$

has been corrected to

$$u(T,\rho) = h_0 - RT_0 + \int_{T_0}^{T} (c_p^0 - R)dT - \int_0^{\rho} \left[T \left(\frac{\partial p}{\partial T} \right)_{\rho} - p \right] \frac{d\rho}{\rho^2}.$$

Transport Properties:
Thermal conductivity and viscosity from reference [2].

The Other Properties:
Equation (3) in reference [3] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), Springer-Verlag
[2] Thermophysical Properties of Refrigerants(1976), 37 ASHRAE
[3] K.Watanabe and M.Okada, Int. J. Thermophysics, 2-2(1981), p.163

Table II–2.44–1 HFC-23(R-23) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 58\times10^6$ [Pa] $200 \le T \le 470$ [K] $1.0 \le P \le 580$ [bar] $-73.15 \le T \le 196.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$22.845\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.22845 \le P \le 48.162$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$210 \le T \le 299.01$ [K] $-63.15 \le T \le 25.86$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$145 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \le P \le 2.3033\times10^6$ [Pa] $0.0257 \le P \le 23.033$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$70.25\times10^3 \le P \le 0.7622\times10^6$ [Pa] $0.7025 \le P \le 7.622$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $189 \le T \le 478$ [K] $-84.15 \le T \le 204.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$122 \le T \le 270$ [K] $-151.15 \le T \le -3.15$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$185 \le T \le 235$ [K] $-88.15 \le T \le -38.15$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$16.56\times10^3 \le P \le 1.7313\times10^6$ [Pa] $0.1656 \le P \le 17.313$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.56626\times10^6 \le P \le 4.8162\times10^6$ [Pa] $5.6626 \le P \le 48.162$ [bar]
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$200 \le T \le 260$ [K] $-73.15 \le T \le -13.15$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$200 \le T \le 290$ [K] $-73.15 \le T \le 16.85$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar]

Table II–2.44–1 HFC-23(R-23) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq4.8162\times10^6$ [Pa] $0.0257\leq P\leq48.162$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq P\leq58\times10^6$ [Pa] $200\leq T\leq470$ [K] $1.0\leq P\leq580$ [bar] $-73.15\leq T\leq196.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$145\leq T\leq299.01$ [K] $-128.15\leq T\leq25.86$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$145\leq T\leq299.01$ [K] $-128.15\leq T\leq25.86$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.2806×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.8162×10^6 [Pa], 48.162 [bar] Pressure S: 'A'='S': 1.272×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 299.01 [K], 25.86 [°C] Temperature V: 'A'='V': 1.923×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq4.8162\times10^6$ [Pa] $0.0257\leq P\leq48.162$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq P\leq58\times10^6$ [Pa] $200\leq T\leq470$ [K] $1.0\leq P\leq580$ [bar] $-73.15\leq T\leq196.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$145\leq T\leq299.01$ [K] $-128.15\leq T\leq25.86$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 70.019 Relative Molecular Mass R: 'A'='R': 118.75 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq4.8162\times10^6$ [Pa] $0.0257\leq P\leq48.162$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq4.8162\times10^6$ [Pa] $0.0257\leq P\leq48.162$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3\leq P\leq58\times10^6$ [Pa] SPT(P,200K)≤S≤ SPT(P,470K) [J/(kg·K)] $1.0\leq P\leq580$ [bar] SPT(P,−73.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]

Table II–2.44–1 HFC-23(R-23) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq P\leq 58\times10^6$ [Pa] $200\leq T\leq 470$ [K] $1.0\leq P\leq 580$ [bar] $-73.15\leq T\leq 196.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.57\times10^3\leq P\leq 4.8162\times10^6$ [Pa] $0.0257\leq P\leq 48.162$ [bar] $0\leq X\leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$145\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$145\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$145\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C] $0\leq X\leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Identification of Substance (Length 20) C: 'A'='C': 'CHF3' Molecular Formula S: 'A'='S': 'HFC-23(R-23)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$16.56\times10^3\leq P\leq 1.7313\times10^6$ [Pa] $1.656\leq P\leq 17.313$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$70.25\times10^3\leq P\leq 0.7622\times10^6$ [Pa] $0.7025\leq P\leq 7.622$ [bar]
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$200\leq T\leq 260$ [K] $-73.15\leq T\leq -13.15$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$185\leq T\leq 235$ [K] $-88.15\leq T\leq -38.15$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$200\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(200K)$\leq P\leq 4.8162\times10^6$ [Pa] ($\sim166\times10^3$) PST(-73.15 °C)$\leq P\leq 48.162$ [bar] ($\sim$1.66)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$200\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq 4.8162\times10^6$ [Pa] $0.0257\leq P\leq 48.162$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.57\times10^3\leq P\leq 4.8162\times10^6$ [Pa] $0.0257\leq P\leq 48.162$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3\leq P\leq 58\times10^6$ [Pa] $200\leq T\leq 470$ [K] $1.0\leq P\leq 580$ [bar] $-73.15\leq T\leq 196.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.57\times10^3\leq P\leq 4.8162\times10^6$ [Pa] $0.0257\leq P\leq 48.162$ [bar] $0\leq X\leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$145\leq T\leq 299.01$ [K] $-128.15\leq T\leq 25.86$ [°C]

Table II–2.44–1 HFC-23(R-23) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$145 \leq T \leq 299.01$ [K] $-128.15 \leq T \leq 25.86$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$145 \leq T \leq 299.01$ [K] $-128.15 \leq T \leq 25.86$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$100\times10^3 \leq P \leq 58\times10^6$ [Pa] HPT(P,200K)≤H≤ HPT(P,470K) [J/kg] $1.0 \leq P \leq 580$ [bar] HPT(P,−73.15°C)≤H≤ HPT(P,196.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \leq P \leq 58\times10^6$ [Pa] SPT(P,200K)≤S≤ SPT(P,470K) [J/(kg·K)] $1.0 \leq P \leq 580$ [bar] SPT(P,−73.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$100\times10^3 \leq P \leq 58\times10^6$ [Pa] VPT(P,200K)≤V≤ VPT(P,470K) [m^3/kg] $1.0 \leq P \leq 580$ [bar] VPT(P,−73.15°C)≤V≤ VPT(P,196.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \leq P \leq 4.8162\times10^6$ [Pa] $0.0257 \leq P \leq 48.162$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \leq P \leq 4.8162\times10^6$ [Pa] $0.0257 \leq P \leq 48.162$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \leq P \leq 4.8162\times10^6$ [Pa] $0.0257 \leq P \leq 48.162$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \leq P \leq 58\times10^6$ [Pa] SPT(P,200K)≤S≤ SPT(P,470K) [J/(kg·K)] $1.0 \leq P \leq 580$ [bar] SPT(P,−73.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]

Table II–2.44–1 HFC-23(R-23) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 58\times10^6$ [Pa] $200 \le T \le 470$ [K] $1.0 \le P \le 580$ [bar $-73.15 \le T \le 196.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$200 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$200 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$145 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$100\times10^3 \le P \le 58\times10^6$ [Pa] SPT(P,200K)≤S≤ SPT(P,470K) [J/(kg·K)] $1.0 \le P \le 580$ [bar] SPT(P,−73.15°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 58\times10^6$ [Pa] $200 \le T \le 470$ [K] $1.0 \le P \le 580$ [bar] $-73.15 \le T \le 196.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.57\times10^3 \le P \le 4.8162\times10^6$ [Pa] $0.0257 \le P \le 48.162$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$145 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$145 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$145 \le T \le 299.01$ [K] $-128.15 \le T \le 25.86$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$100\times10^3 \le P \le 58\times10^6$ [Pa] $200 \le T \le 470$ [K] $1.0 \le P \le 580$ [bar] $-73.15 \le T \le 196.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$2.57\times10^3 \le P < 4.8162\times10^6$ [Pa] $0.0257 \le P < 48.162$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$2.57\times10^3 \le P < 4.8162\times10^6$ [Pa] $0.0257 \le P < 48.162$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]

Table II–2.44–1 HFC-23(R-23) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$2.57\times10^3 \leq P < 4.8162\times10^6$ [Pa] $0.0257 \leq P < 48.162$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$2.57\times10^3 \leq P < 4.8162\times10^6$ [Pa] $0.0257 \leq P < 48.162$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$145 \leq T < 299.01$ [K] $-128.15 \leq T < 25.86$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$145 \leq T < 299.01$ [K] $-128.15 \leq T < 25.86$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$145 \leq T < 299.01$ [K] $-128.15 \leq T < 25.86$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$145 \leq T < 299.01$ [K] $-128.15 \leq T < 25.86$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.45 HFC-134a(R134a)

All equations for HFC-134a(R134a) are based on the Table from Japanese Association of Refrigeration and Japan Flon Gas Association[1].

2.45.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.45.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	HFC-134a, R134a, Refrigerant 134a, 1,2,2,2-Tetrafluoroethane
Library File for UNIX:	libjr134a.a
Library File for DOS,Windows95/NT:	JR134A.LIB
Single Shot Program for UNIX:	r134a-ss
Single Shot Program for DOS,Windows95/NT:	R134A–SS.EXE

2.45.3 Important Constants and Others

Molecular Formula:	CH_2FCF_3
Relative Molecular Mass:	102.032
Gas Constant:	81.4892 J/(kg·K)

Critical Constants:

Critical Pressure:	4.064×10^6Pa (40.64 bar)
Critical Temperature:	374.30 K (101.15 °C)
Critical Specific Volume:	1.9685×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.45.4 Formula

Equation of State:

Equation (IIIA·2·3·3) in a function from of $f = f(\rho, T)$ in reference [1]. Here f=Helmholtz function, ρ=density and T= temperature.

Vapor Pressure:

Equation (IIIA·2·1·1) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation of state, Eq.(IIIA·2·3·1), together with the vapor pressure curve for specific volume of both saturated liquid and saturated vapor. Equations (IIIA·2·6·2), (IIIA·2·5·2), and (IIIA·2·7·2) and (IIIA·2·7·4) (IIIA·2·5·6) and (IIIA·2·5·8), and together with these specific volumes for specific entropy, specific enthalpy, isobaric specific heat and isochoric specific heat, respectively. All these equations have been cited from reference [1].

Transport Properties:

Equations (IIIA·3·1·3)∼ (IIIA·3·1·5) in reference [1] for viscosity. Equations (IIIA·3·3·1)∼ (IIIA·3·1·3) in reference [1] for thermal conductivity.

The Other Properties:

Equation (IIIA·2·10·1) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration·Japan Flon Gas Association, Thermophysical Properties of Environmentally Acceptable Fluorocarbons (HFC-134a, HCFC-123), (1986).

Table II–2.45–1 HFC-134a (R134a) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq15\times10^6$ [Pa] $240\leq T\leq480$ [K] $0<P\leq150$ [bar] $-33.15\leq T\leq206.85$ [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq15\times10^6$ [Pa] $240\leq T\leq480$ [K] $0<P\leq150$ [bar] $-33.15\leq T\leq206.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$0.07\times10^6\leq P\leq4.064\times10^6$ [Pa] $0.7\leq P\leq40.64$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$240\leq T\leq374.3$ [K] $-33.15\leq T\leq101.15$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6\leq P\leq4.064\times10^6$ [Pa] $0.7\leq P\leq40.64$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$240\leq T\leq374.3$ [K] $-33.15\leq T\leq101.15$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$0.07\times10^6\leq P<3.04\times10^6$ [Pa] $0.7\leq P<30.4$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$0.07\times10^6\leq P<3.04\times10^6$ [Pa] $0.7\leq P<30.4$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.07\times10^6\leq P\leq20\times10^6$ [Pa] $240\leq T\leq360$ [K] $0.7\leq P\leq200$ [bar] $-33.15\leq T\leq86.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$240\leq T\leq360$ [K] $-33.15\leq T\leq86.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$240\leq T\leq360$ [K] $-33.15\leq T\leq86.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$0.117\times10^6\leq P\leq2.061\times10^6$ [Pa] $1.17\leq P\leq20.61$ [bar]
12	AMUPDD(P)		
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$298.15\leq T\leq370.208$ [K] $0.07\times10^6\leq P\leq PST(T)$ [Pa] $370.208<T\leq423.15$ [K] $0.07\times10^6\leq P\leq(0.446\times(T-273.15)[K]-5.8577)\times10^5$ [Pa] $25\leq T\leq97.058$ [°C] $0.7\leq P\leq PST(T)$ [bar] $97.058<T\leq150$ [°C] $0.7\leq P\leq0.446\times T[°C]-5.8577$ [bar]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$250\leq T\leq342$ [K] $-23.15\leq T\leq68.85$ [°C]
15	AMUTDD(T)		

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.07\times 10^6\leq P<4.0404\times 10^6$ [Pa] $0.7\leq P<40.404$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.07\times 10^6\leq P<4.0404\times 10^6$ [Pa] $0.7\leq P<40.404$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$240\leq T<374$ [K] $-33.15\leq T<100.85$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$240\leq T<374$ [K] $-33.15\leq T<100.85$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.39101×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.064×10^6 [Pa], 40.64 [bar] Pressure S: 'A'='S': 1.5659×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 374.30 [K], 101.15 [°C] Temperature V: 'A'='V': 1.9685×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.07\times 10^6\leq P\leq 4.064\times 10^6$ [Pa] $0.7\leq P\leq 40.64$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0<P\leq 15\times 10^6$ [Pa] $240\leq T\leq 480$ [K] $0<P\leq 150$ [bar] $-33.15\leq T\leq 206.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$240\leq T\leq 374.3$ [K] $-33.15\leq T\leq 101.15$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 102.032 Relative Molecular Mass R: 'A'='R': 81.4892 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heats of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P < 4.064\times10^6$ [Pa] $0.7 \le P < 40.64$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heats [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \le 15\times10^6$ [Pa] $240 \le T \le 480$ [K] $0 < P \le 150$ [bar] $-33.15 \le T \le 206.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heats of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$240 \le T < 374$ [K] $-33.15 \le T < 100.85$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] SPD(P)≤S≤SPT(P,480K) [J/(kg·K)] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] SPT(P,240K)≤S≤ SPT(P,480K) [J/(kg·K)] $0.7 \le P \le 0.72979$ [bar] SPD(P)≤S≤ SPT(P,206.85°C) [J/(kg·K)] $0.72979 < P \le 150$ [bar] SPT(P,−33.15°C)≤S≤ SPT(P,206.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.07\times10^6 \le P \le 15\times10^6$ [Pa] $240 \le T \le 480$ [K] $0.7 \le P \le 150$ [bar] $-33.15 \le T \le 206.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] $0 \le X \le 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C] $0 \le X \le 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CH2F-CF3' Molecular Formula S: 'A'='S': 'HFC-134A(R134A)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$0.117\times10^6 \le P \le 2.061\times10^6$ [Pa] $1.17 \le P \le 20.61$ [bar]
86	PRPDD(P)		
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$298.15 \le T \le 360$ [K] $0.07\times10^6 \le P \le$ PST(T) [Pa] $25 \le T \le 86.85$ [°C] $0.7 \le P \le$ PST(T) [bar]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$250 \le T \le 342$ [K] $-23.15 \le T \le 68.85$ [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	$0.04376\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.4376 \le P \le 40.64$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$230 \le T \le 374.3$ [K] $-43.15 \le T \le 101.15$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.07\times10^6 \le P \le 15\times10^6$ [Pa] $240 \le T \le 480$ [K] $0.7 \le P \le 150$ [bar] $-33.15 \le T \le 206.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] $0 \le X \le 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C] $0 \le X \le 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] HPD(P)≤H≤HPT(P,480K) [J/kg] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] HPT(P,240K)≤H≤ HPT(P,480K) [J/kg] $0.7 \le P \le 0.72979$ [bar] HPD(P)≤H≤HPT(P,206.85°C) [J/kg] $0.72979 < P \le 150$ [bar] HPT(P,−33.15°C)≤H≤ HPT(P,206.85°C) [J/kg]
6H	TPH2(P,H)		

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] SPD(P)≤S≤SPT(P,480K) [J/(kg·K)] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] SPT(P,240K)≤S≤ SPT(P,480K) [J/(kg·K)] 0.7≤P≤0.72979 [bar] SPD(P)≤S≤ SPT(P,206.85°C) [J/(kg·K)] 0.72979<P≤150 [bar] SPT(P,−33.15°C)≤S≤ SPT(P,206.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] P∗: Pressure [Pa], [bar]	$4.064\times10^6 \le P \le 15\times10^6$ [Pa] 40.64≤P≤150 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] VPD(P)≤V≤VPT(P,480K) [m^3/kg] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] VPT(P,240K)≤V≤ VPT(P,480K) [m^3/kg] 0.7≤P≤0.72979 [bar] VPD(P)≤V≤ VPT(P,206.85°C) [m^3/kg] 0.72979<P≤150 [bar] VPT(P,−33.15°C)≤V≤ VPT(P,206.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] 0.7≤P≤40.64 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] 0.7≤P≤40.64 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] 0.7≤P≤40.64 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] SPD(P)≤S≤SPT(P,480K) [J/(kg·K)] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] SPT(P,240K)≤S≤ SPT(P,480K) [J/(kg·K)] 0.7≤P≤0.72979 [bar] SPD(P)≤S≤ SPT(P,206.85°C) [J/(kg·K)] 0.72979<P≤150 [bar] SPT(P,−33.15°C)≤S≤ SPT(P,206.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.07\times10^6 \le P \le 15\times10^6$ [Pa] 240≤T≤480 [K] 0.7≤P≤150 [bar] −33.15≤T≤206.85 [°C]

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] $0 \le X \le 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C] $0 \le X \le 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.07\times10^6 \le P \le 0.072979\times10^6$ [Pa] SPD(P)≤S≤SPT(P,480K) [J/(kg·K)] $0.072979\times10^6 < P \le 15\times10^6$ [Pa] SPT(P,240K)≤S≤ SPT(P,480K) [J/(kg·K)] $0.7 \le P \le 0.72979$ [bar] SPD(P)≤S≤ SPT(P,206.85°C) [J/(kg·K)] $0.72979 < P \le 150$ [bar] SPT(P,−33.15°C)≤S≤ SPT(P,206.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.07\times10^6 \le P \le 15\times10^6$ [Pa] $240 \le T \le 480$ [K] $0.7 \le P \le 150$ [bar] $-33.15 \le T \le 206.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$240 \le T \le 374.3$ [K] $-33.15 \le T \le 101.15$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0 < P \le 15\times10^6$ [Pa] $240 \le T \le 480$ [K] $0 < P \le 150$ [bar] $-33.15 \le T \le 206.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.07\times10^6 \le P \le 4.064\times10^6$ [Pa] $0.7 \le P \le 40.64$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]

Table II–2.45–1 HFC-134a (R134a) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.07\times10^6 \leq P \leq 4.064\times10^6$ [Pa] $0.7 \leq P \leq 40.64$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.07\times10^6 \leq P \leq 4.064\times10^6$ [Pa] $0.7 \leq P \leq 40.64$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	240≤T≤374.3 [K] −33.15≤T≤101.15 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	240≤T≤374.3 [K] −33.15≤T≤101.15 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	240≤T≤374.3 [K] −33.15≤T≤101.15 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	240≤T≤374.3 [K] −33.15≤T≤101.15 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.46 Halon 1211(R12B1)

All equations for halon 1211(R12B1) are based on the Table from Thermophysical properties of refrigerants of ASHRAE[1].

2.46.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.46.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Halon 1211, R12B1, Refrigerant 12B1, Freon 12B1, Bromochlorodifluoromethane
Library File for UNIX:	libjr12b.a
Library File for DOS,Windows95/NT:	JR12B.LIB
Single Shot Program for UNIX:	r12b1-ss
Single Shot Program for DOS,Windows95/NT:	R12B1-SS.EXE

2.46.3 Important Constants and Others

Molecular Formula:	$CBrC\ell F_2$
Relative Molecular Mass:	165.370
Gas Constant:	50.2782 J/(kg·K)

Critical Constants:

Critical Pressure:	4.2500×10^6Pa (42.500 bar)
Critical Temperature:	426.88 K (153.73 °C)
Critical Specific Volume:	1.4854×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.46.4 Formula

Equation of State:

The Bender equation of state (II· 3 · 1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

satureted state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\ K) < p < p_{sat}(T_c + 1\ K)$ and $v'(T_c - 1\ K) < v < v''(T_c - 1\ K)$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat respectively. However, the sign of the last integration term in u including in Equation (2) has been corrected to −.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), ASHRAE

Table II–2.46–1 Halon 1211(R12B1) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] $360 \leq T \leq 460$ [K] $9.4 \leq P \leq 62$ [bar] $86.85 \leq T \leq 186.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] $360 \leq T \leq 460$ [K] $9.4 \leq P \leq 62$ [bar] $86.85 \leq T \leq 186.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3481×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.25×10^6 [Pa], 42.5 [bar] Pressure S: 'A'='S': 1.405×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 426.88 [K], 153.73 [°C] Temperature V: 'A'='V': 1.4854×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		

Table II–2.46–1 Halon 1211(R12B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] $360 \leq T \leq 460$ [K] $9.4 \leq P \leq 62$ [bar] $86.85 \leq T \leq 186.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 165.37 Relative Molecular Mass R: 'A'='R': 50.2782 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] SPT(P,360K)≤S≤ SPT(P,460K) [J/(kg·K)] $9.4 \leq P \leq 62$ [bar] SPT(P,86.85°C)≤S≤ SPT(P,186.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] $360 \leq T \leq 460$ [K] $9.4 \leq P \leq 62$ [bar] $86.85 \leq T \leq 186.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CBRCLF2' Molecular Formula S: 'A'='S': 'HALON 1211(R12B1)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.46–1 Halon 1211(R12B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] $360 \leq T \leq 460$ [K] $9.4 \leq P \leq 62$ [bar] $86.85 \leq T \leq 186.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] $13.3 \leq P \leq 42.5$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$361.03 \leq T \leq 426.88$ [K] $87.88 \leq T \leq 153.73$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] HPT(P,360K)≤H≤HPT(P,460K) [J/kg] $9.4 \leq P \leq 62$ [bar] HPT(P,86.85°C)≤H≤ HPT(P,186.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] SPT(P,360K)≤S≤ SPT(P,460K) [J/(kg·K)] $9.4 \leq P \leq 62$ [bar] SPT(P,86.85°C)≤S≤ SPT(P,186.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		

Table II–2.46–1 Halon 1211(R12B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] VPT(P,360K)≤V≤ VPT(P,460K) [m^3/kg] 9.4≤P≤62 [bar] VPT(P,86.85°C)≤V≤ VPT(P,186.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] SPT(P,360K)≤S≤ SPT(P,460K) [J/(kg·K)] 9.4≤P≤62 [bar] SPT(P,86.85°C)≤S≤ SPT(P,186.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] 360≤T≤460 [K] 9.4≤P≤62 [bar] 86.85≤T≤186.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	361.03≤T≤426.88 [K] 87.88≤T≤153.73 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	361.03≤T≤426.88 [K] 87.88≤T≤153.73 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	361.03≤T≤426.88 [K] 87.88≤T≤153.73 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.33\times10^6 \leq P \leq 4.25\times10^6$ [Pa] 13.3≤P≤42.5 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.94\times10^6 \leq P \leq 6.2\times10^6$ [Pa] SPT(P,360K)≤S≤ SPT(P,460K) [J/(kg·K)] 9.4≤P≤62 [bar] SPT(P,86.85°C)≤S≤ SPT(P,186.85°C) [J/(kg·K)]

Table II–2.46–1 Halon 1211(R12B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \le P \le 6.2\times10^6$ [Pa] $360 \le T \le 460$ [K] $9.4 \le P \le 62$ [bar] $86.85 \le T \le 186.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.33\times10^6 \le P \le 4.25\times10^6$ [Pa] $13.3 \le P \le 42.5$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$361.03 \le T \le 426.88$ [K] $87.88 \le T \le 153.73$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$361.03 \le T \le 426.88$ [K] $87.88 \le T \le 153.73$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$361.03 \le T \le 426.88$ [K] $87.88 \le T \le 153.73$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.94\times10^6 \le P \le 6.2\times10^6$ [Pa] $360 \le T \le 460$ [K] $9.4 \le P \le 62$ [bar] $86.85 \le T \le 186.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.33\times10^6 \le P < 4.25\times10^6$ [Pa] $13.3 \le P < 42.5$ [bar] $HPD(P) \le H \le HPDD(P)$ [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.33\times10^6 \le P < 4.25\times10^6$ [Pa] $13.3 \le P < 42.5$ [bar] $SPD(P) \le S \le SPDD(P)$ [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.33\times10^6 \le P < 4.25\times10^6$ [Pa] $13.3 \le P < 42.5$ [bar] $UPD(P) \le U \le UPDD(P)$ [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.33\times10^6 \le P < 4.25\times10^6$ [Pa] $13.3 \le P < 42.5$ [bar] $VPD(P) \le V \le VPDD(P)$ [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$361.03 \le T < 426.88$ [K] $87.88 \le T < 153.73$ [°C] $HTD(T) \le H \le HTDD(T)$ [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$361.03 \le T < 426.88$ [K] $87.88 \le T < 153.73$ [°C] $STD(T) \le S \le STDD(T)$ [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$361.03 \le T < 426.88$ [K] $87.88 \le T < 153.73$ [°C] $UTD(T) \le U \le UTDD(T)$ [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$361.03 \le T < 426.88$ [K] $87.88 \le T < 153.73$ [°C] $VTD(T) \le V \le VTDD(T)$ [m^3/kg]

2.47 Halon 1301(R13B1)

All equations for halon 1301(R13B1) are based on the Table from Japanese Association of Refrigeration [1].

2.47.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.47.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Halon 1301, R13B1, Refrigerant 13B1, Freon 13B1, Bromotrifluoromethane
Library File for UNIX:	libjr13b.a
Library File for DOS,Windows95/NT:	JR13B.LIB
Single Shot Program for UNIX:	r13b1-ss
Single Shot Program for DOS,Windows95/NT:	R13B1–SS.EXE

2.47.3 Important Constants and Others

Molecular Formula:	$CBrF_3$
Relative Molecular Mass:	148.91
Gas Constant:	55.8346 J/(kg·K)

Critical Constants:

Critical Pressure:	3.9628×10^6Pa (39.628 bar)
Critical Temperature:	340.08 K (66.93°C)
Critical Specific Volume:	1.3089×10^{-3}m^3/kg

Reference State:

At 0 °C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.47.4 Formula

Equation of State:

Equation (II·2·1) in a function from of $Z = Z(\rho, T)$ in reference [1]. Here Z=compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (II·2·20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated liquid: Equations (II·2·3), (II·2·9), (II·2·17) and (II·2·21) for specific volume, specific enthalpy, specific entropy and isobaric specific heat, respectively.

saturated vapor: Equations (II·2·20) and (II·2·1) for specific volume, (II·2·15) and (II·2·11) for specific enthalpy and (II·2·5) with (II·2·15) for isobaric specific heat. Equation (II·2·4) with (II·2·15) for isochoric specific heat.

All of these equations have been cited from reference [1]. However, the coefficients of A_{13} and A_{16} in the equation (II·2·14) have been corrected to $5T_r^{-6}$ from T_r^{-6}.

Transport Properties:

Equations (II·3·5) and (II·3·1) in reference [1] for thermal conductivity and dynamic viscosity of saturated liquid, respectively. Equations (II·3·7) and (II·3·3) in reference [1] for thermal conductivity of vapor and dynamic viscosity at the atmospheric pressure, respectively. Also equation (II·3·3) for dynamic viscosity of superheated vapor.

The Other Properties:
Equation (II·2·40) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration, Thermophysical Properties of Refrigerants (R13B1, Bromotrifluoromethane), (1989).

Table II–2.47–1 Halon 1301 (R13B1) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] TSP(P)≤T≤460 [K] 0.074≤P≤150 [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$5.858\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.05858≤P≤39.628 [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	170≤T≤340.08 [K] −103.15≤T≤66.93 [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.074≤P≤39.628 [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(160K)≤P≤2.635×10^6 [Pa] PST(113.15°C)≤P≤26.35 [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$77.91\times10^3 \leq P \leq 3.51\times10^6$ [Pa] 0.779≤P≤35.1 [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy 270≤T≤434 [K] −3.15≤T≤160.85 [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	100≤T≤320 [K] −173.15≤T≤46.85 [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	210≤T≤334 [K] −63.15≤T≤60.85 [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	PST(190K)≤P≤PST(332K) [Pa] (∼25×10^3) (∼3.37×10^6) PST(−83.15°C)≤P≤PST(58.85°C) (∼0.25) (∼33.7) [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.8419\times10^6 \leq P \leq 3.9628\times10^6$ [Pa] 8.419≤P≤39.628 [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \leq P \leq 10\times10^6$ [Pa] 273.15≤T≤448.15 [K] $1.6667\times10^{-3} \leq V(P,T)$ [m^3/kg] 1.0≤P≤100 [bar] 0≤T≤175 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	190≤T≤332 [K] −83.15≤T≤58.85 [°C]

Table II–2.47–1 Halon 1301 (R13B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 340.08$ [K] $0 \leq T \leq 66.93$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.4\times10^{3} \leq P \leq 3.9628\times10^{6}$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.4\times10^{3} \leq P \leq 3.9628\times10^{6}$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^{3} \leq P \leq 15\times10^{6}$ [Pa] $TSP(P) \leq T \leq 460$ [K] $0.074 \leq P \leq 150$ [bar] $TSP(P) \leq T \leq 186.85$ [°C] see Fig.II-2.47-1
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.2778×10^{6} [J/kg] Specific Enthalpy P∗: 'A'='P': 3.9628×10^{6} [Pa], 39.628 [bar] Pressure S: 'A'='S': 1.241×10^{3} [J/(kg·K)] Specific Entropy T∗: 'A'='T': 340.08 [K], 66.93 [°C] Temperature V: 'A'='V': 1.3089×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.4\times10^{3} \leq P \leq 3.9628\times10^{6}$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^{3} \leq P \leq 15\times10^{6}$ [Pa] $TSP(P) \leq T \leq 460$ [K] $0.074 \leq P \leq 150$ [bar] $TSP(P) \leq T \leq 186.85$ [°C] see Fig.II-2.47-1
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 148.91 Relative Molecular Mass R: 'A'='R': 55.8346 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		

Table II–2.47–1 Halon 1301 (R13B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] $0.074 \leq P \leq 150$ [bar] see Fig.II-2.47-3 for S
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] TSP(P)≤T≤460 [K] $0.074 \leq P \leq 150$ [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CBRF3' Molecular Formula S: 'A'='S': 'HALON 1301(R13B1)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$25\times10^3 \leq P \leq 2.635\times10^6$ [Pa] $0.25 \leq P \leq 26.35$ [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.8419\times10^6 \leq P \leq 3.51\times10^6$ [Pa] $8.419 \leq P \leq 35.1$ [bar]
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $270 \leq T \leq 434$ [K] $-3.15 \leq T \leq 160.85$ [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$190 \leq T \leq 320$ [K] $-83.15 \leq T \leq 46.85$ [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 334$ [K] $0 \leq T \leq 60.85$ [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(160K)$\leq P \leq 3.9628\times10^6$ [Pa] ($\sim 20\times10^3$) PST(−113.15 °C)$\leq P \leq$39.628 ($\sim$0.2) [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	$160 \leq T \leq 340.08$ [K] $-113.15 \leq T \leq 66.93$ [°C]

Table II–2.47–1 Halon 1301 (R13B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] TSP(P)≤T≤460 [K] $0.074 \leq P \leq 150$ [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$173 \leq T \leq 340.08$ [K] $-100.15 \leq T \leq 66.93$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] $0.074 \leq P \leq 150$ [bar] see Fig.II-2.47-2 for H
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] $0.074 \leq P \leq 150$ [bar] see Fig.II-2.47-3 for S
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$7.4\times10^3 \leq$ P ≤ PST(333K) [Pa] VPD(P)≤V≤ VPT(P,460K) [m^3/kg] PST(333K)<P≤15×10^6 [Pa] VPT(P,333K)≤V≤ VPT(P,460K) [m^3/kg] 0.074≤P≤PST(59.85°C) [bar] VPD(P)≤V≤ VPT(P,186.85°C) [m^3/kg] PST(59.85°C)<P≤150 [bar] VPT(P,59.85°C)≤V≤ VPT(P,186.85°C) [m^3/kg] see Fig.II-2.47-1 for V
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] $0.074 \leq P \leq 39.628$ [bar]
74	TSPD(P)		
75	TSPDD(P)		

Table II–2.47–1 Halon 1301 (R13B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.4\times10^3\leq P\leq15\times10^6$ [Pa] $0.074\leq P\leq150$ [bar] see Fig.II-2.47-3 for S
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3\leq P\leq15\times10^6$ [Pa] TSP(P)≤T≤460 [K] $0.074\leq P\leq150$ [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$7.4\times10^3\leq P\leq15\times10^6$ [Pa] $0.074\leq P\leq150$ [bar] see Fig.II-2.47-3 for S
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3\leq P\leq15\times10^6$ [Pa] TSP(P)≤T≤460 [K] $0.074\leq P\leq150$ [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$7.4\times10^3\leq P\leq3.9628\times10^6$ [Pa] $0.074\leq P\leq39.628$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		

Table II–2.47–1 Halon 1301 (R13B1) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$7.4\times10^3 \leq P \leq 15\times10^6$ [Pa] TSP(P)≤T≤460 [K] 0.074≤P≤150 [bar] TSP(P)≤T≤186.85 [°C] see Fig.II-2.47-1
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.074≤P≤39.628 [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.074≤P≤39.628 [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.074≤P≤39.628 [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$7.4\times10^3 \leq P \leq 3.9628\times10^6$ [Pa] 0.074≤P≤39.628 [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	173≤T≤340.08 [K] −100.15≤T≤66.93 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

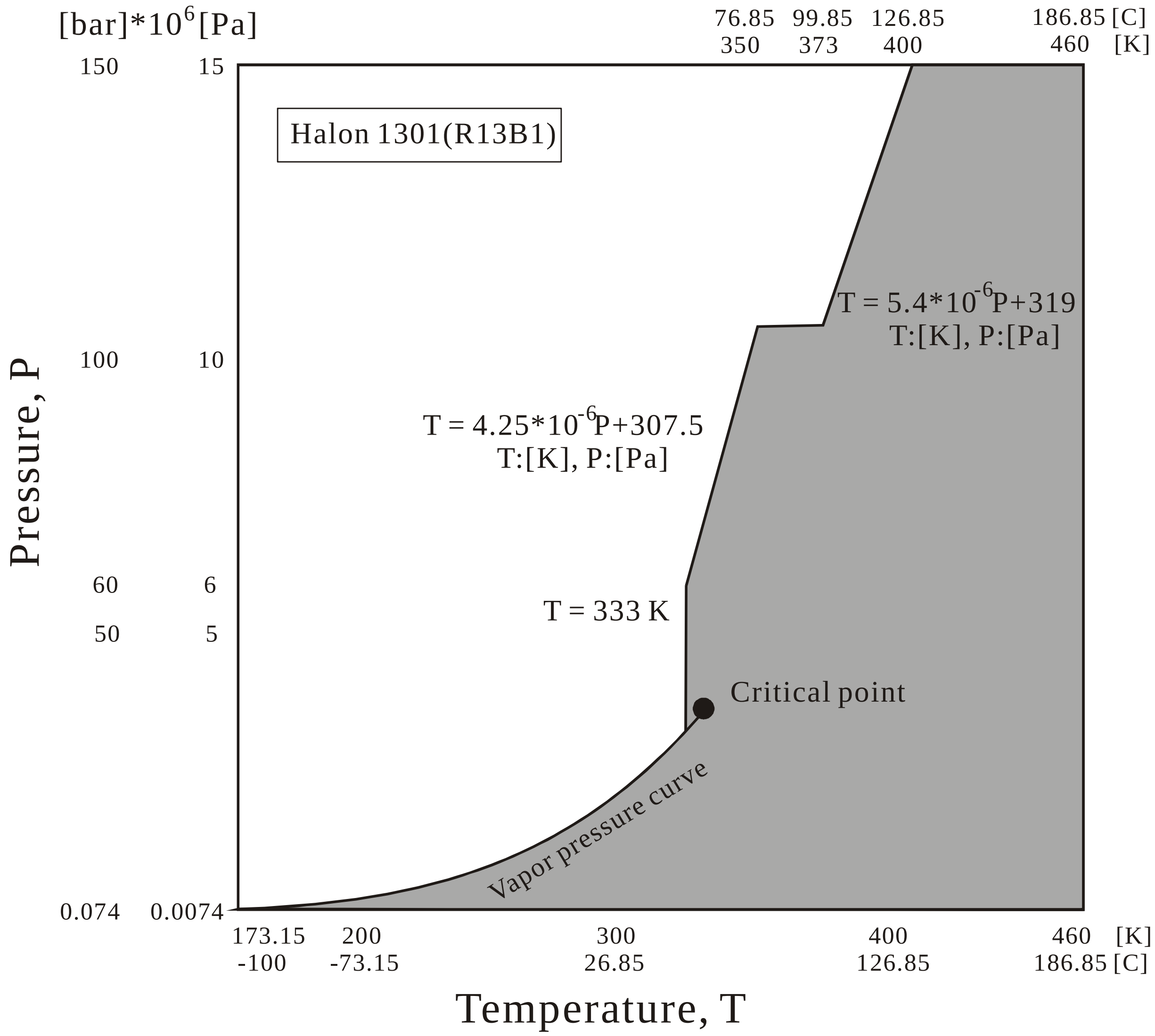


Fig.II–2.47–1 Range of Arguments(P,T) for AKPT(P,T),CPPT(P,T),CVPT(P,T),HPT(P,T), SPT(P,T),UPT(P,T),VPT(P,T) and WPT(P,T).

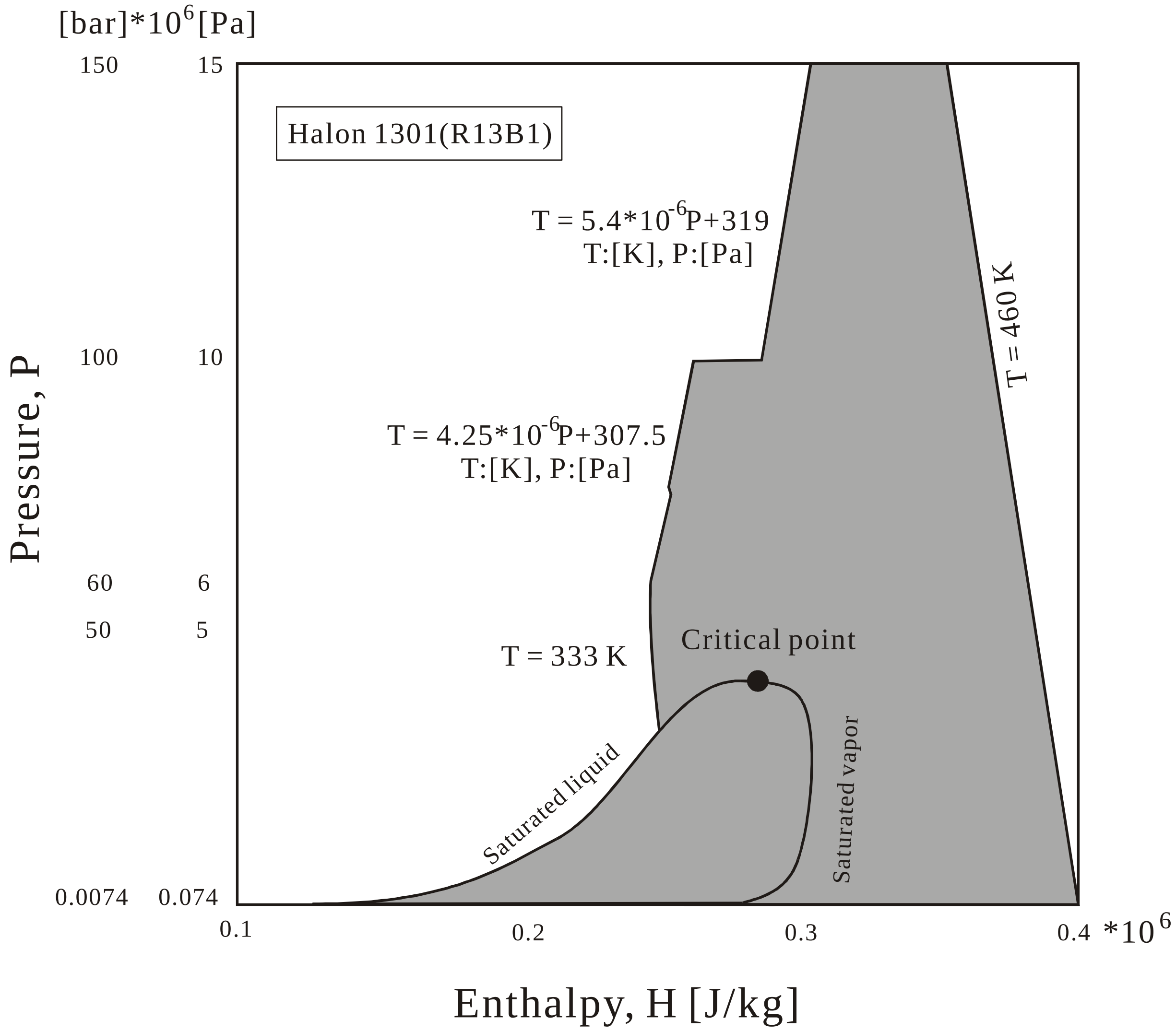


Fig.II–2.47–2 Range of Arguments(P,H) for TPH(P,H).

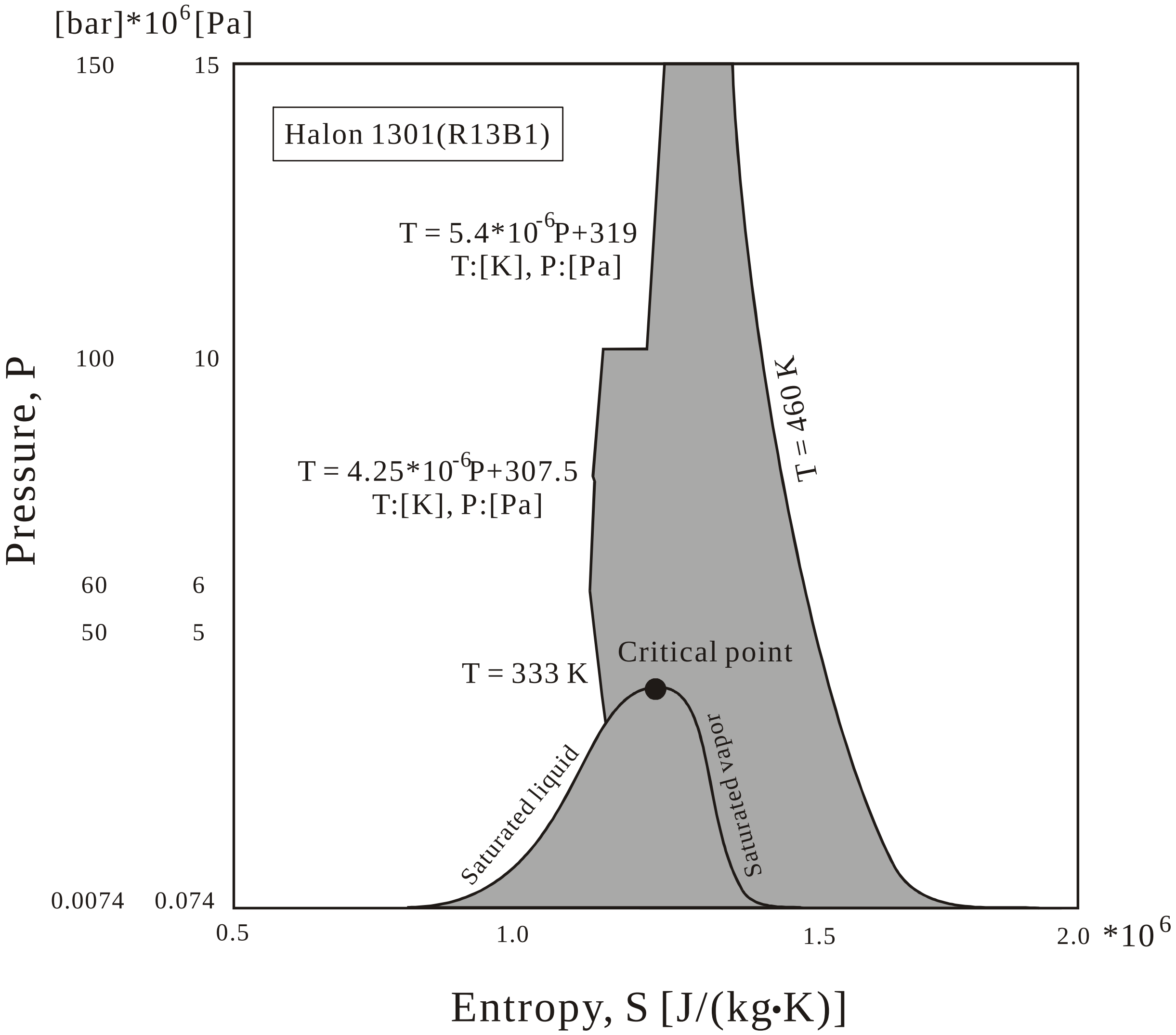


Fig.II–2.47–3 Range of Arguments(P,S) for HPS(P,S),TPS(P,S),UPS(P,S) and VPS(P,S).

2.48 Refrigerant 500

All equations for R500 are based on the Table from Thermophysical properties of refrigerants of ASHRAE[1].

2.48.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.48.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	R500, Refrigerant 500, Freon 500, Azeotrope of R12 and R152a, Azeotrope of CFC-12 and HFC-152a
Library File for UNIX:	libjr500.a
Library File for DOS,Windows95/NT:	JR500.LIB
Single Shot Program for UNIX:	r500-ss
Single Shot Program for DOS,Windows95/NT:	R500–SS.EXE

2.48.3 Important Constants and Others

Molecular Formula:	$CC\ell_2F_2$(72.8mass% +CH_3CHF_2(26.2mass%)
Relative Molecular Mass:	99.300
Gas Constant:	83.7312 J/(kg·K)

Critical Constants:

Critical Pressure:	4.4256×10^6Pa (44.256 bar)
Critical Temperature:	378.70 K (105.55 °C)
Critical Specific Volume:	2.0121×10^{-3}m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.48.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z=compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\ K) < p < p_{sat}(T_c + 1\ K)$ and $v'(T_c - 1\ K) < v < v''(T_c - 1\ K)$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat respectively. However, the sign of the last integration term in u including in Equation (2) has been corrected to −.

Transport Properties:

Equation (3.28) in reference [2] and Eq.(3.27) in reference [3] for thermal conductivity and dynamic viscosity of saturated liquid respectively.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990) ASHRAE
[2] JSME Data Book: Thermophysical Properties of Fluids, JSME (1983), 527

Table II–2.48–1 Refrigerant 500 Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] $300 \leq T \leq 470$ [K] $0.2 \leq P \leq 58.5$ [bar] $26.85 \leq T \leq 196.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(160K)$\leq P \leq 2.635\times10^6$ [Pa] PST(−113.15°C)$\leq P \leq 26.35$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$100 \leq T \leq 320$ [K] $-173.15 \leq T \leq 46.85$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	PST(190K)≤P≤PST(332K) [Pa] ($\sim25\times10^3$) ($\sim3.37\times10^6$) PST(−83.15°C)≤P≤PST(58.85°C) (∼0.25) (∼33.7) [bar]
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$190 \leq T \leq 332$ [K] $-83.15 \leq T \leq 58.85$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] $300 \leq T \leq 470$ [K] $0.2 \leq P \leq 58.5$ [bar] $26.85 \leq T \leq 196.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]

Table II–2.48–1 Refrigerant 500 Function (cont'd)

No.	Name of Function	Function and Argum ent(s)	Range of Argument(s)
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3698×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.4256×10^6 [Pa], 44.256 [bar] Pressure S: 'A'='S': 1.498×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 378.70 [K], 105.55 [°C] Temperature V: 'A'='V': 2.0121×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] $300 \leq T \leq 470$ [K] $0.2 \leq P \leq 58.5$ [bar] $26.85 \leq T \leq 196.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 99.30 Relative Molecular Mass R: 'A'='R': 83.7312 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] SPT(P,300K)≤S≤ SPT(P,470K) [J/(kg·K)] $0.2 \leq P \leq 58.5$ [bar] SPT(P,26.85°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] $300 \leq T \leq 470$ [K] $0.2 \leq P \leq 58.5$ [bar] $26.85 \leq T \leq 196.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]

Table II–2.48–1 Refrigerant 500 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CCL2F2+CH3CHF2' Molecular Formula S: 'A'='S': 'REFRIGERANT 500' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$25\times10^3 \leq P \leq 2.635\times10^6$ [Pa] $0.25 \leq P \leq 26.35$ [bar]
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$190 \leq T \leq 320$ [K] $-83.15 \leq T \leq 46.85$ [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(T)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] $300 \leq T \leq 470$ [K] $0.2 \leq P \leq 58.5$ [bar] $26.85 \leq T \leq 196.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] $7.7 \leq P \leq 44.256$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$298.15 \leq T \leq 378.7$ [K] $25 \leq T \leq 105.55$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] HPT(P,300K)≤H≤ HPT(P,470K) [J/kg] $0.2 \leq P \leq 58.5$ [bar] HPT(P,26.85°C)≤H≤ HPT(P,196.85°C) [J/kg]

Table II–2.48–1 Refrigerant 500 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] SPT(P,300K)≤S≤ SPT(P,470K) [J/(kg·K)] 0.2≤P≤58.5 [bar] SPT(P,26.85°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
98	TPSEUP(P)		
6S	TPS2(P,S)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] VPT(P,300K)≤V≤ VPT(P,470K) [m^3/kg] 0.2≤P≤58.5 [bar] VPT(P,26.85°C)≤V≤ VPT(P,196.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] 7.7≤P≤44.256 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] 7.7≤P≤44.256 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] 7.7≤P≤44.256 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] SPT(P,300K)≤S≤ SPT(P,470K) [J/(kg·K)] 0.2≤P≤58.5 [bar] SPT(P,26.85°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \leq P \leq 5.85\times10^6$ [Pa] 300≤T≤470 [K] 0.2≤P≤58.5 [bar] 26.85≤T≤196.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] 7.7≤P≤44.256 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	298.15≤T≤378.7 [K] 25≤T≤105.55 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	298.15≤T≤378.7 [K] 25≤T≤105.55 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	298.15≤T≤378.7 [K] 25≤T≤105.55 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \leq P \leq 4.4256\times10^6$ [Pa] 7.7≤P≤44.256 [bar]

Table II–2.48–1 Refrigerant 500 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.77\times10^6 \le P \le 4.4256\times10^6$ [Pa] $7.7 \le P \le 44.256$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.02\times10^6 \le P \le 5.85\times10^6$ [Pa] SPT(P,300K)≤S≤ SPT(P,470K) [J/(kg·K)] $0.2 \le P \le 58.5$ [bar] SPT(P,26.85°C)≤S≤ SPT(P,196.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \le P \le 5.85\times10^6$ [Pa] $300 \le T \le 470$ [K] $0.2 \le P \le 58.5$ [bar] $26.85 \le T \le 196.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.77\times10^6 \le P \le 4.4256\times10^6$ [Pa] $7.7 \le P \le 44.256$ [bar] $0 \le X \le 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$298.15 \le T \le 378.7$ [K] $25 \le T \le 105.55$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$298.15 \le T \le 378.7$ [K] $25 \le T \le 105.55$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$298.15 \le T \le 378.7$ [K] $25 \le T \le 105.55$ [°C] $0 \le X \le 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.02\times10^6 \le P \le 5.85\times10^6$ [Pa] $300 \le T \le 470$ [K] $0.2 \le P \le 58.5$ [bar] $26.85 \le T \le 196.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.77\times10^6 \le P < 4.4256\times10^6$ [Pa] $7.7 \le P < 44.256$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.77\times10^6 \le P < 4.4256\times10^6$ [Pa] $7.7 \le P < 44.256$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.77\times10^6 \le P < 4.4256\times10^6$ [Pa] $7.7 \le P < 44.256$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.77\times10^6 \le P < 4.4256\times10^6$ [Pa] $7.7 \le P < 44.256$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$298.15 \le T < 378.7$ [K] $25 \le T < 105.55$ [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$298.15 \le T < 378.7$ [K] $25 \le T < 105.55$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$298.15 \le T < 378.7$ [K] $25 \le T < 105.55$ [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$298.15 \le T < 378.7$ [K] $25 \le T < 105.55$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

2.49 Refrigerant 502

All equations for R502 are based on the Table from Japanese Association of Refrigeration [1].

2.49.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.49.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	R502, Refrigerant 502, Freon 502, Azeotrope of R22 and R115, Azeotrope of HCFC-22 and CFC-115
Library File for UNIX:	libjr502.a
Library File for DOS,Windows95/NT:	JR502.LIB
Single Shot Program for UNIX:	r502-ss
Single Shot Program for DOS,Windows95/NT:	R502–SS.EXE

2.49.3 Important Constants and Others

Molecular Formula:	$CHC\ell F_{2(48.8\mathrm{mass\%})} + C_2C\ell F_{5(51.2\mathrm{mass\%})}$
Relative Molecular Mass:	111.6
Gas Constant:	74.577 J/(kg·K)

Critical Constants:

Critical Pressure:	4.065×10^6Pa (40.65 bar)
Critical Temperature:	355.37 K (82.22 °C)
Critical Specific Volume:	$1.764\times10^{-3}\mathrm{m^3/kg}$

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.49.4 Formula

Equation of State:

Equation (II·2·1) in a function from of $Z = Z(\rho, T)$ in reference [1]. Here Z=compressibility, ρ=density and T= temperature.

Vapor Pressure:

Equation (II·2·15) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated liquid: Equations (II·2·10), (II·2·12), (II·2·14) and (II·2·5) with (II·2·15) for specific volume, specific enthalpy, specific entropy and isobaric specific heat, respectively.

saturated vapor: Equations (II·2·15) and (II·2·1) for specific volume, (II·2·15) and (II·2·11) for specific enthalpy and (II·2·5) with (II·2·15) for isobaric specific heat. Equation (II·2·4) with (II·2·15) for isochoric specific heat.

All of these equations have been cited from reference [1].

Transport Properties:

Equations (II·3·5) and (II·3·1) in reference [1] for thermal conductivity and dynamic viscosity of saturated liquid, respectively. Equations (II·3·9) and (II·3·2) in reference [1] for thermal conductivity of vapor and dynamic viscosity at the atmospheric pressure, respectively. Equations (II·3·3) in reference[1] for dynamic viscosity of superheated vapor.

The Other Properties:

Equation (II·2·25) in reference [1] for surface tension.

References

[1] Japanese Association of Refrigeration, Thermophysical Properties of Refrigerants (R502, Azeotrope of R22 and R115), (1986).

Table II–2.49–1 Refrigerant 502 Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] $TSP(P) \le T \le 500$ [K] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] $330 \le T \le 500$ [K] $0.02 \le P \le 12.078$ [bar] $TSP(P) \le T \le 226.85$ [°C] $12.078 < P \le 100$ [bar] $56.85 \le T \le 226.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$22.845\times10^3 \le P \le 4.065\times10^6$ [Pa] $0.22845 \le P \le 40.65$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$200 \le T \le 355.37$ [K] $-73.15 \le T \le 82.22$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] $0.02 \le P \le 40.65$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$167.5 \le T \le 355.37$ [K] $-105.65 \le T \le 82.22$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 1.147\times10^6$ [Pa] $0.02 \le P \le 11.47$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$127.9\times10^3 \le P \le 3.5187\times10^6$ [Pa] $1.279 \le P \le 35.187$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity at Ordinary Pressure [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy $230 \le T \le 434$ [K] $-43.15 \le T \le 160.85$ [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$140 \le T \le 298$ [K] $-133.15 \le T \le 24.85$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$233 \le T \le 348$ [K] $-40.15 \le T \le 74.85$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$PST(201K) \le P \le PST(285K)$ [Pa] $(\sim24.2\times10^3)$ $(\sim0.806\times10^6)$ $PST(-72.15°C) \le P \le PST(11.85°C)$ (~0.242) (~8.06) [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$0.56626\times10^6 \le P \le 4.065\times10^6$ [Pa] $5.6626 \le P \le 40.65$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.1\times10^6 \le P \le 7.2\times10^6$ [Pa] $273.15 \le T \le 398.15$ [K] $3.3333\times10^{-3} \le V(P,T)$ [m^3/kg] $1.0 \le P \le 72$ [bar] $0 \le T \le 125$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$201 \le T \le 285$ [K] $-72.15 \le T \le 11.75$ [°C]

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$273.15 \leq T \leq 355.37$ [K] $0 \leq T \leq 82.22$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] $0.02 \leq P \leq 40.65$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] $0.02 \leq P \leq 40.65$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \leq P \leq 1.2078\times10^6$ [Pa] $TSP(P) \leq T \leq 500$ [K] $1.2078\times10^6 < P \leq 10.0\times10^6$ [Pa] $330 \leq T \leq 500$ [K] $0.02 \leq P \leq 12.078$ [bar] $TSP(P) \leq T \leq 226.85$ [°C] $12.078 < P \leq 100$ [bar] $56.85 \leq T \leq 226.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$167.5 \leq T \leq 355.37$ [K] $-105.65 \leq T \leq 82.22$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$167.5 \leq T \leq 355.37$ [K] $-105.65 \leq T \leq 82.22$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.3259×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.065×10^6 [Pa], 40.65 [bar] Pressure S: 'A'='S': 1.383×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 355.37 [K], 82.22 [°C] Temperature V: 'A'='V': 1.764×10^{-3} [m^3/kg] Specific Volume	one of 'H','P','S','T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] $0.02 \leq P \leq 40.65$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \leq P \leq 1.2078\times10^6$ [Pa] $TSP(P) \leq T \leq 500$ [K] $1.2078\times10^6 < P \leq 10.0\times10^6$ [Pa] $330 \leq T \leq 500$ [K] $0.02 \leq P \leq 12.078$ [bar] $TSP(P) \leq T \leq 226.85$ [°C] $12.078 < P \leq 100$ [bar] $56.85 \leq T \leq 226.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$167.5 \leq T \leq 355.37$ [K] $-105.65 \leq T \leq 82.22$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 111.6 Relative Molecular Mass R: 'A'='R': 74.577 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] $0.02 \leq P \leq 40.65$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] $0.02 \leq P \leq 40.65$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$2.0\times10^3 \leq P \leq 1.2078\times10^6$ [Pa] SPD(P)≤S≤SPT(P,500K) [J/(kg·K)] $1.2078\times10^6 < P \leq 10.0\times10^6$ [Pa] SPT(P,330K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.02≤P≤12.078 [bar] SPD(P)≤S≤ SPT(P,226.85°C) [J/(kg·K)] 12.078<H≤100 [bar] SPT(P,56.85°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \leq P \leq 1.2078\times10^6$ [Pa] TSP(P)≤T≤500 [K] $1.2078\times10^6 < P \leq 10.0\times10^6$ [Pa] 330≤T≤500 [K] 0.02≤P≤12.078 [bar] TSP(P)≤T≤226.85 [°C] 12.078<P≤100 [bar] 56.85≤T≤226.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0\times10^3 \leq P \leq 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar] 0≤X≤1.0 [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CHCLF2+C2CLF5' Molecular Formula S: 'A'='S': 'REFRIGERANT 502' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C','S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$24.2\times10^3 \leq P \leq 0.806\times10^6$ [Pa] 0.242≤P≤8.06 [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$0.56626\times10^6 \leq P \leq 3.5187\times10^6$ [Pa] 5.6626≤P≤35.187 [bar]

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
81	PRPT(P,T)	PRPT: Prandtl Number at Ordinary Pressure [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	P=Dummy 230≤T≤434 [K] −43.15≤T≤160.85 [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	201≤T≤285 [K] −72.15≤T≤11.85 [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	273.15≤T≤348 [K] 0≤T≤74.85 [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(200K)≤P≤4.065×10^6 [Pa] (∼20×10^3) PST(−73.15 °C)≤P≤40.65 [bar] (∼0.2)
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	200≤T≤355.37 [K] −73.15≤T≤82.22 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	2.0×10^3≤P≤4.065×10^6 [Pa] 0.02≤P≤40.65 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	2.0×10^3≤P≤4.065×10^6 [Pa] 0.02≤P≤40.65 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.0×10^3≤P≤1.2078×10^6 [Pa] TSP(P)≤T≤500 [K] 1.2078×10^6<P≤10.0×10^6 [Pa] 330≤T≤500 [K] 0.02≤P≤12.078 [bar] TSP(P)≤T≤226.85 [°C] 12.078<P≤100 [bar] 56.85≤T≤226.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	2.0×10^3≤P≤4.065×10^6 [Pa] 0.02≤P≤40.65 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C] 0≤X≤1.0 [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	2.0×10^3≤P≤1.2078×10^6 [Pa] HPD(P)≤H≤HPT(P,500K) [J/kg] 1.2078×10^6<P≤10.0×10^6 [Pa] HPT(P,330K)≤H≤ HPT(P,500K) [J/kg] 0.02≤P≤12.078 [bar] HPD(P)≤H≤HPT(P,226.85°C) [J/kg] 12.078<H≤100 [bar] HPT(P,56.85°C)≤H≤ HPT(P,226.85°C) [J/kg]

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] SPD(P)≤S≤SPT(P,500K) [J/(kg·K)] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] SPT(P,330K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.02≤P≤12.078 [bar] SPD(P)≤S≤ SPT(P,226.85°C) [J/(kg·K)] 12.078<H≤100 [bar] SPT(P,56.85°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] VPD(P)≤V≤VPT(P,500K) [m^3/kg] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] VPT(P,330K)≤V≤ VPT(P,500K) [m^3/kg] 0.02≤P≤12.078 [bar] VPD(P)≤V≤VPT(P,226.85°C) [m^3/kg] 12.078<H≤100 [bar] VPT(P,56.85°C)≤V≤ VPT(P,226.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] SPD(P)≤S≤SPT(P,500K) [J/(kg·K)] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] SPT(P,330K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.02≤P≤12.078 [bar] SPD(P)≤S≤ SPT(P,226.85°C) [J/(kg·K)] 12.078<H≤100 [bar] SPT(P,56.85°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] TSP(P)≤T≤500 [K] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] 330≤T≤500 [K] 0.02≤P≤12.078 [bar] TSP(P)≤T≤226.85 [°C] 12.078<P≤100 [bar] 56.85≤T≤226.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] SPD(P)≤S≤SPT(P,500K) [J/(kg·K)] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] SPT(P,330K)≤S≤ SPT(P,500K) [J/(kg·K)] 0.02≤P≤12.078 [bar] SPD(P)≤S≤ SPT(P,226.85°C) [J/(kg·K)] 12.078<H≤100 [bar] SPT(P,56.85°C)≤S≤ SPT(P,226.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] TSP(P)≤T≤500 [K] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] 330≤T≤500 [K] 0.02≤P≤12.078 [bar] TSP(P)≤T≤226.85 [°C] 12.078<P≤100 [bar] 56.85≤T≤226.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$2.0\times10^3 \le P \le 4.065\times10^6$ [Pa] 0.02≤P≤40.65 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	167.5≤T≤355.37 [K] −105.65≤T≤82.22 [°C] 0≤X≤1.0 [–]

Table II–2.49–1 Refrigerant 502 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$2.0\times10^3 \le P \le 1.2078\times10^6$ [Pa] $TSP(P) \le T \le 500$ [K] $1.2078\times10^6 < P \le 10.0\times10^6$ [Pa] $330 \le T \le 500$ [K] $0.02 \le P \le 12.078$ [bar] $TSP(P) \le T \le 226.85$ [°C] $12.078 < P \le 100$ [bar] $56.85 \le T \le 226.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$2.0\times10^3 \le P < 4.065\times10^6$ [Pa] $0.02 \le P < 40.65$ [bar] $HPD(P) \le H \le HPDD(P)$ [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$2.0\times10^3 \le P < 4.065\times10^6$ [Pa] $0.02 \le P < 40.65$ [bar] $SPD(P) \le S \le SPDD(P)$ [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$2.0\times10^3 \le P < 4.065\times10^6$ [Pa] $0.02 \le P < 40.65$ [bar] $UPD(P) \le U \le UPDD(P)$ [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$2.0\times10^3 \le P < 4.065\times10^6$ [Pa] $0.02 \le P < 40.65$ [bar] $VPD(P) \le V \le VPDD(P)$ [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$167.5 \le T < 355.37$ [K] $-105.65 \le T < 82.22$ [°C] $HTD(T) \le H \le HTDD(T)$ [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$167.5 \le T < 355.37$ [K] $-105.65 \le T < 82.22$ [°C] $STD(T) \le S \le STDD(T)$ [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$167.5 \le T < 355.37$ [K] $-105.65 \le T < 82.22$ [°C] $UTD(T) \le U \le UTDD(T)$ [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	$167.5 \le T < 355.37$ [K] $-105.65 \le T < 82.22$ [°C] $VTD(T) \le V \le VTDD(T)$ [m^3/kg]

2.50 Refrigerant 503

All equations for R503 are based on the Table from Thermophysical properties of refrigerants of ASHRAE[1].

2.50.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.50.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	R503, Refrigerant 503, Freon 503, Azeotrope of R13 and R23, Azeotrope of CFC-13 and HFC-23
Library File for UNIX:	libjr503.a
Library File for DOS,Windows95/NT:	JR503.LIB
Single Shot Program for UNIX:	r503-ss
Single Shot Program for DOS,Windows95/NT:	R503–SS.EXE

2.50.3 Important Constants and Others

Molecular Formula:	$CC\ell F_3$(59.9mass% +CHF_3(40.1mass%)
Relative Molecular Mass:	87.280
Gas Constant:	95.2624 J/(kg·K)

Critical Constants:

Critical Pressure:	$4.3316{\times}10^6$Pa (43.316 bar)
Critical Temperature:	292.40 K (19.25 °C)
Critical Specific Volume:	$1.7841{\times}10^{-3}$m^3/kg

Reference State:

At 0°C, 1.0000 kJ/(kg·K) and 200.00 kJ/kg are assigned to the specific entropy and the specific enthalpy of saturated liquid, respectively.

2.50.4 Formula

Equation of State:

The Bender equation of state (II·3·1) in reference [1], which is in a function from of $Z = Z(\rho, T)$. Here Z= compressibility, ρ=density and T=temperature.

Vapor Pressure:

Equation (20) in reference [1].

Properties at Vapor-Liquid Equilibrium:

saturated state: The Bender equation of state is utilized to obtaining saturated specific volume by the aid of maxwell's criterion according to the author's recommendation. The Bender equation of state shows unreasonable behavior near the critical point. This temperature range is evaluated by $T_c \pm 1$ K. Therefore, in the temperature range and above the critical pressure, the values of u, h and s would include some uncertainity. Also, in the ranges of $p_{sat}(T_c - 1\ K) < p < p_{sat}(T_c + 1\ K)$ and $v'(T_c - 1\ K) < v < v''(T_c - 1\ K)$, the calculated values of p, v, T, c_p, c_v, isentropic exponent, Laplace coefficient, Prandtl number, velocity of sound and dryness fraction of wet vapor would have some uncertainity. Equations (2), (3), and (5) for specific enthalpy, specific entropy and isobaric specific heat respectively. However, the sign of the last integration term in u including in Equation (2) has been corrected to −.

Transport Properties:

Equation (3.31) in reference [2] and Eq.(3.30) in reference [3] for thermal conductivity and dynamic viscosity of saturated liquid respectively.

The Other Properties:
Equation (3) in reference [3] for surface tension.

References

[1] B.Platzer, A.Polt and G.Maurer, Thermophysical Properties of Refrigerants (1990), ASHRAE
[2] JSME Data Book: Thermophysical Properties of Fluids, JSME (1983), 527
[3] K.Watanabe and M.Okada, Proc. of 7th Symp. on Thermophysical Properties, (1977), 851 ASME New York

Table II–2.50–1 Refrigerant 503 Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29\times10^6 \le P \le 10.0\times10^6$ [Pa] $213 \le T \le 490$ [K] $2.9 \le P \le 100$ [bar] $-60.15 \le T \le 216.85$ [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient[m] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \le P \le 4.3316\times10^6$ [Pa] $2.9 \le P \le 43.316$ [bar]
3	ALAPT(T)	ALAPP: Laplace Coefficient[m] T∗: Temperature [K], [°C]	$213.02 \le T \le 292.4$ [K] $-60.13 \le T \le 19.25$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \le P \le 4.3316\times10^6$ [Pa] $2.9 \le P \le 43.316$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$213.02 \le T \le 292.4$ [K] $-60.13 \le T \le 19.25$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	PST(160K)$\le P \le 2.732\times10^6$ [Pa] PST(−113.15°C)$\le P \le 27.32$ [bar]
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	$150 \le T \le 273.15$ [K] $-123.15 \le T \le 0$ [°C]
10	ALMTDD(T)		
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	PST(190K)≤P≤PST(250K) [Pa] ($\sim0.132\times10^6$) ($\sim1.44\times10^6$) PST(−83.15°C)≤P≤PST(−23.15°C) (∼1.32) (∼14.4) [bar]
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$190 \le T \le 250$ [K] $-83.15 \le T \le -23.15$ [°C]
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \le P \le 4.3316\times10^6$ [Pa] $2.9 \le P \le 43.316$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \le P \le 4.3316\times10^6$ [Pa] $2.9 \le P \le 43.316$ [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29\times10^6 \le P \le 10.0\times10^6$ [Pa] $213 \le T \le 490$ [K] $2.9 \le P \le 100$ [bar] $-60.15 \le T \le 216.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$213.02 \le T \le 292.4$ [K] $-60.13 \le T \le 19.25$ [°C]

Table II–2.50–1 Refrigerant 503 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 0.2550×10^6 [J/kg] Specific Enthalpy P∗: 'A'='P': 4.3316×10^6 [Pa], 43.316 [bar] Pressure S: 'A'='S': 1.186×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 292.40 [K], 19.25 [°C] Temperature V: 'A'='V': 1.7841×10^{-3} [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 87.280 Relative Molecular Mass R: 'A'='R': 95.2624 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] SPT(P,213K)≤S≤ SPT(P,490K) [J/(kg·K)] $2.9 \leq P \leq 100$ [bar] SPT(P,-60.15°C)≤S≤ SPT(P,216.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$[bar] $0 \leq X \leq 1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]

Table II–2.50–1 Refrigerant 503 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C] $0 \leq X \leq 1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CCLF3+CHF3' Molecular Formula S: 'A'='S': 'REFRIGERANT 503' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	$190 \leq T \leq 320$ [K] $-83.15 \leq T \leq 46.85$ [°C]
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	PST(204.4K)$\leq P \leq 4.3316\times10^6$ [Pa] ($\sim 27\times10^4$) PST(-68.75°C)$\leq P \leq 43.316$ [bar] ($\sim$2.7)
32	SIGT(T)	SIGP: Surface Tension [N/m] T∗: Temperature [K], [°C]	$204.4 \leq T \leq 292.4$ [K] $-68.75 \leq T \leq 19.25$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar] $0 \leq X \leq 1.0$ [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]

Table II–2.50–1 Refrigerant 503 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C] $0 \leq X \leq 1.0$ [–]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] HPT(P,213K)≤H≤HPT(P,490K) [J/kg] $2.9 \leq P \leq 100$ [bar] HPT(P,-60.15°C)≤H≤ HPT(P,216.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] SPT(P,213K)≤S≤ SPT(P,490K) [J/(kg·K)] $2.9 \leq P \leq 100$ [bar] SPT(P,-60.15°C)≤S≤ SPT(P,216.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] VPT(P,213K)≤V≤ VPT(P,490K) [m^3/kg] $2.9 \leq P \leq 100$ [bar] VPT(P,-60.15°C)≤V≤ VPT(P,216.85°C) [m^3/kg]
41	TRPL('A')		
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] SPT(P,213K)≤S≤ SPT(P,490K) [J/(kg·K)] $2.9 \leq P \leq 100$ [bar] SPT(P,-60.15°C)≤S≤ SPT(P,216.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29\times10^6 \leq P \leq 10.0\times10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.29\times10^6 \leq P \leq 4.3316\times10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar] $0 \leq X \leq 1.0$ [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]

Table II–2.50–1 Refrigerant 503 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C] $0 \leq X \leq 1.0$ [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] SPT(P,213K)≤S≤ SPT(P,490K) [J/(kg·K)] $2.9 \leq P \leq 100$ [bar] SPT(P,-60.15°C)≤S≤ SPT(P,216.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$0.29 \times 10^6 \leq P \leq 4.3316 \times 10^6$ [Pa] $2.9 \leq P \leq 43.316$ [bar] $0 \leq X \leq 1.0$ [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$213.02 \leq T \leq 292.4$ [K] $-60.13 \leq T \leq 19.25$ [°C] $0 \leq X \leq 1.0$ [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$0.29 \times 10^6 \leq P \leq 10.0 \times 10^6$ [Pa] $213 \leq T \leq 490$ [K] $2.9 \leq P \leq 100$ [bar] $-60.15 \leq T \leq 216.85$ [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$0.29 \times 10^6 \leq P < 4.3316 \times 10^6$ [Pa] $2.9 \leq P < 43.316$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$0.29 \times 10^6 \leq P < 4.3316 \times 10^6$ [Pa] $2.9 \leq P < 43.316$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$0.29 \times 10^6 \leq P < 4.3316 \times 10^6$ [Pa] $2.9 \leq P < 43.316$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$0.29 \times 10^6 \leq P < 4.3316 \times 10^6$ [Pa] $2.9 \leq P < 43.316$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.50–1 Refrigerant 503 Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	213.02≤T<292.4 [K] −60.13≤T<19.25 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	213.02≤T<292.4 [K] −60.13≤T<19.25 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	213.02≤T<292.4 [K] −60.13≤T<19.25 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	213.02≤T<292.4 [K] −60.13≤T<19.25 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

III A-PROPATH: Moist Air

Use is made of two different formulations. One is that of ideal gas mixture of dry air and steam. Another is that of real fluid.

1. General Features

1.1 FUNCTION SUBPROGRAM REFERENCE

Every A-PROPATH user has to make an initialization process by one of the following two procedures.

1.1.1 Initialization by COMMON VARIABLEs

Every user's PROGRAM UNIT which is going to CALL the A-PROPATH FUNCTION SUBPROGRAM should include the following one LINE before the first EXECUTABLE STATEMENT.

```
COMMON/UNIT/KPA, MESS
```

`KPA` and `MESS` are reserved as INTEGER VARIABLEs. Furthermore, the following two LINEs must be placed in the user's PROGRAM UNIT before the first FUNCTION CALL appears.

KPA= M
MESS= N

where both M and N are INTEGERs selected by a user.

`KPA` specifies the units of pressure and temperature for A-PROPATH FUNCTIONs and their ARGUMENTs. Descriptions on the system of units will be found both in 1.3 and the relation between the value of M and the units is shown there. When a user wishes to use other units in his/her PROGRAM UNIT later, he/she is supposed to do the same at thar place.

`MESS` specifies whether the message to the erroneous FUNCTION REFERENCE is to be printed out to the standard listing device or not. PROPATH does not return any messages when $N = 0$, while it does when $N \neq 0$.

1.1.2 Initialization by SUBROUTINE SUBPROGRAM KPAMES

The alternative method to set the values for `KPA` and `MESS` is to make use of SUBROUTINE SUBPROGRAM `KPAMES` as the following.

```
CALL KPAMES(KPA,MESS)
```

1.2 Operations to Manage Erroneous FUNCTION REFERENCE

A predetermined sequence of operations will occur to process the erroneous FUNCTION REFERENCE when an improper FUNCTION REFERENCE has been done. Erroneous FUNCTION REFERENCEs are grouped into 3 levels, with the ascending severity of the user's mistake. (A user has committed a more serious mistake when he/she gets a level 2 ERROR than when a level 1 ERROR occurs)

1.2.1 Level 1 ERROR (Convergence Failure)

The method of iteration, which is built into some of the A-PROPATH FUNCTION SUBPROGRAMs to solve an implicit equation, may not work in some cases where a user has specified an ARGUMENT of FUNCTION very close to the saturation line or the critical point. A level 1 ERROR means A-PROPATH has stopped performing the iteration after the preset maximum number of iteration. Then the A-PROPATH FUNCTION SUBPROGRAM returns him/her an unexpected FUNCTION value and an ERROR message, though the user is not responsible for this type of ERROR,. A level 1 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+10
output to the standard listing device:
`**** NO CONVERGENCE AT (`*`NAME OF FUNCTION CALLED`*`) ****`

The PROPATH group is working hard to ensure that A-PROPATH FUNCTION SUBPROGRAM will not react with level 1 ERRORs because of poor programing technique. However when a user wants to get a value of a thermophysical property just on the saturation line or at the critical point and not at a point very close to it, he/she should try to CALL another FUNCTION for the states on the saturation line or at the critical point.

1.2.2 Level 2 ERROR (Invalid ARGUMENT(s))

A level 2 ERROR occurs when the ARGUMENT a user transferred to A-PROPATH FUNCTION has failed to drop in the proper range. A level 2 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+20
output to the standard listing device:
`**** OUT OF RANGE AT (`*`NAME OF FUNCTION`*`) FOR (`*`NAME OF SUBSTANCE`*`) WHEN (`*`FIRST ARGUMENT`*`) AND (`*`SECOND ARGUMENT, if any`*`) ****`

FUNCTION tables provides the proper range of ARGUMENT(s) for each substance.

1.2.3 Level 3 ERROR (FUNCTION Unavailable)

A user encounters a level 3 ERROR when a A-PROPATH FUNCTION SUBPROGRAM is not available for the substance selected. A level 3 ERROR is processed as shown below.

value of FUNCTION returned to the CALLing program: −1.0E+30
output to the standard listing device:
`**** FUNCTION (`*`NAME OF FUNCTION CALLED`*`) UNAVAILABLE FOR (`*`NAME OF SUBSTANCE`*`) ****`

Function table provides a list of FUNCTION SUBPROGRAMs available for each substance.

1.3 System of Units

All quantities, REAL ARGUMENTs and values of FUNCTION, are in the fundamental SI or in the coherent derived SI with two exceptions. Pressure can be in the unit of Pascal Pa or bar, and temperature in the unit of Kelvin K or degree Celsius °C. Users are allowed to make their own selection on these units by specifing a value to COMMON INTEGER VARIABLE `KPA`. The procedure to set a value to `KPA` is described in chapter 1, and the relation between the value of `KPA` and the units of pressure and temperature is shown in the table below. The temperature is based on the International Practical Temperature Scale, 1968.

Table III-1.3-1 Units of Pressure and Temperature Specified by `KPA`

`KPA`	unit of pressure	unit of temperature
0	Pa	K
1	bar	°C
2	bar	K
3	Pa	°C
others	Pa	K

1.4 Reserved NAMEs in A-PROPATH

As listed below, A-PROPATH for moit air uses a lot of NAMEs for its own purpose. These are the NAMEs of FUNCTION SUBPROGRAMs to which a user can access directly, KPA, the first COMMON INTEGER VARIABLE, to specify the units of pressure and temperature, and MESS, the second COMMON INTEGER VARIABLE, to allow or suppress the error messages. These are supposed to appear in the user's PROGRAM UNIT only when they mean their original meaning. D, E, F, $\cdots$ are the first LETTERs in the NAMEs listed in the same line.

NAMEs of FUNCTION SUBPROGRAMs:

D : DPA, DPC, DPD, DPE, DPF, DSA, DSB, DSC, DSD, DSE, DSF
E : ENHFAC
F : FC
H : HA, HB, HC, HD
I : IDENTF
P : PST
R : RHA, RHB, RHD, RHE, RHF, RWA, RWB, RWC, RWD, RWE, RWF
S : SA, SB, SC, SD, SE, SF
T : TF, T68, T90
V : VA, VB, VC, VD, VE, VF
W: WBB, WBC, WBD, WBE, WBF
X : XA, XB, XC, XE

NAMEs of COMMON INTEGER VARIABLEs:

K : KPA
M: MESS

1.5 Naming Convention of FUNCTION SUBPROGRAMs in A-PROPATH

The NAMEs of FUNCTION SUBPROGRAM have been allocated to in a regular pattern. This will help a user to remember them. The first one to six LETTERs stand for the kinds of the thermophysical properties. These are, in alphabetical order,

DP*	=dew point temperature
DS*	=degree of saturation
ENHFAC	=enhancement factor
FC	=fundamental constants
H*	=specific enthalpy
IDENTF	=package identification
PST	=saturation vapor pressure of pure water (or ice)
RH*	=relative humidity
RW*	=mole fraction of water vapor
S*	=specific entropy
T*	=dry-bulb temperature
V*	=specific volume
WB*	=thermodynamic wet-bulb temperature
X*	=humidity ratio (mixing ratio)

* stands for a character of one of A, B, C, D, E and F, and they represent the type of FUNCTIONs shown below:

Table III-1.5-1 Type of FUNCTIONs and Arguments in A-PROPATH

type	FUNCTION	ARGUMENTs	
A	#A(P,T,WB)	P:	total pressure
		T:	dry-bulb temperature
		WB:	thermodynamic wet-bulb temperature
B	#B(P,T,DP)	P:	total pressure
		T:	dry-bulb temperature
		DP:	dew point temperature
C	#C(P,T,RH)	P:	total pressure
		T:	dry-bulb temperature
		RH:	relative humidity
D	#D(P,T,X)	P:	total pressure
		T:	dry-bulb temperature
		X:	humidity ratio
E	#E(P,T,H)	P:	total pressure
		T:	dry-bulb temperature
		H:	specific enthalpy
F	#F(P,X,H)	P:	total pressure
		X:	humidity ratio
		H:	specific enthalpy

stands for one or two alphabetical letters and means the dependent variables. From the table of reserved NAMEs, # must be one of DP, DS, H, RH, RW, S, T, V, WB and X.

1.6 Fundamental Definitions and Terms of Moist Air

1.6.1 Important Constants and Others

Molecular Formula:	Two-component mixture of dry air and water vapor
Percentage composition of dry air by volume:	
N_2:	78.09 vol%
O_2:	20.95 vol%
Ar:	0.93 vol%
CO_2 and others:	0.03 vol%
Relative Molecular Mass :	
Dry air:	28.9645
Water vapor:	18.01528
Gas Constant:	
Dry air:	287.055 J/(kg·K)
Water vaopr:	461.520 J/(kg·K)

1.6.2 Moist Air Terminology and Others

(1) Humidity Ratio (Mixing Ratio), X

The ratio of the mass of water vapor to the mass of dry air contained in a given moist air sample.

$$\mathrm{X = 0.62198RW/(1 - RW)}$$

where the value of 0.62198 is the ratio of relative molecular masses between water vapor and dry air.

(2) Mole fraction of water vapor, RW

The number of moles of water vapor divided by the total number of moles of all components in a given moist air sample.

(3) Relative Humidity, RH

The ratio of the mole fraction of water vapor RW in a given moist air sample to the mole fraction $\mathrm{RW_s}$ in a air sample, saturated at the same temperature and pressure.

$$\mathrm{RH = (RW/RW_s)_{T,P}}$$

(4) Degree of Saturation, DS

The ratio of the air humidity ratio X to the humidity ratio of saturated air $\mathrm{X_s}$, at the same temperature and pressure.

$$\mathrm{DS = (X/X_s)_{T,P}}$$

(5) Dew Point Temperature, DP

The temperature of moist air, saturated at the same pressure P, with the same humidity ratio X as that of the given sample of moist air. It is defined as the unique solution of DP the following equation:

$$\mathrm{X_s(P, DP) = X}$$

(6) Thermodynamic Wet-Bulb Temperature, WB

The temperature defined as the unique solution WB(P,T,X) of the following equation:

$$\mathrm{H + (X'_s - X) \cdot H'_w = H'_s}$$

or

$$\mathrm{H(P, T, X) + [X'_s(P, WB) - X] \cdot H'_w(P, WB) = H'_s(P, WB)}$$

where

H	=H(P,T,X)	=	specific enthalpy of moist air at pressure P, temperature T, and humidity ratio X.
$\mathrm{H'_s}$	$\mathrm{= H'_s(P, WB)}$	=	specific enthalpy of moist air saturated at pressure P and temperature WB.
$\mathrm{X'_s}$	$\mathrm{= X'_s(P, WB)}$	=	specific humidity ratio at pressure P and temperature WB.
$\mathrm{H'_w}$	$\mathrm{= H'_w(P, WB)}$	=	specific enthalpy of liquid water (or ice) at pressure P and temperature WB.

The thermodynamic wet-bulb temperature is the same as the temperature of adiabatic saturation and hence it can alternatively be defined as the temperature at which wtater (or ice), by evaporating into moist air, can bring the air to saturation adiabatically at the same temperature and pressure.

(7) Enhancement Factor, ENHFAC

The enhancement factor accounts for the non-ideal behavior of moist air in the saturated state, which is defined by the following equation:

$$\mathrm{ENHFAC} = \mathrm{RW_s} \cdot \mathrm{P/PST}$$

or

$$\mathrm{ENHFAC(P,T)} = \mathrm{RW_s(P,T)} \cdot \mathrm{P/PST(T)}$$

where

$\mathrm{RW_s}$	$= \mathrm{RW_s(P,T)}$	=	mole fraction of water vapor in most air saturated with water at pressure P and temperature T.
PST	=PST(T)	=	saturation vapor pressure of pure water (or ice) at temperature T.

(8) Others

The values of humidity ratio X, specific volume V, specific enthalpy H and specific entropy S are based on unit mass of dry air in a given moist air sample. The unit symbol kg_{DA} in Tables III-2.1-1 and III-2.2-1 indicates kilogram of dry air. The subscripts a and s in the Tables indicate dry air and saturated air, respectively. Moreover, the FUNCTION subprograms do not cover the region of supersaturated air (fogged air).

1.7 An Example of User's PROGRAM UNIT

[**Example**] The dry- and wet-bulb temperatures of atmospheric air at 1.01325 bar are measured with a psychrometer and determined to be 25°C and 15°C, respectively. Determine (a) humidity ratio, (b) reletive humidity, (c) dew point and (d) specific enthalpy of air.

Sample Program

```
*************************************************
*    SAMPLE PROGRAM FOR /A-PROPATH/ USERS       *
*                                               *
*    EAMPLE FROM     Y.A. CENGEL AND M.A. BOLES *
*                    THERMODYNAMICS,            *
*                    MCGRAW-HILL  1989          *
*************************************************
*
***** EX.13-3 ON PAGE 603 *****
*
      COMMON/UNIT/KPA, MESS
      KAP=1
      MESS=1
      P=1.01325
      T=25.0
      TWB=15.0
      OMEGA=XA(P,T,TWB)
      PHI=RHA(P,T,TWB)
      DEWPNT=DPA(P,T,TWB)
      H=HA(P,T,TWB)
      WRITE(6,*)'****** SAMPLE PROGRAM FOR /A-PROPATH/ USERS ******'
      WRITE(6,*)'   HUMIDITY RATIO     OMEGA =',OMEGA
      WRITE(6,*)'   RELATIVE HUMIDITY    PHI =',PHI
      WRITE(6,*)'   DEW POINT          DEWPNT=',DEWPNT
      WRITE(6,*)'   SPECIFIC ENTHALPY     H  =',H
      STOP
      END
```

Output

```
****** SAMPLE PROGRAM FOR /A-PROPATH/ USERS ******
   HUMIDITY RATIO         OMEGA =   6.522585E-03
   RELATIVE HUMIDITY        PHI =   3.318627E-01
   DEW POINT             DEWPNT=       7.706512
   SPECIFIC ENTHALPY         H  =   41739.000000
```

2. Individual Formulation

2.1 Moist Air as Mixture of Ideal Gases

2.1.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.1.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Moist Air
Library File for UNIX:	libjmaig.a
Library File for DOS,Windows95/NT:	JMAIG.LIB
Single Shot Program for UNIX:	maig-ss
Single Shot Program for DOS,Windows95/NT:	MAIG–SS.EXE

2.1.3 Reference State and Formula

The specific enthalpy and entropy of dry air are both assigned the value zero at 101325 Pa and 273.15 K (0°C). The specific enthalpy and entropy of saturated liquid water are both assigned the value zero at 273.15K.

All equations for calculating thermodynamic properties of moist air have been cited from reference [1], which are based on ideal gas relations and do not include any correction with enhancement factor for the saturated state of moist air, i.e. $\mathrm{RW_s} \cdot \mathrm{P} = \mathrm{PST}$ for every FUNCTION SUBPROGRAM other than ENHFAC itself.

References

[1] ASHURAE HANDBOOK FUNDAMENTALS, (1993), Chapter 6, pp.6.1-6.10.

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	DPA(P,T,WB)	DPA: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq WB \leq T \leq 473.15$ [K] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq WB \leq T \leq 200$ [°C]
2	DPC(P,T,RH)	DPC: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq T \leq 473.15$ [K] $0 \leq RH \leq 1.0$ [–] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq T \leq 200$ [°C] $0 \leq RH \leq 1.0$ [–]
3	DPD(P,T,X)	DPD: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq T \leq 473.15$ [K] $0 \leq X \leq Xs$ [kg/kg_{DA}] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq T \leq 200$ [°C] $0 \leq X \leq Xs$ [kg/kg_{DA}]
4	DPE(P,T,H)	DPE: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq T \leq 473.15$ [K] $Ha \leq H \leq Hs$ [J/kg_{DA}] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq T \leq 200$ [°C] $Ha \leq H \leq Hs$ [J/kg_{DA}]
5	DPF(P,X,H)	DPF: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $PST/0.99 \leq P \leq 50$ [bar] $0 \leq X \leq Xs$ [kg/kg_{DA}] $Ha \leq H \leq Hs$ [J/kg_{DA}]
6	DSA(P,T,WB)	DSA: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq WB \leq T \leq 473.15$ [K] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq WB \leq T \leq 200$ [°C]
7	DSB(P,T,DP)	DSB: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq DP \leq T \leq 473.15$ [K] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq DP \leq T \leq 200$ [°C]
8	DSC(P,T,RH)	DSC: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq T \leq 473.15$ [K] $0 \leq RH \leq 1.0$ [–] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq T \leq 200$ [°C] $0 \leq RH \leq 1.0$ [–]
9	DSD(P,T,X)	DSD: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	$PST/0.99 \leq P \leq 5.0\times10^6$ [Pa] $173.15 \leq T \leq 473.15$ [K] $0 \leq X \leq Xs$ [kg/kg_{DA}] $PST/0.99 \leq P \leq 50$ [bar] $-100 \leq T \leq 200$ [°C] $0 \leq X \leq Xs$ [kg/kg_{DA}]

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
10	DSE(P,T,H)	DSE: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
11	DSF(P,X,H)	DSF: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
50	ENHFAC(P,T)	ENHFAC: Enhancement Factor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C]
89	FC('A')	FC: Fundamental Constants MA: 'A'='MA': 28.9645 Relative Molecular Mass of Dry Air MW: 'A'='MW': 18.01528 Relative Molecular Mass of Water RA: 'A'='RA': 461.520 Gas Constant of Dry Air RW: 'A'='RW': 287.055 Gas Constant of Water Vapor	one of 'MA', 'MW', 'RA' and 'RW'
12	HA(P,T,WB)	HA: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
13	HB(P,T,DP)	HB: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
14	HC(P,T,RH)	HC: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
15	HD(P,T,X)	HD: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg$_{DA}$]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'MIXTURE OF DRY AIR AND WATER VAPOR' S: 'A'='S': 'MOIST AIR' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
49	PST(T)	PST: Saturation Pressure of Pure Water [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C]	173.15≤T≤473.15 [K] −100≤T≤200 [°C]

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
22	RHA(P,T,WB)	RHA: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
23	RHB(P,T,DP)	RHB: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
24	RHD(P,T,X)	RHD: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
25	RHE(P,T,H)	RHE: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]
26	RHF(P,X,H)	RHF: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg_{DA}] Ha≤H≤Hs [J/kg_{DA}]
16	RWA(P,T,WB)	RWA: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
17	RWB(P,T,DP)	RWB: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
18	RWC(P,T,RH)	RWC: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
19	RWD(P,T,X)	RWD: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
20	RWE(P,T,H)	RWE: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
21	RWF(P,X,H)	RWF: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
27	SA(P,T,WB)	SA: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
28	SB(P,T,DP)	SB: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
29	SC(P,T,RH)	SC: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
30	SD(P,T,X)	SD: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg$_{DA}$]
31	SE(P,T,H)	SE: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
32	SF(P,X,H)	SF: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
33	TF(P,X,H)	TF: Dry-Bulb Temperature [K], [°C] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
34	VA(P,T,WB)	VA: Specific Volume [m^3/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	VB(P,T,DP)	VB: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
36	VC(P,T,RH)	VC: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
37	VD(P,T,X)	VD: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
38	VE(P,T,H)	VE: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]
39	VF(P,X,H)	VF: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg_{DA}] Ha≤H≤Hs [J/kg_{DA}]
40	WBB(P,T,DP)	WBB: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
41	WBC(P,T,RH)	WBC: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
42	WBD(P,T,X)	WBD: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
43	WBE(P,T,H)	WBE: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]

Table III–2.1–1 Moist Air as Mixture of Ideal Gas Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	WBF(P,X,H)	WBF: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
45	XA(P,T,WB)	XA: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
46	XB(P,T,DP)	XB: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
47	XC(P,T,RH)	XC: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
48	XE(P,T,H)	XE: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]

2.2 Moist Air as Real Fluids

2.2.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.2.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Moist Air
Library File for UNIX:	libjmarf.a
Library File for DOS,Windows95/NT:	JMARF.LIB
Single Shot Program for UNIX:	marf-ss
Single Shot Program for DOS,Windows95/NT:	MARF–SS.EXE

2.2.3 Reference State and Formula

The specific enthalpy and entropy of dry air are both assigned the value zero at 101325 Pa (1 atm) and 273.15 K (0°C). The specific enthalpy and entropy of saturated liquid water are both assigned the value zero at the triple point (273.16 K, 0.01°C).

All equations for the thermodynamic properties of dry air, saturated moist air, and the saturated phases of water have been cited from references [1] and [2].

References

[1] R.W.Hyland and A.Wexler, ASHRAE Transactions 89(2A), (1983), pp.520-535
[2] R.W.Hyland and A.Wexler, ASHRAE Transactions 89(2A), (1983), pp.500-519

Table III–2.2–1 Moist Air as Real Fluid Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	DPA(P,T,WB)	DPA: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
2	DPC(P,T,RH)	DPC: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
3	DPD(P,T,X)	DPD: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
4	DPE(P,T,H)	DPE: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]
5	DPF(P,X,H)	DPF: Dew Point Temperature [K] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg_{DA}] Ha≤H≤Hs [J/kg_{DA}]
6	DSA(P,T,WB)	DSA: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
7	DSB(P,T,DP)	DSB: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
8	DSC(P,T,RH)	DSC: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
9	DSD(P,T,X)	DSD: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]

Table III–2.2–1 Moist Air as Real Fluid Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
10	DSE(P,T,H)	DSE: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
11	DSF(P,X,H)	DSF: Degree of Saturation [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
50	ENHFAC(P,T)	ENHFAC: Enhancement Factor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C]
89	FC('A')	FC: Fundamental Constants MA: 'A'='MA':28.9645 Relative Molecular Weight of Dry Air MW: 'A'='MW':18.01528 Relative Molecular Mass of Water RA: 'A'='RA':461.520 Gas Constant of Dry Air RW: 'A'='RW':287.055 Gas Constant of Water Vapor	one of 'MA', 'MW', 'RA' and 'RW'
12	HA(P,T,WB)	HA: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
13	HB(P,T,DP)	HB: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
14	HC(P,T,RH)	HC: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
15	HD(P,T,X)	HD: Specific Enthalpy [J/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg$_{DA}$]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'MIXTURE OF DRY AIR AND WATER VAPOR' S: 'A'='S': 'MOIST AIR' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
49	PST(T)	PST: Saturation Pressure of Pure Water [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C]	173.15≤T≤473.15 [K] −100≤T≤200 [°C]

Table III–2.2–1 Moist Air as Real Fluid Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
22	RHA(P,T,WB)	RHA: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
23	RHB(P,T,DP)	RHB: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
24	RHD(P,T,X)	RHD: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
25	RHE(P,T,H)	RHE: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]
26	RHF(P,X,H)	RHF: Relative Humidity [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg_{DA}] Ha≤H≤Hs [J/kg_{DA}]
16	RWA(P,T,WB)	RWA: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
17	RWB(P,T,DP)	RWB: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
18	RWC(P,T,RH)	RWC: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
19	RWD(P,T,X)	RWD: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]

Table III–2.2–1 Moist Air as Real Fluid Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
20	RWE(P,T,H)	RWE: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
21	RWF(P,X,H)	RWF: Mole Fraction of Water Vapor [–] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
27	SA(P,T,WB)	SA: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
28	SB(P,T,DP)	SB: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
29	SC(P,T,RH)	SC: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
30	SD(P,T,X)	SD: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg$_{DA}$]
31	SE(P,T,H)	SE: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]
32	SF(P,X,H)	SF: Specific Entropy [J/(kg$_{DA}$·K)] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
33	TF(P,X,H)	TF: Dry-Bulb Temperature [K], [°C] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
34	VA(P,T,WB)	VA: Specific Volume [m^3/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]

Table III–2.2–1 Moist Air as Real Fluid Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	VB(P,T,DP)	VB: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
36	VC(P,T,RH)	VC: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
37	VD(P,T,X)	VD: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
38	VE(P,T,H)	VE: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]
39	VF(P,X,H)	VF: Specific Volume [m^3/kg_{DA}] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg_{DA}] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg_{DA}] Ha≤H≤Hs [J/kg_{DA}]
40	WBB(P,T,DP)	WBB: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
41	WBC(P,T,RH)	WBC: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
42	WBD(P,T,X)	WBD: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] X: Humidity Ratio [kg/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤X≤Xs [kg/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤X≤Xs [kg/kg_{DA}]
43	WBE(P,T,H)	WBE: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg_{DA}]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg_{DA}] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg_{DA}]

Table III–2.2–1 Moist Air as Real Fluid Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
44	WBF(P,X,H)	WBF: Wet-Bulb Temperature [K] P∗: Total Pressure [Pa], [bar] X: Humidity Ratio [kg/kg$_{DA}$] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] PST/0.99≤P≤50 [bar] 0≤X≤Xs [kg/kg$_{DA}$] Ha≤H≤Hs [J/kg$_{DA}$]
45	XA(P,T,WB)	XA: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] WB∗: Wet-Bulb Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤WB≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤WB≤T≤200 [°C]
46	XB(P,T,DP)	XB: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] DP∗: Dew Point Temperature [K], [°C]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤DP≤T≤473.15 [K] PST/0.99≤P≤50 [bar] −100≤DP≤T≤200 [°C]
47	XC(P,T,RH)	XC: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] RH: Relative Humidity [–]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] 0≤RH≤1.0 [–] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] 0≤RH≤1.0 [–]
48	XE(P,T,H)	XE: Humidity Ratio [kg/kg$_{DA}$] P∗: Total Pressure [Pa], [bar] T∗: Dry-Bulb Temperature [K], [°C] H: Specific Enthalpy [J/kg$_{DA}$]	PST/0.99≤P≤5.0×10^6 [Pa] 173.15≤T≤473.15 [K] Ha≤H≤Hs [J/kg$_{DA}$] PST/0.99≤P≤50 [bar] −100≤T≤200 [°C] Ha≤H≤Hs [J/kg$_{DA}$]

IV M-PROPATH: Binary Mixtures

Binary mixtures in part IV stand for those that have been formulated as binary mixtures by their own formulations.

1. General Features

1.1 SUBPROGRAM REFERENCE

Every M-PROPATH user has to make the initiation process by writing the following 2 lines before the first REFERENCE to a M-PROPATH SUBPROGRAM (FUNCTION SUBPROGRAM or SUBROUTINE SUBPROGRAM) in the MAIN PROGRAM. If a user happens to want to use other settings in other places of his/her PROGRAM UNIT, he/she is supposed to do a similar at those places.

```
CALL KPAMES(value of KPA, value of MESS)
CALL STNKAS(value of KSTAN, value of KAS)
```

The arguments of these SUBROUTINE SUBPROGRAMs specify the system of units, reference values of enthalpy and entropy and necessity of listing error messages to erroneous SUBPROGRAM REFERENCEs on the standard output device. All arguments in these SUBROUTINE SUBPROGRAMs are INTEGERs. KPA specifies the units of pressure and temperature, and KAS unit of the amount of substance. KSTAN selects the reference values of enthalpy and entropy. The relation between KPA and the units of pressure and temperature and that between KAS and the unit of amount of substance are shown in 1.3. M-PROPATH does not return any messages when MESS=0, while it does when MESS≠0. KSTAN differs from one mixture to another, and is described in the section of each mixture.

1.2 Operations to Manage Erroneous SUBPROGRAM REFERENCE

A predetermined sequence of operations will occur to process an erroneous SUBPROGRAM REFERENCE when an improper SUBPROGRAM REFERENCE has been done. Erroneous SUBPROGRAM REFERENCEs are grouped into 2 levels, with the ascending severity of user's mistake. A user has committed a more serious mistake when a level 2 ERROR occurs than when level 1 ERROR does.

1.2.1 Level 1 ERROR (Convergence Failure)

The method of iterations built in to some of the M-PROPATH SUBPROGRAMs to solve implicit relations will not work somehow from time to time. M-PROPATH stops further iterations after executing the preset number of iterations. Though the user is not responsible for level 1 ERROR, the M-PROPATH detects this type of ERROR time to time, unfortunately.

A level 1 ERROR is processed as below.

FUNCTION SUBPROGRAM

value of REAL FUNCTION returned to the CALLing program : −1.0E+10
value of INTEGER FUNCTION returned to the CALLing Program : −1
output to the standard output device :
**** NO CONVERGENCE AT (NAME OF FUNCTION CALLED) ****

SUBROUTINE SUBPROGRAM

value of error detection cord : −1
output to the standard output device :
**** NO CONVERGENCE AT (NAME OF SUBROUTINE CALLED) ****

1.2.2 Level 2 ERROR (Invalid ARGUMENT(s))

A level 2 ERROR will occur when the ARGUMENT(s) a user transferred to M-PROPATH SUBPROGRAM from his/her MAIN PROGRAM fail to drop in the proper range.

A level 2 ERROR is processed as below.

FUNCTION SUBPROGRAM

value of REAL FUNCTION returned to the CALLing program : −1.0E+20
value of INTEGER FUNCTION returned to the CALLing Program : −2
output to the standard output device :
**** OUT OF RANGE AT (NAME OF FUNCTION CALLED) ****

SUBROUTINE SUBPROGRAM

value of error detection cord : −2
output to the standard output device :
**** OUT OF RANGE AT (NAME OF SUBROUTINE CALLED) ****

1.3 System of Units and Reference Value of Enthalpy and Entropy

All REAL quantities are in the fundamental SI or in the coherent derived SI with three exceptions. Pressure can be in the unit of Pascal Pa or bar, temperature in the unit of Kelvin K or degree Celsius °C. These depend on the value of INTEGER KPA when a user referred the SUBROUTINE SUBPROGRAM KPAMES(KPA, MESS) shown in 1.1. The amount of substance can be in the unit of kilomole kmol or kilogram kg. INTEGER KAS in the SUBROUTINE SUBPROGRAM STNKAS(KSTAN, KAS) in 1.1 switches this. These go as shown in the table below. The INTEGER KSTAN in the SUBROUTINE SUBPROGRAM STNKAS(KSTAN, KAS) controls the reference values of enthalpy and entropy and is explained for each specific mixture, since they differ from one mixture to another.

Table IV-1.3-1 Units of Pressure and Temperature Specified by `KPA`

KPA	unit of pressure	unit of temperature
0	Pa	K
1	bar	°C
2	bar	K
3	Pa	°C
others	Pa	K

Table IV-1.3-2 Amount of Substance Specified by `KAS`

KAS	amount of substance
0	kmol
1	kg
others	kmol

1.4 Reserved NAMEs

M-PROPATH uses a lot of NAMEs, listed below, for its own purpose. These are the NAMEs of SUBPROGRAMs and NAMED COMMON BLOCK to which a user can access directly and NAMEs of SUBPROGRAM headed by "FMF" which an user cannot access. A user is supposed to use the NAMEs of SUBPROGRAM and COMMON BLOCK only when he/she does so in the original meaning. The letters in the first column are the first LETTERs in the NAMEs listed in the same line.

Name of COMMON BLOCK, FUNCTION and SUBROUTINE

F FCM, FMF**** , COMMON /FMFC/
I IDENTM, IPHASE
K KPAMES
P PSTM
S STNKAS, SUBM, SUBMIX, SUBPB, SUBPD, SUBPST, SUBPUR, SUBTB, SUBTD, SUBTSP, SUBXY
T T68, T90, TSPM
U COMMON /UNIT/

1.5 Terminology, Symbols and Compositions

The component with lower critical temperature is to be called as the first component. A composition is supposed to stand for the mole fraction or the mass fraction of the first component. The symbolic distinction of the compositions between the two phases and that between two saturation temperatures are done as shown below.

total composition Z	:	composition of mixture as a whole
composition at liquid phase X	:	liquid composition at vapor-liquid equilibrium
composition at vapor phase Y	:	vapor composition at vapor-liquid equilibrium
temperature at dew point	:	The lowest temperature of vapor for given pressure and Z
temperature at bubble point	:	The highest temperature of liquid for given pressure and Z
pressure at dew point	:	The highest pressure of vapor for given temperature and Z
pressure at bubble point	:	The lowest pressure of liquid for given temperature and Z

1.6 The NAME of FUNCTION and SUBROUTINE SUBPROGRAMS

NAMEs of FUNCTIONs and SUBROUTINEs are shown below and the full descripion of these SUBPROGRAMs is given in 1.7. Some of these SUBPROGRAMs have not been prepared in each equation shown in 2. and after. These are listed there for each equation.

1.6.1 FUNCTION

REAL valued FUNCTION (conversion of temperature scale)

T68 = conversion from ITS–1990 to IPTS–1968
T90 = conversion from IPTS-1968 to ITS-1990

REAL valued FUNCTION (pure component)

FCM = fundamental constants of pure components
PSTM = vapor pressure of pure components
TSPM = saturation temperature of pure components

REAL valued FUNCTION (mixture)

AKG = mole fraction to mass fraction conversion
AKMOL = mass fraction to mole fraction conversion

INTEGER valued FUNCTION

IPHASE = distinction between phases of mixture

CHARACTER valued FUNCTION

IDENTM = name of pure components and version number

1.6.2 SUBROUTINE

initialization

KPAMES/STNKAS = See 1.1

pure component

SUBPST = saturation properies of pure components (temperature input)
SUBPUR = single phase properties of pure component
SUBTSP = saturation properties of pure components (pressure input)

mixture

SUBPB = bubble point pressure and other properties of mixture (temperature and X input)
SUBPD = dew point pressure and other properties of mixture (temperature and Y input)
SUBTB = bubble point temperature and other properties of mixture (pressure and X input)
SUBTD = dew point temperature and other properties of mixture (pressure and Y input)
SUBM = adiabatic and isobaric mixing of two streams
SUBMIX = properties of mixture
SUBXY = properties of mixture at VLE
SUBMXH = isobaric mixing of two mixtures with different composition, enthalpy input
SUBMXT = isobaric mixing of two mixtures with different composition, temperature input

1.7 Descriptions of FUNCTIONs and SUBROUTINEs

Shown in alphabetical order of NAMEs.

AKG

REAL FUNCTION **AKG(Z)** : mole fraction to mass fraction conversion

REAL Z : mole fraction [kmol/kmol]
REAL AKG : mass fraction[kg/kg]

AKMOL

REAL FUNCTION **AKMOL(Z)** : mass fraction to mole fraction conversion

REAL Z : mass fraction [kg/kg]
REAL AKMOL : mole fraction [kmol/kmol]

FCM

REAL FUNCTION **FCM(I,A)** : fundamental constants of pure components

INTEGER I : component
  1 : first component
  2 : second componet
CHARACTER*1 A : kind of fundamental constants of pure components
  'M' : molar mass [kg/kmol]
  'R' : gas constant [J/(kg·K)]
  'T' : critical temperature [K], [°C]
  'P' : critical pressure [Pa], [bar]
  'V' : critical volume [m^3/kmol], [m^3/kg]
  'E' : acentric factor [-]

IDENTM

CHARACTER*40 FUNCTION **IDENTM(I,A)** : name of pure component and version number

INTEGER I : component
  1 : first component
  2 : second component
CHARACTER*1 A : kind of characters returned
  'C' : molecular formula
  'S' : name of substance
  'V' : version number

IPHASE

INTEGER FUNCTION **IPHASE(T,P,Z)** : distinction between phases of mixture

REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]
REAL Z : composition [kmol/kmol] , [kg/kg]

value of IPHASE

1 : single phase
2 : two phase
−1 : Convergence failure
−2 : invalid ARGUMENT(s)

KPAMES

SUBROUTINE **KPAMES(KPA,MESS)**

See 1.1

PSTM

REAL FUNCTION **PSTM(I,T)** : saturation pressure of pure component

INTEGER	I	: component
		1 : first component
		2 : second component
REAL	T	: temperature [K] , [°C]
REAL	PSTM	: saturation pressure [Pa], [bar]

STNKAS

SUBROUTINE **STNKAS(KSTAN,KAS)**

See 1.1

SUBMIX

SUBROUTINE **SUBMIX(I,J,T,P,Z,V,H,S)** : properties of mixture

INTEGER	I	: type of problem(input)
		1 : inputs (T,P,Z) → outputs (V,H,S)
		2 : inputs (P,Z,H) → outputs (T,V,S)
		3 : inputs (P,Z,S) → outputs (T,V,H)
		4 : inputs (P,Z,V) → outputs (T,H,S)
INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	T	: temperature [K] , [°C]
REAL	P	: pressure [Pa] , [bar]
REAL	Z	: total composition [kmol/kmol] , [kg/kg]
REAL	V	: volume [m^3/kmol] , [m^3/kg]
REAL	H	: enthalpy [J/kmol] , [J/kg]
REAL	S	: entropy [J/(kmol·K)] , [J/(kg·K)]

SUBMXH

SUBROUTINE **SUBMXH(J,T,P,ZA,ZB,Z,V,HA,HB,H,S,W)** : isobaric mixing of two mixtures with different compositions, enthalpy input

input

REAL	P	: pressure [Pa] , [bar]
REAL	ZA	: total composition of A [kmol/kmol] , [kg/kg]
REAL	ZB	: total composition of B [kmol/kmol] , [kg/kg]
REAL	HA	: enthalpy of A [J/kmol] , [J/kg]
REAL	HB	: enthalpy of B [J/kmol] , [J/kg]
REAL	W	: Fraction of A in Mixing [kmol/kmol] , [kg/kg]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	T	: temperature after mixing [K] , [°C]
REAL	Z	: total composition after mixing [kmol/kmol] , [kg/kg]
REAL	V	: volume after mixing [m^3/kmol] , [m^3/kg]
REAL	H	: enthalpy after mixing [J/kmol] , [J/kg]
REAL	S	: entropy after mixing [J/(kmol·K)] , [J/(kg·K)]

SUBMXT

SUBROUTINE **SUBMXT(J,T,P,ZA,ZB,Z,V,TA,TB,H,S,W)** : isobaric mixing of two mixtures with different compositions, temperature input

input
- REAL P : pressure [Pa] , [bar]
- REAL ZA : total composition of A [kmol/kmol] , [kg/kg]
- REAL ZB : total composition of B [kmol/kmol] , [kg/kg]
- REAL TA : temperature of A [K] , [°C]
- REAL TB : temperature of B [K] , [°C]
- REAL W : Fraction of A in Mixing [kmol/kmol] , [kg/kg]

output
- INTEGER J : error detection code
  - −1 : convergence failure
  - −2 : invalid ARGUMENT(s)
- REAL T : temperature after mixing [K] , [°C]
- REAL Z : total composition after mixing [kmol/kmol] , [kg/kg]
- REAL V : volume after mixing [m^3/kmol] , [m^3/kg]
- REAL H : enthalpy after mixing [J/kmol] , [J/kg]
- REAL S : entropy after mixing [J/(kmol·K)] , [J/(kg·K)]

SUBPB

SUBROUTINE **SUBPB(J,T,P,X,V,H,S)**
: bubble point pressure and other properties of mixture (temperature and X input)

input
- REAL T : temperature [K] , [°C]
- REAL X : composition [kmol/kmol] , [kg/kg]

output
- INTEGER J : error detection code
  - −1 : convergence failure
  - −2 : invalid ARGUMENT(s)
- REAL P : bubble point pressure [Pa] , [bar]
- REAL V : bubble point volume [m^3/kmol] , [m^3/kg]
- REAL H : bubble point enthalpy [J/kmol] , [J/kg]
- REAL S : bubble point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPD

SUBROUTINE **SUBPD(J,T,P,Y,V,H,S)**
: dew point pressure and other properties of mixture (temperature and Y input)

input
- REAL T : temperature [K] , [°C]
- REAL Y : composition [kmol/kmol] , [kg/kg]

output
- INTEGER J : error detection code
  - −1 : convergence failure
  - −2 : invalid ARGUMENT(s)
- REAL P : dew point pressure [Pa] , [bar]
- REAL V : dew point volume [m^3/kmol] , [m^3/kg]
- REAL H : dew point enthalpy [J/kmol] , [J/kg]
- REAL S : dew point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPST

SUBROUTINE **SUBPST(I,J,T,PS,VL,VV,HL,HV,SL,SV)**
: saturation properties of pure component (temperature intput)

input
- INTEGER I : component

1 : first component
2 : second component
REAL T : temperature [K] , [°C]

output
INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL PS : saturation pressure [Pa] , [bar]
REAL VL : liquid volume [m^3/kmol] , [m^3/kg]
REAL VV : vapor volume [m^3/kmol] , [m^3/kg]
REAL HL : liquid enthalpy [J/kmol] , [J/kg]
REAL HV : vapor enthalpy [J/kmol] , [J/kg]
REAL SL : liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL SV : vapor entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPUR

SUBROUTINE **SUBPUR(I,J,T,P,V,H,S)** : single phase properties of pure component

input
INTEGER I : component
1 : first component
2 : second component
REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]

output
output are those of satureted liquid, when temperature-pressure is on saturation line

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL V : volume [m^3/kmol] , [m^3/kg]
REAL H : enthalpy [J/kmol] , [J/kg]
REAL S : entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTB

SUBROUTINE **SUBTB(J,T,P,X,V,H,S)**
: bubble point temperature and other properties of mixture (pressure and X input)

input
REAL P : pressure [Pa] , [bar]
REAL X : composition [kmol/kmol] , [kg/kg]

output
INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : bubble point temperature [K] , [°C]
REAL V : bubble point volume [m^3/kmol] , [m^3/kg]
REAL H : bubble point enthalpy [J/kmol] , [J/kg]
REAL S : bubble point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTD

SUBROUTINE **SUBTD(J,T,P,Y,V,H,S)**
: dew point temperature and other properties of mixture (pressure and Y input)

input
REAL P : pressure [Pa] , [bar]
REAL Y : composition [kmol/kmol] , [kg/kg]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	T	: dew point temperature[K] , [°C]
REAL	V	: dew point volume [m^3/kmol] , [m^3/kg]
REAL	H	: dew point enthalpy[J/kmol] , [J/kg]
REAL	S	: dew point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTSP

SUBROUTINE **SUBTSP(I,J,TS,P,VL,VV,HL,HV,SL,SV)**
: saturation properties of pure component (pressure input)

input

INTEGER	I	: component
		1 : first component
		2 : second component
REAL	P	: pressure [Pa] , [bar]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	TS	: temperature [K] , [°C]
REAL	VL	: liquid volume [m^3/kmol] , [m^3/kg]
REAL	VV	: vapor volume [m^3/kmol] , [m^3/kg]
REAL	HL	: liquid enthalpy [J/kmol] , [J/kg]
REAL	HV	: vapor enthalpy [J/kmol] , [J/kg]
REAL	SL	: liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL	SV	: vapor entropy [J/(kmol·K)] , [J/(kg·K)]

SUBXY

SUBROUTINE **SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)** :properties of mixture at VLE

input

REAL	T	: temperature [K] , [°C]
REAL	P	: pressure [Pa] , [bar]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	X	: composition of liquid X [kmol/kmol] , [kg/kg]
REAL	Y	: composition of vapor Y [kmol/kmol] , [kg/kg]
REAL	VL	: liquid volume [m^3/kmol] , [m^3/kg]
REAL	VV	: vapor voluem [m^3/kmol] , [m^3/kg]
REAL	HL	: liquid enthalpy [J/kmol] , [J/kg]
REAL	HV	: vapor enthalpy [J/kmol] , [J/kg]
REAL	SL	: liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL	SV	: vapor entropy [J/(kmol·K)] , [J/(kg·K)]

TSPM

REAL FUNCTION **TSPM(I,P)** saturation temperature of pure components

INTEGER	I	: component
		1 : first component
		2 : second component
REAL	P	: pressure of pure component [Pa] , [bar]
REAL	TSPM	: saturation temperature [K], [°C]

2. Individual Mixture and Formulation

2.1 Ammonia–Water(Ibrahim and Klein)

Thermodynamic properties are evaluated by the formulation of Ibrahim et al. [1]. No provision is made for transport properties at this moment.

2.1.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.1.2 The Names of Substance, Library File and Single Shot Program

Substance:	Ammonia-Water Mixture
First Component:	Ammonia
Second Component:	Water
Library File fot UNIX:	`libjawmx.a`
Library File for DOS,Windows95/NT:	JAWMX.LIB
Single Shot Program for UNIX:	`awmx-ss`
Single Shot Program for DOS,Windows95/NT:	AWMX–SS.EXE

2.1.3 Important Constants and Others

Table IV-2.1-1 Molecular Formula,Relative Molecular Mass and Gas Constant

	Molecular Formula	Relative Molecular Mass	Gas Constant
Ammonia	NH_3	17.03026kg/kmol	488.2197×10^3J/(kg·K)
Water	H_2O	18.0153kg/kmol	461.5249×10^3J/(kg·K)

Table IV-2.1-2 Critical Constant

	Critical temperature	Critical pressure	Critical specific volume
Ammonia	405.4K 132.35°C	11.304×10^6Pa 113.04bar	72.46×10^{-3}m^3/kmol 4.255×10^{-3}m^3/kg
Water	647.30K 374.15°C	22.12×10^6Pa 221.2bar	57.11×10^{-3}m^3/kmol 3.170×10^{-3}m^3/kg

Table IV-2.1-3 Reference State Specified by `KSTAN`

KSTAN	Standard state and value of enthalpy and entropy
0	comforms to reference[1] Ammonia T_0 =322.52K, p_0 =20.0bar, T_B =100K : $h^l_{oR} = h^l_o/(RT_B)$=4.878573kJ/kmol : $h^v_{oR} = h^v_o/(RT_B)$=26.468879kJ/kmol : $s^l_{oR} = s^l_o/R$=1.644773kJ/(kmol·K) : $s^v_{oR} = s^v_o/R$=8.339026kJ/(kmol·K) Water T_0 =507.05K, p_0 =30.0bar, T_B =100K : $h^l_{oR} = h^l_o/(RT_B)$=21.821141kJ/kmol : $h^v_{oR} = h^v_o/(RT_B)$=60.965058kJ/kmol : $s^l_{oR} = s^l_o/R$=5.733498kJ/(kmol·K) : $s^v_{oR} = s^v_o/R$=13.453430kJ/(kmol·K)
1	enthalpy and entropy of saturated liquid pure ammonia at 273.15K 200kJ/kg, 1kJ/(kg·K) enthalpy and entropy of saturated liquid pure water at 273.15K 200kJ/kg, 1kJ/(kg·K)
others	the same with when KSTAN=0

2.1.4 Formula

A correction to [1] has been made as below.

11th term of r.h.s. of eq.(7) : $C_2(P_r/T_r^3 - 4P_{r,0}/T_r^3 + 3P_{r,0}T_r/T_{r,0}^4)$
$\rightarrow C_2(P_r/T_r^3 - 4P_{r,0}/T_{r,0}^3 + 3P_{r,0}T_r/T_{r,0}^4)$

2.1.5 Valid Range

$$0.2[\mathrm{bar}]<p<110[\mathrm{bar}]$$
$$230[\mathrm{K}]<T<600[\mathrm{K}]$$

2.1.6 Example of User's PROGRAM UNIT

Sample Program 1

example1.for :

```
c     ------------------------------------------------
c       This program calculates temperature at bubble
c       point (p=8[bar])from z=0.0 to 1.0[kg NH3/kg]
c       at every 0.1[kg NH3/kg] interval.
c     ------------------------------------------------
      REAL T,P,Z,V,H,S
      INTEGER I,J
C
c     ----------------------------------------------
c       T=[deg],p=[bar],quantity=[kg]
c       standard state=(273.15[K],saturated liquid)
c     ----------------------------------------------
      CALL KPAMES(1,1)
      CALL STNKAS(1,1)
C
c     ----------------------------------------
c       Bubble point pressure using
c       subtb.
c     ----------------------------------------
      P=8.0
      DO 10 I=0,10
         Z=FLOAT(I)*0.1
         CALL SUBTB(J,T,P,Z,V,H,S)
         WRITE(*,*) Z,T
 10   CONTINUE
      STOP
      END
C
c     ------------------------------
c               Results
c     ------------------------------
c      0.000000E+00      170.330100
c      1.000000E-01      143.563200
c      2.000000E-01      118.597400
c      3.000000E-01       95.639790
c      4.000000E-01       74.913720
c      5.000000E-01       57.048260
c      6.000000E-01       42.734430
c      7.000000E-01       32.359450
c      8.000000E-01       25.701210
c      9.000000E-01       21.752430
c          1.000000       18.764890
```

Sample Program 2

example2.for :

```
c     --------------------------------------------
c       This program calculates the properties
c       in saturated state at p=1.0[bar],T=150[K]
c     --------------------------------------------
      REAL T,P,X,Y,VL,VV,HL,HV,SL,SV
      INTEGER J
C
c     ------------------------------------
c       T=[K],p=[Pa]
c       standard state=(bibliography [1])
c       unit of quantity=[kmol]
c     ------------------------------------
      CALL KPAMES(0,1)
      CALL STNKAS(0,0)
C
c     ----------------------------------------------
c       Properties in saturated state.
c     ----------------------------------------------
      P=5.0E5
      T=300.0
      CALL SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)
      IF (J.NE.0) THEN
         WRITE(*,*) ' ERROR IN SUBXY J=',J
         STOP
      ENDIF
      HL=HL*1.0E-6
      HV=HV*1.0E-6
      SL=SL*1.0E-3
      SV=SV*1.0E-3
      WRITE(*,*) '  X[kmol NH3/kmol]=',X, '    y[kmol NH3/kmol]=',Y
      WRITE(*,*) ' vL[m^3/kmol]     =',VL,'  vV[m^3/kmol]     =',VV
      WRITE(*,*) ' hL[MJ/kmol]      =',HL,'  hV[MJ/kmol]      =',HV
      WRITE(*,*) ' sL[MJ/(kmol K)]  =',SL,'  sV[MJ/(kmol K)]  =',SV
      STOP
      END
C
c     ------------------------------------------------------------------
c          Results
c     ------------------------------------------------------------------
c     X[kmol NH3/kmol]=   6.188429E-01   y[kmol NH3/kmol]=   9.988968E-01
c    vL[m^3/kmol]     =   2.220031E-02  vV[m^3/kmol]     =       4.716768
c    hL[MJ/kmol]      =      -1.828154  hV[MJ/kmol]      =      22.576830
c    sL[MJ/(kmol K)]  =       4.394936  sV[MJ/(kmol K)]  =      81.492060
```

2.1.7 Sample Output of Single Shot Program

```
========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                     |
|   an Application Program by M-PROPATH Ver.9.1                        |
|   Thermophysical Properties of Ammonia-Water Mixtures                |
|----------------------------------------------------------------------|
|  ## First Menu ##                                                    |
| No.                      Current                                     |
| 1 --> Go to Second Menu                                              |
| 2 --> Read Help                                                      |
| 3 --> Set Logfile       [OFF]                                        |
| 0 --> Quit                                                           |
========================================================================
Input No.
2

 This is help for this program (AWMX-SS.EXE)
  Nomenclature
 ==== First Charactor ====
```

```
   H : Enthalpy
   P : Pressure
   S : Entropy
   T : Temperature
   V : Volume
   X : Ammonia Composition of Liquid
   Y : Ammonia Composition of Vapor
   Z : Total Composition of Ammonia
 ==== Second Charactor ====
   B : Bubble Point
   D : Dew Point
   L : Liquid
   V : Vapor

----- Hit RETURN Key -----

=========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                      |
|   an Application Program by M-PROPATH Ver.9.1                         |
|   Thermophysical Properties of Ammonia-Water Mixtures                 |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                       Current                                     |
| 1 --> Go to Second Menu                                               |
| 2 --> Read Help                                                       |
| 3 --> Set Logfile       [OFF]                                         |
| 0 --> Quit                                                            |
=========================================================================
Input No.
3

 1: Logfile ON
 2: Logfile OFF
Input No.
1
Input Filename
AWMIX.LOG
=========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                      |
|   an Application Program by M-PROPATH Ver.9.1                         |
|   Thermophysical Properties of Ammonia-Water Mixtures                 |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                       Current                                     |
| 1 --> Go to Second Menu                                               |
| 2 --> Read Help                                                       |
| 3 --> Set Logfile       [ON] AWMIX.LOG                                |
| 0 --> Quit                                                            |
=========================================================================
Input No.
1
================================================================
| ## Second Menu ##                                            |
|  <Single and Two Phase States>                               |
| No.  Input                    Output                         |
| 1 --(P,T,Z)-->    H  HL HV S  SL SV V  VL VV X  Y  QUALITY   |
| 2 --(P,Z,H)--> T     HL HV S  SL SV V  VL VV X  Y  QUALITY   |
| 3 --(P,Z,S)--> T  H  HL HV    SL SV V  VL VV X  Y  QUALITY   |
| 4 --(P,Z,V)--> T  H  HL HV S  SL SV    VL VV X  Y  QUALITY   |
|--------------------------------------------------------------|
|  <Two Phase State>                                           |
| 5 --(P,Z)----> X=Z : TB HB SB VB    Y=Z : TD HD SD VD        |
| 6 --(T,Z)----> X=Z : PB HB SB VB    Y=Z : PD HD SD VD        |
| 7 --(P,T)----> Coexisting Phases: X  Y  HL HV SL SV VL VV    |
|--------------------------------------------------------------|
| 8 -----------> Fundamental Constants                         |
| 9 -----------> Conversion of Composition and Relative        |
|                Molcular Mass of Mixture                      |
|10 -----------> Change System of Unit, and Standard Values of|
|                Enthalpy and Entropy                          |
|99 -----------> Return to First Menu                          |
```

```
| 0 -----------> Quit                                          |
===============================================================
Input No.
10

=======================================================
 No.                                   current
=======================================================
 1 --> Pressure and Temperature    [bar, C]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [1] Ibrahim & Klein
 0 --> Return to Second Menu
=======================================================
Input No.
1

===============================
 No.  <Pressure> <Temperature>
===============================
 1 -->   Pa           K
 2 -->   bar          C
 3 -->   bar          K
 4 -->   Pa           C
===============================
Input No.
1

=======================================================
 No.                                   current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [1] Ibrahim & Klein
 0 --> Return to Second Menu
=======================================================
Input No.
2

===========================
 No.   Amount of Substance
 1 -->   kmol
 2 -->   kg
===========================
Input No.
1

=======================================================
 No.                                   current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [1] Ibrahim & Klein
 0 --> Return to Second Menu
=======================================================
Input No.
3

================================================
 No.   Standard States and Values of h and s
 1 --> As defined in:
       O.M.Ibrahim and S.A.Klein, Thermodynamic
       Properties  of  Ammonia-Water  Mixtures,
       ASHRAE Transactions: Symposia, vol.99,
       1993, pp.1495
 2 --> Convention of International Institute of
       Refrigeration(IIR):
       h=200[kJ/kg], s=1.0[kJ/(kg*K)]
       Saturated Pure Liquids at 0[C]
================================================
Input No.
2
```

```
=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [2] IIR
 0 --> Return to Second Menu
=======================================================
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
9

==================================================================
 Conversion of Composition and Relative Molecular Mass of Mixture
==================================================================

 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
1
Input Z[kmol/kmol]
0.5
 Z  =    .50000000[kmol/kmol]
 Z  =    .48594630[kg/kg]
 Relative Molecular Mass of Mixture =      17.52278000[kg/kmol]
 Relative Molecular Mass of Ammonia =      17.03026000[kg/kmol]
 Relative Molecular Mass of Water   =      18.01530000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
2
Input Z[kg/kg]
0.5
 Z  =    .50000000[kg/kg]
 Z  =    .51405370[kmol/kmol]
 Relative Molecular Mass of Mixture =      17.50894000[kg/kmol]
 Relative Molecular Mass of Ammonia =      17.03026000[kg/kmol]
 Relative Molecular Mass of Water   =      18.01530000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
8

=======================
 Fundamental Constants
=======================
    <Constants>               <Ammonia>       <Water>
Relative Molecular Mass       17.03026000     18.01530000  [kg/kmol]
Gas Constants                488.18980000    461.49660000  [J/(kg*K)]
Critical Temperature         405.65000000    647.13000000  [K]
                             132.50000000    373.98000000  [C]
Critical Pressure            112.78000000    220.55000000  [bar]
```

```
Critical Volume             .72470000E-01   .55950000E-01  [m**3/kmol]
                            .42553670E-02   .31056930E-02  [m**3/kg]
----- Hit RETURN Key -----

=================================================================
| ## Second Menu ##                                             |
 contents not shown
=================================================================
Input No.
1

=====================================
 (P,T,Z) --> H, S, V, QUALITY
            X, HL, SL, VL
            Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
250.0
Input Z[kmol/kmol]
0.5
T  =     250.00000000[K]          P  =     100.00000000[kPa]
Z  =         .50000000[kmol/kmol]  H  =   -2604.64600000[kJ/kmol]
S  =       7.09724800[kJ/(kmol*K)]V  =    .20689990E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
300.0
Input Z[kmol/kmol]
0.5
T  =     300.00000000[K]          P  =     100.00000000[kPa]
Z  =         .50000000[kmol/kmol]  H  =    8604.31400000[kJ/kmol]
S  =      47.05576000[kJ/(kmol*K)]V  =    .64970690E+01[m**3/kmol]
X  =         .32842270[kmol/kmol]  Y  =        .98106720[kmol/kmol]
HL =    2107.11700000[kJ/kmol]    HV =   26821.11000000[kJ/kmol]
SL =      23.16687000[kJ/(kmol*K)]SV =     114.03530000[kJ/(kmol*K)]
VL =    .19941250E-01[m**3/kmol]  VV =    .24657600E+02[m**3/kmol]
QUALITY =       .26289550[kmol/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
=================================================================
| ## Second Menu ##                                             |
 contents not shown
=================================================================
Input No.
2

=====================================
 (P,Z,H) --> T, S, V, QUALITY
            X, HL, SL, VL
            Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input H[J/kmol]
-2604646.0
T  =     250.00000000[K]          P  =     100.00000000[kPa]
Z  =         .50000000[kmol/kmol]  H  =   -2604.64600000[kJ/kmol]
S  =       7.09724600[kJ/(kmol*K)]V  =    .20689990E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
=================================================================
| ## Second Menu ##                                             |
```

```
 contents not shown
================================================================
Input No.
3

======================================
 (P,Z,S) --> T, H, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
======================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input S[J/(kmol*K)]
7097.248
T  =     250.00000000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =   -2604.64600000[kJ/kmol]
S  =       7.09724900[kJ/(kmol*K)]V  =    .20689990E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
4

========================================
 (P,Z,V) --> T, H, S, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
========================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input V[m**3/kmol]
0.02068999
T  =     256.96330000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =   -2024.96600000[kJ/kmol]
S  =       9.38436200[kJ/(kmol*K)]V  =    .20689990E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
5

===============================================
 (P,Z) --> X=Z : TB, HB, SB, VB
           Y=Z : TD, HD, SD, VD
===============================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
P  =     100.00000000[kPa]        Z  =        .50000000[kmol/kmol]
TB =     272.16450000[K]          TD =     355.92290000[K]
HB =    -790.82810000[kJ/kmol]    HD =   39835.19000000[kJ/kmol]
SB =      14.05111000[kJ/(kmol*K)]SD =     139.75980000[kJ/(kmol*K)]
VB =    .20754300E-01[m**3/kmol]  VD =    .29210500E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
```

```
==================================================================
| ## Second Menu ##                                              |
 contents not shown
==================================================================
Input No.
6

===============================================
 (T,Z) --> X=Z : PB, HB, SB, VB
           Y=Z : PD, HD, SD, VD
===============================================
Input Z[kmol/kmol]   (Z < 0 : Second Menu)
0.5
Input T[K]
300.0
T  =     300.00000000[K]          Z  =        .50000000[kmol/kmol]
PB =     296.73480000[kPa]        PD =       6.83075500[kPa]
HB =    1411.31000000[kJ/kmol]    HD =   38011.88000000[kJ/kmol]
SB =      21.74171000[kJ/(kmol*K)]SD =     156.36270000[kJ/(kmol*K)]
VB =    .21098430E-01[m**3/kmol]  VD =    .36442130E+03[m**3/kmol]

Input Z[kmol/kmol]   (Z < 0 : Second Menu)
-1
==================================================================
| ## Second Menu ##                                              |
 contents not shown
==================================================================
Input No.
7

==============================================
 (P,T) --> Coexisting Phases
           X, HL, SL, VL
           Y, HV, SV, VV
==============================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
300.0
T  =     300.00000000[K]          P  =     100.00000000[kPa]
X  =        .32842270[kmol/kmol]  Y  =        .98106720[kmol/kmol]
HL =    2107.11700000[kJ/kmol]    HV =   26821.11000000[kJ/kmol]
SL =      23.16687000[kJ/(kmol*K)]SV =     114.03530000[kJ/(kmol*K)]
VL =    .19941250E-01[m**3/kmol]  VV =    .24657600E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
==================================================================
| ## Second Menu ##                                              |
 contents not shown
==================================================================
Input No.
0

***** See You Again ! *****
Stop - Program terminated.
```

References

[1] O.M.Ibrahim and S.A.Klein, Thermodynamic properties of ammonia-water mixtures, ASHRAE Transactions:Symposia, CH-93-21-2, 1993

2.2 Ammonia–Water(Tillner-Roth and Friend)

Thermodynamic properties are evaluated by the formulation of Tillner-Roth et al. [1]. This uses the water equation of state by Pruss et al. [2] and ammonia equation of state by Tillner-Roth et al. [3]. No provision is made for transport properties at this moment.

Notice

This program has some problems in high pressure region. The calculation in the region may not terminate successfully from time to time.

2.2.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

2.2.2 The Names of Substance, Library File and Single Shot Program

Substance:	Ammonia-Water Mixture
First Component:	Ammonia
Second Component:	Water
Library File for UNIX:	`libjawmx2.a`
Library File for DOS,Windows95/NT:	JAWMX2.LIB
Single Shot Program for UNIX:	`awmx2-ss`
Single Shot Program for DOS,Windows95/NT:	AWMX2–SS.EXE

2.2.3 Important Constants and Others

Table IV-2.2-1 Molecular Formula,Relative Molecular Mass and Gas Constant

	Molecular Formula	Relative Molecular Mass	Gas Constant
Ammonia	NH_3	17.03026kg/kmol	488.189×10^3J/(kg·K)
Water	H_2O	18.015268kg/kmol	461.5189×10^3J/(kg·K)

Table IV-2.2-2 Critical Constant

	Critical temperature	Critical pressure	Critical specific volume
Ammonia	405.40K	11.36×10^6Pa	75.7×10^{-3}m^3/kmol
	132.25°C	113.6bar	4.44×10^{-3}m^3/kg
Water	647.096K	22.064×10^6Pa	55.9×10^{-3}m^3/kmol
	373.946°C	220.64bar	3.11×10^{-3}m^3/kg

Table IV-2.2-3 Reference State Specified by `KSTAN`

KSTAN	Values of enthalpy (or internal energy) and entropy at the reference state
0	Comforms to reference[1] For saturated liquid at the triple-point temperature of both pure components , 273.16 K for water and 195.495 K for ammonia , the internal energy and entropy have been set as : u=0 and s=0
1	Enthalpy and entropy of saturated liquid of pure ammonia at 273.15K 200kJ/kg and 1kJ/(kg·K), respectively Enthalpy and entropy of saturated liquid of pure water at 273.15K 200kJ/kg and 1kJ/(kg·K), respectively
others	The same with when KSTAN=0

2.2.4 Formula

No correction has been made to the original formulations.

2.2.5 Valid Range

$$0.01[\text{bar}]<p<400[\text{bar}]$$
$$200[\text{K}]<T<620[\text{K}]$$

2.2.6 Example of User's PROGRAM UNIT

Sample Program 1

example1.for :

```
c       --------------------------------------------------
c         This program calculateds temperature at bubble
c         points (p=10[bar])from z=0.0 to 1.0 [kg NH3/kg]
c         at every 0.1 [kg NH3/kg] interval.
c       --------------------------------------------------

      REAL T,P,Z,H,S
      INTEGER I,J

      CALL KPAMES(1,1)
      CALL STNKAS(1,1)

c      --------------------------------------------------
c         bubble point pressure using
c         subtb.
C      --------------------------------------------------
      P=10.0
      DO 10 I=0,10
              Z=FLOAT(I)*0.1
              CALL SUBTB(J,T,P,Z,V,H,S)
              WRITE(*,*) Z,T
10    CONTINUE
      STOP
      END

C
c -------------------------------------------
c Results
c -------------------------------------------
c 0.000000E+00 179.877300
c 1.000000E-01 149.922400
c 2.000000E-01 125.212800
c 3.000000E-01 101.825800
c 4.000000E-01  80.509940
c 5.000000E-01  62.563330
c 6.000000E-01  48.753480
c 7.000000E-01  39.080770
c 8.000000E-01  32.721220
c 9.000000E-01  28.394670
c     1.000000  24.894940
```

Sample Program 2

example2.for :

```
c    ---------------------------------------------
c      This program calculates the properties in
c      saturated state at 5.0[bar], T=300[K]
c    ---------------------------------------------
```

```
      REAL T,P,X,Y,VL,VV,HL,HV,SL,SV
      INTEGER J

c    ---------------------------------------------
c        T=[K], P=[Pa]
c        standard state=(bibliography [1])
c        unit of quantity=[kmol]
c    ---------------------------------------------

      CALL KPAMES(0,1)
      CALL STNKAS(0,0)

c    ---------------------------------------------
c       Properties in saturated state
c    ---------------------------------------------
      P=5.0E5
      T=300.0
      CALL SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)
      IF(J.NE.0) THEN
             WRITE(*,*) 'ERROR IN SUBXY J=',J
      ELSE
             HL=HL*1.0E-6
             HV=HV*1.0E-6
             SL=SL*1.0E-3
             SV=SV*1.0E-3
             WRITE(*,*) ' X[kmol NH3/kmol]=',X, '  Y[kmol NH3/kmol]=',Y
             WRITE(*,*) 'VL[M^3/kmol]     =',VL,' VV[M^3/kmol]     =',VV
             WRITE(*,*) 'HL[MJ/kmol]      =',HL,' HV[MJ/kmol]      =',HV
             WRITE(*,*) 'SL[MJ/(kmol.K)]  =',SL,' SV[MJ/(kmol.K)]  =',SV
      ENDIF
      STOP
      END
C
c    -----------------------------------------------------------------
c Results
c    -----------------------------------------------------------------
c    X[kmol NH3/kmol]=   6.012722E-01  Y[kmol NH3/kmol]=   9.987947E-01
c   VL[M^3/kmol]     =   2.212924E-02 VV[M^3/kmol]     =       4.723189
c   HL[MJ/kmol]      =       1.458077 HV[MJ/kmol]      =      28.437260
c   SL[MJ/(kmol.K)]  =      18.430890 SV[MJ/(kmol.K)]  =     106.415300
```

2.2.7 Sample Output of Single Shot Program

```
=========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                      |
|   an Application Program by M-PROPATH Ver.11.1                         |
|   Thermophysical Properties of Ammonia-Water Mixtures                 |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                     Current                                       |
| 1 --> Go to Second Menu                                               |
| 2 --> Read Help                                                       |
| 3 --> Set Logfile       [OFF]                                         |
| 0 --> Quit                                                            |
=========================================================================
Input No.
2

 This is help for this program (AWMX-SS2.EXE)
  Nomenclature
 ==== First Charactor ====
   H : Enthalpy
   P : Pressure
```

```
   S : Entropy
   T : Temperature
   V : Volume
   X : Ammonia Composition of Liquid
   Y : Ammonia Composition of Vapor
   Z : Total Composition of Ammonia
 ==== Second Charactor ====
   B : Bubble Point
   D : Dew Point
   L : Liquid
   V : Vapor

----- Hit RETURN Key -----

=========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                      |
|   an Application Program by M-PROPATH Ver.11.1                        |
|   Thermophysical Properties of Ammonia-Water Mixtures                 |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                       Current                                     |
| 1 --> Go to Second Menu                                               |
| 2 --> Read Help                                                       |
| 3 --> Set Logfile       [OFF]                                         |
| 0 --> Quit                                                            |
=========================================================================
Input No.
3

 1: Logfile ON
 2: Logfile OFF
Input No.
1
Input Filename
AWMIX.LOG
=========================================================================
|   Single Shot Program for Ammonia-Water Mixture,                      |
|   an Application Program by M-PROPATH Ver.11.1                        |
|   Thermophysical Properties of Ammonia-Water Mixtures                 |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                       Current                                     |
| 1 --> Go to Second Menu                                               |
| 2 --> Read Help                                                       |
| 3 --> Set Logfile       [ON] SAMPLE.LOG                               |
| 0 --> Quit                                                            |
=========================================================================
Input No.
1
================================================================
| ## Second Menu ##                                            |
|  <Single and Two Phase States>                               |
| No.  Input            Output                                 |
| 1 --(P,T,Z)-->    H  HL HV S  SL SV V  VL VV X  Y  QUALITY  |
| 2 --(P,Z,H)--> T     HL HV S  SL SV V  VL VV X  Y  QUALITY  |
| 3 --(P,Z,S)--> T  H  HL HV    SL SV V  VL VV X  Y  QUALITY  |
| 4 --(P,Z,V)--> T  H  HL HV S  SL SV    VL VV X  Y  QUALITY  |
|--------------------------------------------------------------|
|  <Two Phase State>                                           |
| 5 --(P,Z)----> X=Z : TB HB SB VB    Y=Z : TD HD SD VD        |
| 6 --(T,Z)----> X=Z : PB HB SB VB    Y=Z : PD HD SD VD        |
| 7 --(P,T)----> Coexisting Phases: X  Y  HL HV SL SV VL VV   |
|--------------------------------------------------------------|
| 8 -----------> Fundamental Constants                         |
| 9 -----------> Conversion of Composition and Relative        |
|                Molcular Mass of Mixture                      |
|10 -----------> Change System of Unit, and Standard Values of|
|                Enthalpy and Entropy                          |
|99 -----------> Return to First Menu                          |
| 0 -----------> Quit                                          |
================================================================
```

```
Input No.
10

========================================================
 No.                                 current
========================================================
 1 --> Pressure and Temperature    [bar, C]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [2]
 0 --> Return to Second Menu
========================================================
Input No.
1

===============================
 No.  <Pressure> <Temperature>
===============================
 1 -->   Pa            K
 2 -->   bar           C
 3 -->   bar           K
 4 -->   Pa            C
===============================
Input No.
2

========================================================
 No.                                 current
========================================================
 1 --> Pressure and Temperature    [ bar, C]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [2]
 0 --> Return to Second Menu
========================================================
Input No.
2

===========================
 No.   Amount of Substance
 1 -->   kmol
 2 -->   kg
===========================
Input No.
2

========================================================
 No.                                 current
========================================================
 1 --> Pressure and Temperature    [ bar, C]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [2]
 0 --> Return to Second Menu
========================================================
Input No.
3

=================================================
 No.   Standard States and Values of h and s
 1 --> As defined in :
       Reiner Tillner-Roth and Daniel G. Friend
       A Helmholtz  Free Energy Formulation  of
       the  Thermodynamic Properties  of  the
       Mixtures {Water + Ammonia}, Journal of
       Physical and Chemical Reference Data,
       27-1,(1996),pp63-96
 2 --> Convention of International Institute of
       Refrigeration(IIR):
       h=200[kJ/kg], s=1.0[kJ/(kg*K)]
       Saturated Pure Liquids at 0[C]
=================================================
Input No.
1
```

```
=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ bar, C]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [1] T-Roth & Friend
 0 --> Return to Second Menu
=======================================================
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
9

==================================================================
 Conversion of Composition and Relative Molecular Mass of Mixture
==================================================================

 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
1
Input Z[kmol/kmol]
0.5
 Z  =    .50000000[kmol/kmol]
 Z  =    .48594670[kg/kg]
 Relative Molecular Mass of Mixture =      17.52276000[kg/kmol]
 Relative Molecular Mass of Ammonia =      17.03026000[kg/kmol]
 Relative Molecular Mass of Water   =      18.01527000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
2
Input Z[kg/kg]
0.5
 Z  =    .50000000[kg/kg]
 Z  =    .51405330[kmol/kmol]
 Relative Molecular Mass of Mixture =      17.50892000[kg/kmol]
 Relative Molecular Mass of Ammonia =      17.03026000[kg/kmol]
 Relative Molecular Mass of Water   =      18.01527000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
8

======================
 Fundamental Constants
======================
    <Constants>                <Ammonia>       <Water>
Relative Molecular Mass       17.03026000     18.01527000  [kg/kmol]
Gas Constants                488.18900000    461.51890000  [J/(kg*K)]
Critical Temperature         405.40000000    647.09600000  [K]
                             132.25000000    373.94600000  [C]
Critical Pressure            113.60000000    220.64000000  [bar]
```

```
Critical Volume             .75690050E-01   .55948040E-01  [m**3/kmol]
                            .44444450E-02   .31055900E-02  [m**3/kg]
----- Hit RETURN Key -----

===============================================================
| ## Second Menu ##                                             |
 contents not shown
===============================================================
Input No.
1

=====================================
 (P,T,Z) --> H, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[bar]          (P=0 : Second Menu)
1
Input T[C]
200
Input Z[kg/kg]
0.5
T  =     200.00000000[C]          P  =       1.00000000[bar]
Z  =        .50000000[kg/kg]      H  =    2481.23400000[kJ/kg]
S  =       8.30849400[kJ/(kg.K)]  V  =    .22386150E+01[m**3/kg]
Vapor Region

Input P[bar]          (P=0 : Second Menu)
1
Input T[C]
50.0
Input Z[kg/kg]
0.5
 T  =      50.00000000[C]          P  =       1.00000000[bar]
 Z  =        .50000000[kg/kg]      H  =     875.56820000[kJ/kg]
 S  =       3.75734900[kJ/(kg*K)]  V  =    .68341210E+00[m**3/kg]
 X  =        .18624860[kg/kg]      Y  =        .90054950[kg/kg]
 HL =     130.32380000[kJ/kg]      HV =    1826.98200000[kJ/kg]
 SL =     912.73970000[J/(kg*K)]   SV =       7.38890700[kJ/(kg*K)]
 VL =    .10951560E-02[m**3/kg]    VV =    .15544890E+01[m**3/kg]
 QUALITY =       .43924260[kg/kg]

Input P[bar]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                             |
 contents not shown
===============================================================
Input No.
2

=====================================
 (P,Z,H) --> T, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[bar]          (P=0 : Second Menu)
1
Input Z[kg/kg]
0.5
Input H[kJ/kg]
2500.
 T  =     208.52500000[C]          P  =       1.00000000[bar]
 Z  =        .50000000[kg/kg]      H  =    2500.00000000[kJ/kg]
 S  =       8.34784100[kJ/(kg*K)]  V  =    .22795030E+01[m**3/kg]
 Vapor Region

Input P[bar]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                             |
```

```
 contents not shown
================================================================
Input No.
3

=======================================
 (P,Z,S) --> T, H, V, QUALITY
            X, HL, SL, VL
            Y, HV, SV, VV
=======================================
Input P[bar]          (P=0 : Second Menu)
1
Input Z[kg/kg]
0.5
Input S[k/(kg*K)]
0.3
 T  =     -11.38488000[C]          P  =       1.00000000[bar]
 Z  =        .50000000[kg/kg]      H  =    -133.57350000[kJ/kg]
 S  =     300.00000000[J/(kg*K)]   V  =    .11689280E-02[m**3/kg]
 Liquid Region

Input P[bar]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
4

=========================================
 (P,Z,V) --> T, H, S, QUALITY
            X, HL, SL, VL
            Y, HV, SV, VV
=========================================
Input P[bar]          (P=0 : Second Menu)
1.0
Input Z[kg/kg]
0.5
Input V[m**3/kg]
2.
 T  =     150.39830000[C]          P  =       1.00000000[bar]
 Z  =        .50000000[kg/kg]      H  =    2373.50700000[kJ/kg]
 S  =       8.06802600[kJ/(kg*K)]  V  =    .20000000E+01[m**3/kg]
Vapor Region

Input P[bar]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
5

================================================
 (P,Z) --> X=Z : TB, HB, SB, VB
          Y=Z : TD, HD, SD, VD
================================================
Input P[bar]          (P=0 : Second Menu)
1.0
Input Z[kg/kg]
0.5
 P  =       5.00000000[bar]        Z  =        .50000000[kg/kg]
 TB =      38.31616000[C]          TD =     128.34460000[C]
 HB =      93.85913000[kJ/kg]      HD =    2303.77000000[kJ/kg]
 SB =       1.09321100[kJ/(kg*K)]  SD =       7.14666800[kJ/(kg*K)]
 VB =    .12341500E-02[m**3/kg]    VD =    .36748830E+00[m**3/kg]

Input P[bar]          (P=0 : Second Menu)
0
```

```
==============================================================
| ## Second Menu ##                                          |
 contents not shown
==============================================================
Input No.
6

===============================================
 (T,Z) --> X=Z : PB, HB, SB, VB
           Y=Z : PD, HD, SD, VD
===============================================
Input Z[kg/kg]   (Z < 0 : Second Menu)
0.5
Input T[K]
80.0
 T  =      80.00000000[C]          Z  =        .50000000[kg/kg]
 PB =      15.33406000[bar]        PD =        .92550240[bar]
 HB =     293.33660000[kJ/kg]      HD =    2224.19800000[kJ/kg]
 SB =       1.69010100[kJ/(kg*K)]  SD =       7.71905800[kJ/(kg*K)]
 VB =    .13032530E-02[m**3/kg]    VD =    .17920140E+01[m**3/kg]

Input Z[kg/kg]   (Z < 0 : Second Menu)
-1
==============================================================
| ## Second Menu ##                                          |
 contents not shown
==============================================================
Input No.
7

==============================================
 (P,T) --> Coexisting Phases
           X, HL, SL, VL
           Y, HV, SV, VV
==============================================
Input P[bar]          (P=0 : Second Menu)
1.0
Input T[C]
50.
 T  =      50.00000000[C]          P  =       1.00000000[bar]
 X  =        .18624860[kg/kg]      Y  =        .90054950[kg/kg]
 HL =     130.32380000[kJ/kg]      HV =    1826.98200000[kJ/kg]
 SL =     912.73970000[J/(kg*K)]   SV =       7.38890700[kJ/(kg*K)]
 VL =    .10951560E-02[m**3/kg]    VV =    .15544890E+01[m**3/kg]

Input P[bar]          (P=0 : Second Menu)
0
==============================================================
| ## Second Menu ##                                          |
 contents not shown
==============================================================
Input No.
0

***** See You Again ! *****
Stop - Program terminated.
```

References

[1] R. Tillner-Roth and D. G. Friend, Helmholtz free energy formulation of the thermodynamic properties of the mixture { water+ammonia } , Journal of Physical and Chemical Reference Data,27-1,(1996),pp63-96

[2] A. Pruss und W. Wagner, Eine neue Fundamental-gleichung fuer das fluide Zustandsgebiet von Wasser fuer Temperaturen von der Schmelzlinie bis zu 1273 K bei Druecken bis zu 1000MPa, Fortschr.-Ber. VDI 6,No.(320) (VDI verlag Duesseldorf)(1995)

[3] R. Tillner-Roth, Harms-Watzenberg und H. D. Bachr, Eine neue Fundamentalgleichung fuer Ammoniak,

Proc. 20th DKV-Tagung Heidelberg, Germany, volII,167(1993)

V F-PROPATH: Binary Mixtures by General Equations

Binary mixtures in part V stand for those that have been formulated by applying mixing rule to base equation. Base equations prepared are those of Peng-Robinson, CSD and BWR, at this moment.

1. General Features

1.1 SUBPROGRAM REFERENCE

Every F–PROPATH user has to make the initiation process by writing the following 3 lines before the first REFERENCE to a F–PROPATH SUBPROGRAM(FUNCTION SUBPROGRAM or SUBROUTINE SUBPROGRAM) in the MAIN PROGRAM. If a user happens to want to use other settings in other places of his or her PROGRAM UNIT, he or she is supposed to do a similar at those places.

```
CALL KPAMES(value of KPA, value of MESS)
CALL STNKAS(value of KSTAN, value of KAS)
CALL START1(J, value of KOMBI)
```

The arguments of the these SUBROUTINE SUBPROGRAMs specify the system of units, reference values of enthalpy and entropy, necessity of listing error messages to erroneous SUBPROGRAM REFERENCEs on the standard output device. All arguments in these SUBROUTINE SUBGROGRAMs are INTEGERs. KPA specifies the units of pressure and temperature, and KAS unit of the amount of substance. KSTAN selects the reference values of enthalpy and entropy. The relation between KPA and the units of pressure and temperature and that between KAS and the unit of amount of substance are shown in 1.3. F–PROPATH does not return any messages when MESS$=0$, while it does when MESS$\neq 0$. KSTAN differs from one equation to another, and is described in the chapter of each equation.

The argument KOMBI in SUBROUTINE START1 selects the kind of mixture from the predetermined list of mixtures, which differs from one general equation to another. Users are asked to consult with sections for each equation. If KOMBI bears a value not listed on the list, level 2 error will occur. See the next section.

1.2 Operations to Manage Erroneous SUBPROGRAM REFERENCE

A predetermined sequence of operations will occur to process an erroneous SUBPROGRAM REFERENCE when an improper SUBPROGRAM REFERENCE has been done. Erroneous SUBPROGRAM REFERENCEs are grouped into 2 levels, with the ascending severity of user's mistake. A user has committed a more serious mistake when a level 2 ERROR occurs than when a level 1 ERROR does.

1.2.1 Level 1 ERROR (Convergence Failure)

The method of iterations built in to some of the M-PROPATH SUBPROGRAMs to solve implicit relations will not work somehow from time to time. F–PROPATH stops further iterations after executing the preset number of iterations. Though the user is not responsible for level 1 ERROR, the F–PROPATH detects this type of ERROR time to time, unfortunately.

A level 1 ERROR is processed as below.

FUNCTION SUBPROGRAM

value of REAL FUNCTION returned to the CALLing program : $-1.0E+10$

value of INTEGER FUNCTION returned to the CALLing Program : -1

output to the standard output device:
**** NO CONVERGENCE AT (NAME OF FUNCTION CALLED) ****

SUBROUTINE SUBPROGRAM

value of error detection cord: -1

output to the standard output device:
**** NO CONVERGENCE AT (NAME OF SUBROUTINE CALLED) ****

1.2.2 Level 2 ERROR (Invalid ARGUMENT(s))

A level 2 ERROR will occur when the ARGUMENT(s) a user transferred to M-PROPATH SUBPROGRAM from his or her MAIN PROGRAM fail to drop in the proper range.

A level 2 ERROR is processed as below.

FUNCTION SUBPROGRAM

value of REAL FUNCTION returned to the CALLing Program: $-1.0E+20$

value of INTEGER FUNCTION returned to the CALLing Program : -2

output to the standard output device:
**** OUT OF RANGE AT (NAME OF FUNCTION CALLED) ****

SUBROUTINE SUBPROGRAM

value of error detection cord: -2

output to the standard output device:
**** OUT OF RANGE AT (NAME OF SUBROUTINE CALLED) ****

1.3 System of Units and Reference Values of Enthalpy and Entropy

All REAL quantities are in the fundamental SI or in the coherent derived SI with three exceptions. Pressure can be in the unit of Pascal Pa or bar, temperature in the unit of Kelvin K or degree Celsius °C. These depend on the value of INTEGER KPA when a user referred the SUBROUTINE SUBPROGAM KPAMES(KPA, MESS) shown in 1.1. The amount of substance can be in the unit of kilomole kmol or kilogram kg. INTEGER KAS in the SUBROUTINE SUBPROGAM STNKAS(KSTAN, KAS) in 1.1 switches this. These go as shown in the table below. The INTEGER KSTAN in the SUBROUTINE SUBPROGAM STNKAS(KSTAN, KAS) controls the reference values of enthalpy and entropy and is explained for each specific equation, since they differ from one equation to another.

Table V-1.3-1 Units of Pressure and Temperature Specified by `KPA`

KPA	unit of pressure	unit of temperature
0	Pa	K
1	bar	°C
2	bar	K
3	Pa	°C
others	Pa	K

Table V-1.3-2 Amount of Substance Specified by `KAS`

KAS	amount of substance
0	kmol
1	kg
others	kmol

1.4 Reserved NAMEs

F–PROPATH uses a lot of NAMEs, listed below, for its own purpose. These are the NAMEs of SUBPROGRAMs and NAMED COMMON BLOCK to which a user can access directly and NAMEs of SUBPROGRAM headed by "FMF" which a user cannot access. A user is supposed to use the NAMEs of SUBPROGRAM and COMMON BLOCK only when he/she does so in the original meaning. The letters in the first column are the first LETTERs in the NAMEs listed in the same line.

Name of COMMON BLOCK, FUNCTION and SUBROUTINE

A AKG, AKMOL
C CRPM
F FCM, FMF**** , COMMON /FMFC/
I IDENTM, IPHASE
K KPAMES
M MKTABL
N COMMON /NAME/
P PBT, PDT, PSTM
Q QMIX
S START1, START2, STNKAS, SUBCRT, SUBM, SUBMIX, SUBPAR, SUBPB, SUBPD, SUBPST, SUBPUR, SUBTB, SUBTD, SUBTSP, SUBXY
T T68, T90, TBP, TDP, TSPM
U COMMON /UNIT/

1.5 Terminology, Symbols and Compositions

The component with lower critical temperature is to be called as the first component. A composition is supposed to stand for the mole fraction or the mass fraction of the first component. The symbolic distinction of the compositions between the two phases and that between two saturation temperatures are done as shown below.

total composition Z	:	composition of mixture as a whole
composition at liquid phase X	:	liquid composition at vapor-liquid equilibrium
composition at vapor phase Y	:	vapor composition at vapor-liquid equilibrium
temperature at dew point	:	The lowest temperature of vapor for given pressure and Z
temperature at bubble point	:	The highest temperature of liquid for given pressure and Z
pressure at dew point	:	The highest pressure of vapor for given temperature and Z
pressure at bubble point	:	The lowest pressure of liquid for given temperature and Z

1.6 The NAMEs of FUNCTION and SUBROUTINE SUBPROGRAMs

NAMEs of FUNCTIONs and SUBROUTINEs are shown below and the full descripion of these SUBPROGRAMs is given in 1.7. Some of these SUBPROGRAMs have not been prepared in each equation shown in 2. and after. These are listed there for each equation.

1.6.1 FUNCTION

REAL valued FUNCTION (conversion of temperature scale)
T68 = conversion from ITS–1990 to IPTS–1968
T90 = conversion from IPTS-1968 to ITS-1990

REAL valued FUNCTION (pure component)
CRPM = critical constants of pure component
FCM = fundamental constants of pure components
PSTM = vapor pressure of pure components
TSPM = saturation temperature of pure components

REAL valued FUNCTION (mixture)
AKG = mole fraction to mass fraction conversion
AKMOL = mass fraction to mole fraction conversion
PBT = bubble point pressure of mixture (temperature and X input)
PDT = dew point pressure of mixture (temperature and Y input)
QMIX = dryness fraction of mixture
TBP = bubble point temperature of mixture (pressure and X input)
TDP = dew point temperature of mixture (pressure and Y input)

INTEGER valued FUNCTION
IPHASE = distinction between phases of mixture

CHARACTER valued FUNCTION
IDENTM = name of pure components and version number

1.6.2 SUBROUTINE

initialization
KPAMES/STNKAS = See 1.1
START1/START2 = consult with chapters for each equation

pure component
MKTABL = listing critical constants and fundamental constants of pure component
SUBPST = saturation properies of pure components (temperature input)
SUBPUR = single phase properties of pure component
SUBTSP = saturation properties of pure components (pressure input)

mixture
SUBCRT = critical constants of mixture
SUBPAR = partial properties of mixture
SUBPB = bubble point pressure and other properties of mixture (temperature and X input)
SUBPD = dew point pressure and other properties of mixture (temperature and Y input)
SUBTB = bubble point temperature and other properties of mixture (pressure and X input)
SUBTD = dew point temperature and other properties of mixture (pressure and Y input)
SUBM = adiabatic and isobaric mixing of two streams
SUBMIX = properties of mixture
SUBXY = properties of mixture at VLE
SUBMXH = isobaric mixing of two mixtures with different composition, enthalpy input
SUBMXT = isobaric mixing of two mixtures with different composition, temperature input

1.7 Descriptions of FUNCTIONs and SUBROUTINEs

Shown in alphabetical order of NAMEs.

AKG

REAL FUNCTION **AKG(Z)** : mole fraction to mass fraction conversion

REAL Z : mole fraction [kmol/kmol]
REAL AKG : mass fraction [kg/kg]

AKMOL

REAL FUNCTION **AKMOL(Z)** : mass fraction to mole fraction conversion

REAL Z : mass fraction [kg/kg]
REAL AKMOL : mole fraction [kmol/kmol]

CRPM

REAL FUNCTION **CRPM(I,A)** : critical constant

INTEGER I : component
1 : first component
2 : second component
CHARACTER*1 A : kind of critical constant returned
'T' : critical temperature [K], [°C]
'P' : critical pressure [Pa], [bar]
'V' : critical volume [m^3/kmol], [m^3/kg]
'H' : critical enthalpy [J/kmol], [J/kg]
'S' : critical entropy [J/(kmol·K)], [J/(kg·K)]

FCM

REAL FUNCTION **FCM(I,A)** : fundamental constants of pure components

INTEGER I : component
1 : first component
2 : secund component
CHARACTER*1 A : kind of fundamental constant returned
'M' : molar mass [kg/kmol]
'R' : gas constant [J/(kg·K)]
'T' : critical temperature [K] , [°C]
'P' : critical pressure [Pa] , [bar]
'V' : critical volume [m^3/kmol] , [m^3/kg]
'E' : acentric factor [-]

IDENTM

CHARACTER*40 FUNCTION **IDENTM(I,A)** : name of pure component and version number

INTEGER I : component
1 : first component
2 : second component
CHARACTER*1 A : kind of characters returned
'C' : molecular formula
'S' : name of substance
'V' : version number

IPHASE

INTEGER FUNCTION **IPHASE(T,P,Z)** : distinction between phases of mixture

REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]
REAL Z : composition [kmol/kmol] , [kg/kg]

value of IPHASE

1	: single phase
2	: two phase
−1	: Convergence failure
−2	: invalid ARGUMENT(s)

KPAMES

SUBROUTINE **KPAMES(KPA,MESS)**
See 1.11

MKTABL

SUBROUTINE **MKTABL(J,M)**
: listing fundamental constants and isobaric specific heat at the ideal gas state

input
INTEGER M : value of KOMBI index to mixtures

output
See example 4. Units of fundamental constants are prefixed as shown below and depend on neither KPA or KAS.

molar mass	: [kg/kmol]
critical temperature	: [K]
critical pressure	: [Pa]
critical volume	: [m^3/kmol]
acentric factor	: [-]

If you use just MKTABL in your main program, you do not need to CALL SUBROUTINE KPAMES,STNKAS and START1 before calling MKTABL.

PBT

REAL FUNCTION **PBT(T,X)** : bubble point pressure

REAL T : temperatuer [K], [°C]
REAL X : composition [kmol/kmol], [kg/kg]
REAL PBT : bubble point pressure [Pa], [bar]

PDT

REAL FUNCTION **PDT(T,Y)** : dew point pressure

REAL T : temperatuer [K], [°C]
REAL Y : composition [kmol/kmol], [kg/kg]
REAL PDT : dew point pressure [Pa], [bar]

PSTM

REAL FUNCTION **PSTM(I,T)** : saturation pressure of pure component

INTEGER I		: component
		1 : first component
		2 : second component
REAL	T	: temperature [K] , [°C]
REAL	PSTM	: saturation pressure [Pa], [bar]

QMIX

REAL FUNCTION **QMIX(T,P,Z)** : dryness fraction

REAL T	: temperature [K], [°C]
REAL P	: pressure [Pa], [bar]
REAL Z	: total composition [kmol/kmol], [kg/kg]
REAL QMIX	: dryness fraction [kmol/kmol], [kg/kg]

START1

SUBROUTINE **START1(J,value of KOMBI)**
See chapters of each equation

START2

SUBROUTINE **START2(J,· · · · ·)**
See chapters of each equation

STNKAS

SUBROUTINE **STNKAS(KSTAN,KAS)**
See 1.1

SUBCRT

SUBROUTINE **SUBCRT(I,J,T,P,Z,V,H,S)** : critical constants of mixture
INTEGER I : type of problem (input, I=1,2)

I= 1 :

input

REAL	Z	: total composition [kmol/kmol], [kg/kg]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	T	: critical temperature [K], [°C]
	P	: critical pressure [Pa], [bar]
	V	: critical volume [m^3/kmol], [m^3/kg]
	H	: critical enthalpy [J/kmol], [J/kg]
	S	: critical entropy [J/(kmol·K)], [J/(kg·K)]

I= 2 :

input

REAL	T	: critical temperature [K], [°C]

output

INTEGER	J	: error detection code
		−1 : convergence failure
		−2 : invalid ARGUMENT(s)
REAL	Z	: total composition [kmol/kmol], [kg/kg]
	P	: critical pressure [Pa], [bar]
	V	: critical volume [m^3/kmol], [m^3/kg]
	H	: critical enthalpy [J/kmol], [J/kg]
	S	: critical entropy [J/(kmol·K)], [J/(kg·K)]

SUBMXH

SUBROUTINE **SUBMXH(J,T,P,ZA,ZB,Z,V,HA,HB,H,S,W)** : isobaric mixing of two mixtures with different compositions, enthalpy input

input

REAL	P	: pressure [Pa] , [bar]
REAL	ZA	: total composition of A [kmol/kmol] , [kg/kg]
REAL	ZB	: total composition of B [kmol/kmol] , [kg/kg]
REAL	HA	: enthalpy of A [J/kmol] , [J/kg]
REAL	HB	: enthalpy of B [J/kmol] , [J/kg]

REAL W : Fraction of A in Mixing [kmol/kmol] , [kg/kg]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : temperature after mixing [K] , [°C]
REAL Z : total composition after mixing [kmol/kmol] , [kg/kg]
REAL V : volume after mixing [m^3/kmol] , [m^3/kg]
REAL H : enthalpy after mixing [J/kmol] , [J/kg]
REAL S : entropy after mixing [J/(kmol·K)] , [J/(kg·K)]

SUBMXT

SUBROUTINE **SUBMXT(J,T,P,ZA,ZB,Z,V,TA,TB,H,S,W)** : isobaric mixing of two mixtures with different compositions, temperature input

input

REAL P : pressure [Pa] , [bar]
REAL ZA : total composition of A [kmol/kmol] , [kg/kg]
REAL ZB : total composition of B [kmol/kmol] , [kg/kg]
REAL TA : temperature of A [K] , [°C]
REAL TB : temperature of B [K] , [°C]
REAL W : Fraction of A in Mixing [kmol/kmol] , [kg/kg]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : temperature after mixing [K] , [°C]
REAL Z : total composition after mixing [kmol/kmol] , [kg/kg]
REAL V : volume after mixing [m^3/kmol] , [m^3/kg]
REAL H : enthalpy after mixing [J/kmol] , [J/kg]
REAL S : entropy after mixing [J/(kmol·K)] , [J/(kg·K)]

SUBMIX

SUBROUTINE **SUBMIX(I,J,T,P,Z,V,H,S)** : properties of mixture

INTEGER I : type of problem (input)
1 : inputs (T,P,Z) → outputs (V,H,S)
2 : inputs (P,Z,H) → outputs (T,V,S)
3 : inputs (P,Z,S) → outputs (T,V,H)
4 : inputs (P,Z,V) → outputs (T,H,S)
INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]
REAL Z : total composition [kmol/kmol] , [kg/kg]
REAL V : volume [m^3/kmol] , [m^3/kg]
REAL H : enthalpy [J/kmol] , [J/kg]
REAL S : entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPAR

SUBROUTINE **SUBPAR(A,J,T,P,XL,XV)**: partial properties

input

CHARACTER*1 A : kind of partial properties, one of 'V','H'and'S'
REAL T : temperature [K], [°C]
REAL P : pressure [Pa], [bar]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)

REAL ARRAY XL(2), XV(2) : one of volume, enthalpy and entropy

A='V'

XL(1) partial volume of first component in liquid [m^3/kmol], [m^3/kg]
XL(2) partial volume of second component in liquid [m^3/kmol], [m^3/kg]
XV(1) partial volume of first component in vapor [m^3/kmol], [m^3/kg]
XV(2) partial volume of second component in vapor [m^3/kmol], [m^3/kg]

A='H'

XL(1) partial enthalpy of first component in liquid [J/kmol], [J/kg]
XL(2) partial enthalpy of second component in liquid [J/kmol], [J/kg]
XV(1) partial enthalpy of first component in vapor [J/kmol], [J/kg]
XV(2) partial enthalpy of second component in vapor [J/kmol], [J/kg]

A='S'

XL(1) partial entropy of first component in liquid [J/(kmol·K)], [J/(kg·K)]
XL(2) partial entropy of second component in liquid [J/(kmol·K)], [J/(kg·K)]
XV(1) partial entropy of first component in vapor [J/(kmol·K)], [J/(kg·K)]
XV(2) partial entropy of second component in vapor [J/(kmol·K)], [J/(kg·K)]

SUBPB

SUBROUTINE **SUBPB(J,T,P,X,V,H,S)**
: bubble point pressure and other properties of mixture (temperature and X input)

input

REAL T : temperature [K] , [°C]
REAL X : composition [kmol/kmol] , [kg/kg]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL P : bubble point pressure [Pa] , [bar]
REAL V : bubble point volume [m^3/kmol] , [m^3/kg]
REAL H : bubble point enthalpy [J/kmol] , [J/kg]
REAL S : bubble point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPD

SUBROUTINE **SUBPD(J,T,P,Y,V,H,S)**
: dew point pressure and other properties of mixture (temperature and Y input)

input

REAL T : temperature [K] , [°C]
REAL Y : composition [kmol/kmol] , [kg/kg]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL P : dew point pressure [Pa] , [bar]
REAL V : dew point volume [m^3/kmol] , [m^3/kg]
REAL H : dew point enthalpy [J/kmol] , [J/kg]
REAL S : dew point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPST

SUBROUTINE **SUBPST(I,J,T,PS,VL,VV,HL,HV,SL,SV)**
: saturation properties of pure component (temperature intput)

input
INTEGER I : component
1 : first component
2 : second component
REAL T : temperature [K] , [°C]
output
INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL PS : saturation pressure [Pa] , [bar]
REAL VL : liquid volume [m^3/kmol] , [m^3/kg]
REAL VV : vapor volume [m^3/kmol] , [m^3/kg]
REAL HL : liquid enthalpy [J/kmol] , [J/kg]
REAL HV : vapor enthalpy [J/kmol] , [J/kg]
REAL SL : liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL SV : vapor entropy [J/(kmol·K)] , [J/(kg·K)]

SUBPUR

SUBROUTINE **SUBPUR(I,J,T,P,V,H,S)** : single phase properties of pure components

input
INTEGER I : component
1 : first component
2 : second component
REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]

output
output are those of satureted liquid, when temperature-pressure is on saturation line

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL V : volume [m^3/kmol] , [m^3/kg]
REAL H : enthalpy [J/kmol] , [J/kg]
REAL S : entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTB

SUBROUTINE **SUBTB(J,T,P,X,V,H,S)**
: bubble point temperature and other properties of mixture (pressure and X input)

input
REAL P : pressure [Pa] , [bar]
REAL X : composition [kmol/kmol] , [kg/kg]
output
INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : bubble point temperature [K] , [°C]
REAL V : bubble point volume [m^3/kmol] , [m^3/kg]
REAL H : bubble point enthalpy [J/kmol] , [J/kg]
REAL S : bubble point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTD

SUBROUTINE **SUBTD(J,T,P,Y,V,H,S)**
: dew point temperature and other properties of mixture (pressure and Y input)

input

REAL P : pressure [Pa] , [bar]
REAL Y : composition [kmol/kmol] , [kg/kg]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL T : dew point temperature[K] , [°C]
REAL V : dew point volume [m^3/kmol] , [m^3/kg]
REAL H : dew point enthalpy[J/kmol] , [J/kg]
REAL S : dew point entropy [J/(kmol·K)] , [J/(kg·K)]

SUBTSP

SUBROUTINE **SUBTSP(I,J,TS,P,VL,VV,HL,HV,SL,SV)**
: saturation properties of pure component (pressure input)

input

INTEGER I : component
1 : first component
2 : second component
REAL P : pressure [Pa] , [bar]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL TS : temperature [K] , [°C]
REAL VL : liquid volume [m^3/kmol] , [m^3/kg]
REAL VV : vapor volume [m^3/kmol] , [m^3/kg]
REAL HL : liquid enthalpy [J/kmol] , [J/kg]
REAL HV : vapor enthalpy [J/kmol] , [J/kg]
REAL SL : liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL SV : vapor entropy [J/(kmol·K)] , [J/(kg·K)]

SUBXY

SUBROUTINE **SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)** : properties of mixture at VLE

input

REAL T : temperature [K] , [°C]
REAL P : pressure [Pa] , [bar]

output

INTEGER J : error detection code
−1 : convergence failure
−2 : invalid ARGUMENT(s)
REAL X : composition of liquid X [kmol/kmol] , [kg/kg]
REAL Y : composition of vapor Y [kmol/kmol] , [kg/kg]
REAL VL : liquid volume [m^3/kmol] , [m^3/kg]
REAL VV : vapor volume [m^3/kmol] , [m^3/kg]
REAL HL : liquid enthalpy [J/kmol] , [J/kg]
REAL HV : vapor enthalpy [J/kmol] , [J/kg]
REAL SL : liquid entropy [J/(kmol·K)] , [J/(kg·K)]
REAL SV : vapor entropy [J/(kmol·K)] , [J/(kg·K)]

TBP

REAL FUNCTION **TBP(P,X)** : bubble point temperature

REAL P : pressure [Pa], [bar]
REAL X : composition [kmol/kmol], [kg/kg]
REAL TBP : bubble point temperatuer [K], [°C]

TDP

REAL FUNCTION **TDP(P,Y)** : dew point temperature

REAL P	:	pressure [Pa], [bar]
REAL Y	:	composition [kmol/kmol], [kg/kg]
REAL TDP	:	dew point temperatuer [K], [°C]

TSPM

REAL FUNCTION **TSPM(I,P)** : saturation temperature of pure components

INTEGER	I	: component 1 : first component 2 : second component
REAL	P	: pressure of pure component [Pa] , [bar]
REAL	TSPM	: saturation temperature [K], [°C]

2. Individual Equation

2.1 Peng-Robinson Equation

Thermodynamic properties are evaluated by Peng–Robinson equation[1]. No provision is made for transport properties at this moment.

2.1.1 The Names of Subroutine, Library File and Single Shot Program

Library File for UNIX:	`libjprmx.a`
Library File for DOS,Windows95/NT:	JPRMX.LIB
Single Shot Program for UNIX:	`prmx--ss`
Single Shot Program for DOS,Windows95/NT:	PRMX–SS.EXE

2.1.2 Reference State

By user's selecton of KSTAN, which is the first ARGUMENT of SUBROUTINE STNKAS, the reference state is determined as shown below. However for KOMBI≥4 or after SUBROUTINE START2(See 2.1.5) being CALLed, these imply KSTAN=0, irrespective of user's selection of KSTAN.

Table V-2.1-1 Reference State Specified by `KSTAN`

KSTAN	Reference State	value of enthalpy and entropy
0	298.15K, 1bar : ideal gas state of pure component	0.0kJ/kmol, 0.0kJ/(kmol·K)
1	273.15K : saturated liquid of pure component	200kJ/kg, 1.0kJ/(kg·K)
others	same with KSTAN= 0	

2.1.3 Missing SUBPROGRAM

Of the SUBPROGRAMs listed in 1.6, the next is missing in F–PROPATH by Peng–Robinson equation.

SUBTSP

2.1.4 Initialization by SUBROUTINE START1

When the mixture you are interested in is one of the mixtures for which table of constants are embedded in F–PROPATH, you can initialize F–PROPATH by writing three lines shown below. See 1.1 and Sample Program 1 of chapter 2.1.6.

```
CALL KPAMES(KPA, MESS)
CALL STNKAS(KSTAN, KAS)
CALL START1(J,KOMBI)
```

ARGUMENTs to the first two SUBROUTINEs are explained in 1.3. The last, START1, works as follows.

START1

SUBROUTINE START1(J,KOMBI)

input

INTEGER KOMBI : user selects one from the Table V–2.1–1.

output

INTEGER J : error detection code
−2 : invalid ARGUMENT(s)

The properties of the substances listed in Table V–2.1–1 are tabulated in Table V–2.1–2, which are used in Peng–Robinson PROPATH.

Table V-2.1-2 Combination of Substances Specified by `KOMBI`

KOMBI	component 1	component 2	interaction parameter	
1	R22	R123	0.0	[2]
2	R32	R125	0.013	[3]
3	R32	R134a	-0.01816	[4]
4	CH_4	C_2H_4	0.022	[5]
5	CH_4	C_2H_6	-0.003	[5]
6	CH_4	C_3H_6	0.033	[5]
7	CH_4	C_3H_8	0.016	[5]
8	CH_4	i–C_4H_{10}	0.026	[5]
9	CH_4	n–C_4H_{10}	0.019	[5]
10	CH_4	i–C_5H_{12}	-0.006	[5]
11	CH_4	n–C_5H_{12}	0.026	[5]
12	CH_4	n–C_6H_{14}	0.040	[5]
13	CH_4	C_6H_6	0.055	[5]
14	CH_4	C_6H_{12}	0.039	[5]
15	CH_4	n–C_7H_{16}	0.035	[5]
16	CH_4	n–C_8H_{18}	0.050	[5]
17	O_2	CO_2	0.09	[6]

Table V-2.1-3 Fundamental Constants of Pure Components tabulated in Table V-2.1-2

substance	M [kg/kmol]	T_c [K]	p_c [MPa]	v_c [m^3/kmol]	ω [-]	reference
R22	86.468	369.30	4.971	0.1660	0.2192	[7]
R123	152.931	456.86	3.6655	0.27500	0.2825	[7]
R32	52.024	351.26	5.778	0.12100	0.278	[3](T_c, p_c, ω), [7](M, v_c)
R125	120.022	339.19	3.631	0.20983	0.306	[3](T_c, p_c, ω), [7](M, v_c)
R134a	102.030	374.21	4.056	0.19812	0.326	[4](T_c, p_c, ω), [8](M, v_c)
CH_4	16.043	190.56	4.5990	0.09860	0.0115	[7]
CO_2	44.010	304.21	7.3830	0.09400	0.2276	[7]
C_2H_4	28.054	282.36	5.0318	0.12907	0.0852	[7]
C_2H_6	30.070	305.32	4.8720	0.14550	0.0995	[7]
C_3H_6	42.081	364.76	4.6126	0.18100	0.1424	[7]
C_3H_8	44.096	369.83	4.2480	0.20000	0.1523	[7]
n–C_4H_{10}	58.123	425.12	3.7960	0.25500	0.2002	[7]
i–C_4H_{10}	58.123	408.14	3.6480	0.26270	0.1770	[7]
i–C_5H_{12}	72.150	460.43	3.3812	0.30583	0.2275	[7]
n–C_5H_{12}	72.150	469.70	3.3700	0.31300	0.2515	[7]
C_6H_6	78.114	562.16	4.8980	0.25894	0.2108	[7]
C_6H_{12}	84.161	553.54	4.0748	0.30788	0.2118	[7]
n–C_6H_{14}	86.177	507.60	3.0250	0.37100	0.3013	[7]
n–C_7H_{16}	100.204	540.20	2.7400	0.42800	0.3495	[7]
n–C_8H_{18}	114.231	568.70	2.4900	0.48600	0.3996	[7]
O_2	31.999	154.58	5.0430	0.07340	0.0218	[7]

2.1.5 Initialization by SUBROUTINE START2

By the procedure described below, user can use F–PROPATH by Peng–Robinson equation for any mixture. However in that case a user has to transfer related constants of each component to F–PROPATH. They are molar mass, critical constants(temperature, pressure, volume), acentric factor, coefficients of isobaric specific heat equation at ideal gas state, and interaction parameter.

A user has to write the lines shown below before he or she makes reference to any F–PROPATH by Peng–Robinson equation SUBPROGRAM.

```
DIMENSION PR1(5),PR2(5),CP1(8),CP2(8)
  DATA STATEMENT for PR1,PR2,CP1,CP2
AKIJ=X
```

CALL KPAMES(KPA,MESS)
CALL STNKAS(KSTAN,KAS)
CALL START2(J,PR1,PR2,AKIJ,CP1,CP2)

PR1 and PR2 are arrays to which a user transfers constants for component 1 and 2, respectively. CP1 and CP2 are arrays to which a user trasfers coefficients of isobaric specific heat equation for component 1 and 2, respectively. AKIJ is the interaction parameter defined in reference [1].

Elements of PR1 and PR2 mean what are shown below.

PR1(1) : molar mass of component 1 [kg/kmol]
PR1(2) : critical temperature of component 1 [K]
PR1(3) : critical pressure of component 1 [Pa]
PR1(4) : critical volume of component 1 [m^3/kmol]
PR1(5) : acentric factor of component 1 [-]

PR2(1) : molar mass of component 2 [kg/kmol]
PR2(2) : critical temperature of component 2 [K]
PR2(3) : critical pressure of component 2 [Pa]
PR2(4) : critical volume of component 2 [m^3/kmol]
PR2(5) : acentric factor of component 2 [-]

A user is allowed to use one of the following two equation of isobaric specific heat at ideal gas state (T : temperature [K]).

(1) CP[J/(kmol·K)] $= A + B[(C/T)\sinh(C/T)]^2 + D[(E/T)\cosh(E/T)]$, CP*(1) = 1.0
(2) CP[J/(kmol·K)] $= A + BT + CT^2 + DT^3 + ET^4$, CP*(1) = 2.0

Elements of CP1 and CP2 mean what are shown below.

CP1(1) : number of equation 1.0 or 2.0 for component 1.
CP1(2) : value of A for component 1
CP1(3) : value of B for component 1
CP1(4) : value of C for component 1
CP1(5) : value of D for component 1
CP1(6) : value of E for component 1
CP1(7) : lower valid bound of the equation [K]
CP1(8) : upper valid bound of the equation [K]

CP2(1) : number of equation 1.0 or 2.0 for component 2.
CP2(2) : value of A for component 2
CP2(3) : value of B for component 2
CP2(4) : value of C for component 2
CP2(5) : value of D for component 2
CP2(6) : value of E for component 2
CP2(7) : lower valid bound of the equation [K]
CP2(8) : upper valid bound of the equation [K]

J is the error detection code. When PR1(2)>PR2(2), $T_{c1} > T_{c2}$, exchange between component 1 and 2 will occur and J= -1 will be returned. For other invalid ARGUMENT(s), J= -2 will occur.

2.1.6 Example of User's PROGRAM UNIT

Sample Program 1

```
      PROGRAM EX1
C-------------------------------------------------------------------
C    Peng-Robinson Equation
C    For R22-R123 mixture(KOMBI=1),this program calculates
C    temperature at buble point from Z=0.0 TO 1.0[kmol R22/kmol] at
C    every 0.1[kmol R22/kmol].
```

```
C-------------------------------------------------------------------
C
C-----------------------------------------------
C    T=[deg],P=[bar],amount of substance=[kmol]
C    standard state=(298.15[K],1[bar])
C-----------------------------------------------
      CALL KPAMES(1,1)
      CALL STNKAS(0,0)
      CALL START1(J,1)
C
C-----------------------------------------
C   Calculation of pressure at buble point
C   using TBP and output results.
C-----------------------------------------
      P=1.0
      DO 10 I=0,10
        Z=FLOAT(I)*0.1
        T=TBP(P,Z)
        WRITE(*,*) Z,T
   10 CONTINUE
      STOP
      END
C
C
C   result
C
C    0.000000E+00       27.395430
C    1.000000E-01        7.765078
C    2.000000E-01       -5.087575
C    3.000000E-01      -14.011260
C    4.000000E-01      -20.619320
C    5.000000E-01      -25.767130
C    6.000000E-01      -29.933280
C    7.000000E-01      -33.404360
C    8.000000E-01      -36.362870
C    9.000000E-01      -38.931340
C        1.000000      -41.196050
```

Sample Program 2

```
      PROGRAM EX2
C------------------------------------------------------------------
C   Peng-Robinson Equation
C   For methane-ethylene mixture(KOMBI=4),this program calculates
C   VLE properties at P=1.0[bar] and T=150[K].
C------------------------------------------------------------------
C
C----------------------------------------
C    T=[K],P=[Pa]
C    standard state=(298.15[K],1[bar])
C    amount of substance=[kmol]
C----------------------------------------
      CALL KPAMES(0,1)
      CALL STNKAS(0,0)
C
C--------------------------
C    Execution START1.
C--------------------------
      CALL START1(J,4)
C
C----------------------------------------------------------
C    Calculation of VLE properties on saturated state
C    and output results.
C----------------------------------------------------------
      P=1.0E5
      T=150.0
```

```
      CALL SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)
      HL=HL*1.0E-6
      HV=HV*1.0E-6
      SL=SL*1.0E-3
      SV=SV*1.0E-3
      WRITE(*,*) '  X[KMOL CH4/KMOL]=',X, '   Y[KMOL CH4/KMOL]=',Y
      WRITE(*,*) ' VL[M^3/KMOL]     =',VL,'  VV[M^3/KMOL]     =',VV
      WRITE(*,*) ' HL[MJ/KMOL]      =',HL,'  HV[MJ/KMOL]      =',HV
      WRITE(*,*) ' SL[KJ/KMOL]      =',SL,'  SV[KJ/KMOL]      =',SV
      STOP
      END
C
C
C....result
C
C   X[KMOL CH4/KMOL]=   5.313301E-02   Y[KMOL CH4/KMOL]=   7.212105E-01
C  VL[M^3/KMOL]     =   4.313929E-02  VV[M^3/KMOL]     =      12.211230
C  HL[MJ/KMOL]      =     -19.099360  HV[MJ/KMOL]      =      -5.234992
C  SL[KJ/KMOL]      =    -105.360700  SV[KJ/KMOL]      =     -19.152850
```

Sample Program 3

```
      PROGRAM EX3
C
C-----------------------------------------------------------------
C    Peng-Robinson Equation
C    For ethane-propane mixture,this program calculates property
C    at buble point at T=250[K] and Z=0.5[kmol C2H6/kmol].
C-----------------------------------------------------------------
C
C-------------------------------------------
C    Definition of array PR1,PR2,CP1 and CP2.
C-------------------------------------------
      DIMENSION PR1(5),PR2(5),CP1(8),CP2(8)
C
C---------------------------------------
C    T=[K],P=[Pa],quantity=[kmol]
C    standard state=(298.15[K],1[bar])
C---------------------------------------
      CALL KPAMES(0,1)
      CALL STNKAS(0,0)
C
C---------------------------------------------------------------------------
C    Putting fundamental constants into PR1 and PR2 using DATA STATEMENT.
C    DATA(PR1(I),I=1,5)/MW1[KG/KMOL],TC1[K],PC1[PA],VC1[M^3/KMOL],OMEGA1[-]/
C    DATA(PR2(I),I=1,5)/MW2[KG/KMOL],TC2[K],PC2[PA],VC2[M^3/KMOL],OMEGA2[-]/
C---------------------------------------------------------------------------
      DATA(PR1(I),I=1,5)/ 30.070, 305.42, 4.8801D6, 0.14792,  0.0990/
      DATA(PR2(I),I=1,5)/ 44.096, 369.82, 4.2492D6, 0.20288,  0.1518/
C
C---------------------------------------------------------------------------
C    Putting isobaric heat capacity at ideal gas state into CP1 and CP2
C    using DATA STATEMENT.
C    DATA(CP1(I),I=1,8)/EQUATION NUMBER,A,B,C,D,E,TMIN[K],TMAX[K]/
C    DATA(CP2(I),I=1,8)/EQUATION NUMBER,A,B,C,D,E,TMIN[K],TMAX[K]/
C---------------------------------------------------------------------------
      DATA(CP1(I),I=1,8)
     &  /1.0, 3.5650E4, 1.35200E5, 1.4300E3, 6.1800E4, 6.1200E2,
     &   100.0, 1500.0 /
      DATA(CP2(I),I=1,8)
     &  /1.0, 4.4000E4, 1.93800E5, 1.3690E3, 9.8000E4, 5.8300E2,
     &   100.0, 1500.0 /
C
C----------------------------------------
C    Setting interaction parametar AKIJ.
C----------------------------------------
```

```
      AKIJ=0.001
C
C--------------------------
C    Execution START2.
C--------------------------
      CALL START2(J,PR1,PR2,AKIJ,CP1,CP2)
C
C-------------------------------------------
C   Calculation of properties at buble point
C   using SUBPB and output results.
C-------------------------------------------
      T=250.0
      Z=0.5
      CALL SUBPB(J,T,P,Z,V,H,S)
      P=P*1.0E-6
      H=H*1.0E-6
      S=S*1.0E-3
      WRITE(*,*) ' P[MPA]      =',P
      WRITE(*,*) ' V[M^3/KMOL] =',V
      WRITE(*,*) ' H[MJ/KMOL]  =',H
      WRITE(*,*) ' S[KJ/KMOL]  =',S
      STOP
      END
C
C
C....result
C
C      P[MPA]      =   7.229552E-01
C      V[M^3/KMOL] =   6.797910E-02
C      H[MJ/KMOL]  =     -18.242270
C      S[KJ/KMOL]  =     -79.194690
```

Sample Program 4

```
      PROGRAM EX4
C-----------------------------------------
C     Peng-Robinson Equation
C     For R32-R125 mixture (KOMBI=2),
C     this program execute only MKTABL.
C-----------------------------------------
      CALL MKTABL(J,2)
      STOP
      END
C
C
C     You do not need to CALL SUBROUTINE
C     KPAMES, STNKAS and START1 before
C     CALLing MKTABL
C
C    result
C
C   FUNDAMENTAL CONSTANTS
C                                             R32               R125
C   MOLECULAR FORMULA                          CH2F2             CF3CHF2
C   RELATIVE MOLECULAR MASS [KG/KMOL]         52.024            120.020
C   GAS CONSTANT            [J/(KG*K)]       159.821             69.276
C   CRITICAL TEMPERATURE    [K]               351.60             339.40
C   CRITICAL PRESSURE       [MPA]             5.8302             3.6310
C   CRITICAL VOLUME         [M^3/KMOL]       .121000            .209830
C   ACENTRIC FACTOR         [-]                .2763              .3060
C   INTERACTION PATAMETER   [-]                         .0130

C   IDEAL GAS HEAT CAPACITY
C                                                R32               R125
C   EQUATION NUMBER                                1                  2
C   A                                    .340600E+05        .236022E+05
```

```
C   B                                 .714400E+05        .283723E+03
C   C                                 .142200E+04       -.123028E+00
C   D                                 .394000E+05       -.567252E-04
C   E                                 .677000E+03        .000000E+00
C   LOW TEMPERATURE LIMIT  [K]              100.0              150.0
C   HIGH TEMPERATURE LIMIT [K]             1500.0              500.0
```

2.1.7 Sample Output of Single Shot Program

```
========================================================================
|   Single Shot Program for Peng-Robinson Equation,                    |
|   an Application Program by F-PROPATH Ver.9.1                        |
|   Thermophysical Properties of Binary Mixtures                       |
|----------------------------------------------------------------------|
|  ## First Menu ##                                                    |
| No.                       Current                                    |
| 1 --> Go to Second Menu                                              |
| 2 --> Select Mixture    (Component1 - Component2)                    |
|                         [ R32 - R125 ]                               |
| 3 --> Read Help                                                      |
| 4 --> Set Logfile       [OFF]                                        |
| 0 --> Quit                                                           |
========================================================================
Input No.
3

 This is help for this program (PRMX-SS.EXE)
  Nomenclature
 ==== First Charactor ====
   H : Enthalpy
   P : Pressure
   S : Entropy
   T : Temperature
   V : Volume
   X : Component1 Composition of Liquid
   Y : Component1 Composition of Vapor
   Z : Total Composition of Component1
 ==== Second Charactor ====
   B : Bubble Point
   D : Dew Point
   L : Liquid
   V : Vapor

----- Hit RETURN Key -----

========================================================================
|   Single Shot Program for Peng-Robinson Equation,                    |
|   an Application Program by F-PROPATH Ver.9.1                        |
|   Thermophysical Properties of Binary Mixtures                       |
|----------------------------------------------------------------------|
|  ## First Menu ##                                                    |
| No.                       Current                                    |
| 1 --> Go to Second Menu                                              |
| 2 --> Select Mixture    (Component1 - Component2)                    |
|                         [ R32 - R125 ]                               |
| 3 --> Read Help                                                      |
| 4 --> Set Logfile       [OFF]                                        |
| 0 --> Quit                                                           |
========================================================================
Input No.
4

 1: Logfile ON
 2: Logfile OFF
```

```
Input No.
1
Input Filename
PRMIX.LOG
=========================================================================
|   Single Shot Program for Peng-Robinson Equation,                     |
|   an Application Program by F-PROPATH Ver.9.1                         |
|   Thermophysical Properties of Binary Mixtures                        |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                        Current                                    |
| 1 --> Go to Second Menu                                               |
| 2 --> Select Mixture     (Component1 - Component2)                    |
|                          [ R32 - R125 ]                               |
| 3 --> Read Help                                                       |
| 4 --> Set Logfile        [ON] PRMIX.LOG                               |
| 0 --> Quit                                                            |
=========================================================================
Input No.
2
=====================================
| No.|  Component1 - Component2     |
|----|------------------------------|
|  1 | [ R22 - R123 ]               |
|  2 | [ R32 - R125 ]               |
|  3 | [ R32 - R134a ]              |
|  4 | [ CH4 - C2H4 ]               |
|  5 | [ CH4 - C2H6 ]               |
|  6 | [ CH4 - C3H6 ]               |
|  7 | [ CH4 - C3H8 ]               |
|  8 | [ CH4 - i-C4H10 ]            |
|  9 | [ CH4 - n-C4H10 ]            |
| 10 | [ CH4 - i-C5H12 ]            |
| 11 | [ CH4 - n-C5H12 ]            |
| 12 | [ CH4 - C6H14(n-Hexane) ]    |
| 13 | [ CH4 - C6H6(Benzene) ]      |
| 14 | [ CH4 - C6H12(Cyclohexane) ] |
| 15 | [ CH4 - C7H16(n-Heptan) ]    |
| 16 | [ CH4 - C8H18(n-Octane) ]    |
=====================================
Input No.
1
=========================================================================
|   Single Shot Program for Peng-Robinson Equation,                     |
|   an Application Program by F-PROPATH Ver.9.1                         |
|   Thermophysical Properties of Binary Mixtures                        |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                        Current                                    |
| 1 --> Go to Second Menu                                               |
| 2 --> Select Mixture     (Component1 - Component2)                    |
|                          [ R22 - R123 ]                               |
| 3 --> Read Help                                                       |
| 4 --> Set Logfile        [ON] PRMIX.LOG                               |
| 0 --> Quit                                                            |
=========================================================================
Input No.
1
================================================================
| ## Second Menu ##                                            |
|  <Single and Two Phase States>                               |
| No.  Input                    Output                         |
| 1 --(P,T,Z)-->    H  HL HV S  SL SV V  VL VV X  Y  QUALITY   |
| 2 --(P,Z,H)--> T     HL HV S  SL SV V  VL VV X  Y  QUALITY   |
| 3 --(P,Z,S)--> T  H  HL HV    SL SV V  VL VV X  Y  QUALITY   |
| 4 --(P,Z,V)--> T  H  HL HV S  SL SV    VL VV X  Y  QUALITY   |
|--------------------------------------------------------------|
|  <Two Phase State>                                           |
| 5 --(P,Z)----> X=Z : TB HB SB VB    Y=Z : TD HD SD VD        |
| 6 --(T,Z)----> X=Z : PB HB SB VB    Y=Z : PD HD SD VD        |
| 7 --(P,T)----> Coexisting Phases: X  Y  HL HV SL SV VL VV    |
```

```
|------------------------------------------------------------|
| 8 -----------> Fundamental Constants                       |
| 9 -----------> Conversion of Composition and Relative      |
|                Molcular Mass of Mixture                    |
|10 -----------> Change System of Unit, and Standard Values of|
|                Enthalpy and Entropy                        |
|99 -----------> Return to First Menu                        |
| 0 -----------> Quit                                        |
==============================================================
Input No.
10

======================================================
 No.                               current
======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance        [kmol]
 3 --> Standard Values of h and s  [1] Ideal Gas State
 0 --> Return to Second Menu
======================================================
Input No.
1

==============================
 No.  <Pressure> <Temperature>
==============================
 1 -->   Pa           K
 2 -->   bar          C
 3 -->   bar          K
 4 -->   Pa           C
==============================
Input No.
1

======================================================
 No.                               current
======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance        [kmol]
 3 --> Standard Values of h and s  [1] Ideal Gas State
 0 --> Return to Second Menu
======================================================
Input No.
2

==========================
 No.   Amount of Substance
 1 -->   kmol
 2 -->   kg
==========================
Input No.
1

======================================================
 No.                               current
======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance        [kmol]
 3 --> Standard Values of h and s  [2] IIR
 0 --> Return to Second Menu
======================================================
Input No.
3

================================================
 No.   Standard States and Values of h and s
 1 --> Ideal Gas State of Pure Components
       h=0.0[kJ/kg], s=0.0[kJ/(kg*K)]
       Pure Ideal Gases at 0[C], 1.0[bar]
 2 --> Convention of International Institute of
       Refrigeration(IIR):
```

```
       h=200[kJ/kg], s=1.0[kJ/(kg*K)]
       Saturated Pure Liquids at 0[C]
================================================
Input No.
1

=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [1] Ideal Gas State
 0 --> Return to Second Menu
=======================================================
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
9

==================================================================
 Conversion of Composition and Relative Molecular Mass of Mixture
==================================================================

 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
1
Input Z[kmol/kmol]
0.5
 Z  =    .50000000[kmol/kmol]
 Z  =    .36118780[kg/kg]
 Relative Molecular Mass of Mixture =     119.69950000[kg/kmol]
 Relative Molecular Mass of [ R22 ]
    86.46800000[kg/kmol]
 Relative Molecular Mass of [ R123 ]
   152.93100000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
2
Input Z[kg/kg]
0.5
 Z  =    .50000000[kg/kg]
 Z  =    .63881220[kmol/kmol]
 Relative Molecular Mass of Mixture =     110.47360000[kg/kmol]
 Relative Molecular Mass of [ R22 ]
    86.46800000[kg/kmol]
 Relative Molecular Mass of [ R123 ]
   152.93100000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
8
```

```
======================
 Fundamental Constants
======================
    <Constants>                 [ R22 ]            [ R123 ]
Relative Molecular Mass       86.46800000         152.93100000  [kg/kmol]
Gas Constants                 96.15707000          54.36772000  [J/(kg*K)]
Critical Temperature         369.30000000         456.86000000  [K]
                              96.14999000         183.71000000  [C]
Critical Pressure             49.71000000          36.66000000  [bar]
Critical Volume             .16861500E+00        .27527600E+00  [m**3/kmol]
                            .19500280E-02        .18000010E-02  [m**3/kg]
Acentric Factor             .21920000E+00        .28160000E+00  [-]

----- Hit RETURN Key -----

===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
1

=====================================
 (P,T,Z) --> H, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
1000000.0
Input T[K]
300.0
Input Z[kmol/kmol]
0.5
T  =     300.00000000[K]          P  =    1000.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =  -21618.98000000[kJ/kmol]
S  =     -65.95230000[kJ/(kmol*K)]V  =    .86610340E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
250.0
Input Z[kmol/kmol]
0.7
T  =     250.00000000[K]          P  =     100.00000000[kPa]
Z  =        .70000000[kmol/kmol]  H  =  -15176.73000000[kJ/kmol]
S  =     -51.98681000[kJ/(kmol*K)]V  =    .10478000E+02[m**3/kmol]
X  =        .44631380[kmol/kmol]  Y  =        .93874230[kmol/kmol]
HL =  -28246.19000000[kJ/kmol]    HV =   -2877.16200000[kJ/kmol]
SL =     -98.26443000[kJ/(kmol*K)]SV =      -8.43526600[kJ/(kmol*K)]
VL =    .80284680E-01[m**3/kmol]  VV =    .20263210E+02[m**3/kmol]
QUALITY =       .51517370[kmol/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
2

=====================================
 (P,Z,H) --> T, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
1000000.0
Input Z[kmol/kmol]
0.5
```

```
Input H[J/kmol]
-21618000.0
T  =     300.00770000[K]          P  =    1000.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =  -21618.00000000[kJ/kmol]
S  =     -65.94904000[kJ/(kmol*K)]V  =     .86611980E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
============================================================
| ## Second Menu ##                                        |
 contents not shown
============================================================
Input No.
3

========================================
 (P,Z,S) --> T, H, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
========================================
Input P[Pa]          (P=0 : Second Menu)
1000000.0
Input Z[kmol/kmol]
0.5
Input S[J/(kmol*K)]
-65952.0
T  =     300.00070000[K]          P  =    1000.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =  -21618.89000000[kJ/kmol]
S  =     -65.95200000[kJ/(kmol*K)]V  =     .86610490E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
============================================================
| ## Second Menu ##                                        |
 contents not shown
============================================================
Input No.
4

==========================================
 (P,Z,V) --> T, H, S, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
==========================================
Input P[Pa]          (P=0 : Second Menu)
1000000.0
Input Z[kmol/kmol]
0.5
Input V[m**3/kmol]
0.08661034
T  =     300.00000000[K]          P  =    1000.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =  -21618.97000000[kJ/kmol]
S  =     -65.95229000[kJ/(kmol*K)]V  =     .86610340E-01[m**3/kmol]
Liquid Region

Input P[Pa]          (P=0 : Second Menu)
0
============================================================
| ## Second Menu ##                                        |
 contents not shown
============================================================
Input No.
5

=================================================
 (P,Z) --> X=Z : TB, HB, SB, VB
           Y=Z : TD, HD, SD, VD
=================================================
Input P[Pa]          (P=0 : Second Menu)
```

```
100000.0
Input Z[kmol/kmol]
0.5
P  =     100.00000000[kPa]        Z  =        .50000000[kmol/kmol]
TB =     247.38290000[K]          TD =     284.15500000[K]
HB =  -27952.04000000[kJ/kmol]    HD =   -1276.68500000[kJ/kmol]
SB =     -98.41191000[kJ/(kmol*K)]SD =       1.58987600[kJ/(kmol*K)]
VB =    .78221300E-01[m**3/kmol]  VD =    .22974330E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
6

================================================
 (T,Z) --> X=Z : PB, HB, SB, VB
           Y=Z : PD, HD, SD, VD
================================================
Input Z[kmol/kmol]   (Z < 0 : Second Menu)
0.5
Input T[K]
247.0
T  =     247.00000000[K]          Z  =        .50000000[kmol/kmol]
PB =      98.46436000[kPa]        PD =      17.06069000[kPa]
HB =  -27995.27000000[kJ/kmol]    HD =   -3909.78100000[kJ/kmol]
SB =     -98.65056000[kJ/(kmol*K)]SD =      -1.19786100[kJ/(kmol*K)]
VB =    .78173880E-01[m**3/kmol]  VD =    .11956650E+03[m**3/kmol]

Input Z[kmol/kmol]   (Z < 0 : Second Menu)
-1
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
7

===============================================
 (P,T) --> Coexisting Phases
           X, HL, SL, VL
           Y, HV, SV, VV
===============================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
250.0
T  =     250.00000000[K]          P  =     100.00000000[kPa]
X  =        .44631380[kmol/kmol]  Y  =        .93874230[kmol/kmol]
HL =  -28246.19000000[kJ/kmol]    HV =   -2877.16200000[kJ/kmol]
SL =     -98.26443000[kJ/(kmol*K)]SV =      -8.43526600[kJ/(kmol*K)]
VL =    .80284680E-01[m**3/kmol]  VV =    .20263210E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
99
=========================================================================
|   Single Shot Program for Peng-Robinson Equation,                     |
|   an Application Program by F-PROPATH Ver.9.1                         |
|   Thermophysical Properties of Binary Mixtures                        |
|-----------------------------------------------------------------------|
|  ## First Menu ##                                                     |
| No.                        Current                                    |
```

```
| 1 --> Go to Second Menu                                          |
| 2 --> Select Mixture     (Component1 - Component2)              |
|                          [ R22 - R123 ]                          |
| 3 --> Read Help                                                  |
| 4 --> Set Logfile        [ON] PRMIX.LOG                          |
| 0 --> Quit                                                       |
====================================================================
Input No.
0

***** See You Again ! *****
Stop - Program terminated.
```

References

[1] D. Y. Peng and D. B. Robinson, A New Two–Constant Equation of State, Ind. Eng. Chem., Fundam., Vol.15, No.1, 1976.

[2] T. Takagi, Kyoto Institute of Technology, private communication.

[3] M. Fukushima, Prediction of Thermodynamic Properties for non–Azeotropic Refrigerant Mixtures (in Japanese), The Fourteenth Japan Symposium on Thermophysical Properties, (1993).

[4] Y. Sumida, N. Tanaka, H. Iijima and F. Matsuoka, Simulation of a Vapor Compression Cycle with Refrigerant Mixtures (in Japanese), The Fourteenth Japan Symposium on Thermophysical Properties, (1993).

[5] S. I. Sandler, Chemical and Engineering Thermodynamics, Wiley Series in Chemical Engineering, (1989), pp.319.

[6] Uenishi et.al.

[7] T. E. Daubert and R. P. Dannar, Physical and Thermodynamics Properties of Pure Chemicals: Data Complilation. Taylor &Francis, (1989).

[8] Japanese Association of Refrigeration and Japan Flon Gas Association, Thermophysical Properties of Environmentally Acceptable Fluorocarbons HFC–134a and HCFC–123 (in Japanese), (1990).

2.2 CSD Equation

Thermodynamic properties are evaluated by Carnahan–Starling–DeSantis equation[1]. No provision is made for transport properties at this moment.

2.2.1 The Names of Subroutine, Library File and Single Shot Program

Library File for UNIX:	`libjcsdmx.a`
Library File for DOS,Windows95/NT:	JCSDMX.LIB
Single Shot Program for UNIX:	`csdmx--ss`
Single Shot Program for DOS,Windows95/NT:	CSDMX–SS.EXE

2.2.2 Reference State

By user's selecton of KSTAN, which is the first ARGUMENT of SUBROUTINE STNKAS, the reference state is determined as shown below.

Table V-2.2-1 Reference State Specified by `KSTAN`

KSTAN	Reference State	value of enthalpy and entropy
0	298.15K, 1bar : ideal gas state of pure component	0.0kJ/kmol, 0.0kJ/(kmol·K)
1	273.15K : saturated liquid of pure component	200kJ/kg, 1.0kJ/(kg·K)
others	same with KSTAN=0	

2.2.3 Missing SUBPROGRAM

Of the SUBPROGRAMs listed in 1.6, the next is missing in F–PROPATH by CSD equation.

CRPM, SUBCRT, SUBPAR, PBT, PDT, QMIX, TBP, TDP

2.2.4 Initialization of F–PROPATH by CSD equation

You can initialize F–PROPATH by writing three lines shown below. See 1.1 and Sample Program 1 of 2.1.6.

```
CALL KPAMES(KPA, MESS)
CALL STNKAS(KSTAN, KAS)
CALL START1(J,KOMBI)
```

ARGUMENTs to the first two SUBROUTINEs are explained in 1.3. The last, START1, works as follows.

START1

SUBROUTINE START1(J,KOMBI)

input

INTEGER KOMBI : user selects one from the table below.

output

INTEGER J : error detection code
−2 : invalid ARGUMENT(s)

Table V-2.2-2 Combination of Substances Specified by `KOMBI`

KOMBI	component 1	component 2	KOMBI	component 1	component 2
1	R22	R123	6	R12	R152a
2	R13B1	R152a	7	R22	R114
3	R22	R12	8	R23	R12
4	R23	R13	9	R22	R11
5	R13	R12	10	not defined	

2.2.5 Example of User's PROGRAM UNIT

Sample Program 1

EX1.for :

```
c     ------------------------------------------------
c       CSD Equation
c       This program calculates the VLE properties of
c       R22-R123 mixture at p=1.0[bar],T=150[K]
c     ------------------------------------------------
c
      REAL T,P,X,Y,VL,VV,HL,HV,SL,SV
      INTEGER J
c
c     --------------------------------------------------
c       T=[K],p=[Pa]
c       standard state=(bibliography [1] of chapter 10)
c       amount of substance=[kmol]
c     --------------------------------------------------
      CALL KPAMES(0,1)
      CALL STNKAS(0,0)
      CALL START1(J,1)
c
c     -------------------------------------------------
c       Calculation of property on saturated state and
c       output results.
c     -------------------------------------------------
      P=1.0E5
      T=290.0
      CALL SUBXY(J,T,P,X,Y,VL,VV,HL,HV,SL,SV)
      IF (J.NE.0) THEN
         WRITE(*,*) ' ERROR IN SUBXY J=',J
         STOP
      ENDIF
      HL=HL*1.0E-6
      HV=HV*1.0E-6
      SL=SL*1.0E-3
      SV=SV*1.0E-3
      WRITE(*,*) '  X[kmol/kmol]    =',X, '   y[kmol/kmol]    =',Y
      WRITE(*,*) ' vL[m^3/kmol]     =',VL,'  vV[m^3/kmol]     =',VV
      WRITE(*,*) ' hL[MJ/kmol]      =',HL,'  hV[MJ/kmol]      =',HV
      WRITE(*,*) ' sL[MJ/(kmol K)]  =',SL,'  sV[MJ/(kmol K)]  =',SV
      STOP
      END
c
c     -----------------------------------------------------------------
c          Results
c     -----------------------------------------------------------------
c
c     X[kmol/kmol]    =   4.420045E-02   y[kmol/kmol]    =   3.520642E-01
c    vL[m^3/kmol]     =   1.019272E-01  vV[m^3/kmol]     =      23.330370
c    hL[MJ/kmol]      =     -31.306840  hV[MJ/kmol]      =  -9.433830E-01
c    sL[MJ/(kmol K)]  =     -58.291830  sV[MJ/(kmol K)]  =       2.713856
c
```

2.2.6 Sample Output of Single Shot Program

```
========================================================================
|   Single Shot Program for Peng-Robinson Equation,                    |
|   an Application Program by F-PROPATH Ver.9.1                        |
|   Thermophysical Properties of Binary Mixtures                       |
```

```
|---------------------------------------------------------------------|
|  ## First Menu ##                                                   |
| No.                        Current                                  |
| 1 --> Go to Second Menu                                             |
| 2 --> Select Mixture     (Component1 - Component2)                  |
|                          [ R22 - R152a ]                            |
| 3 --> Read Help                                                     |
| 4 --> Set Logfile        [OFF]                                      |
| 0 --> Quit                                                          |
=======================================================================
Input No.
3

 This is help for this program (CSDMX-SS.EXE)
  Nomenclature
 ==== First Charactor ====
   H : Enthalpy
   P : Pressure
   S : Entropy
   T : Temperature
   V : Volume
   X : Component1 Composition of Liquid
   Y : Component1 Composition of Vapor
   Z : Total Composition of Component1
 ==== Second Charactor ====
   B : Bubble Point
   D : Dew Point
   L : Liquid
   V : Vapor

----- Hit RETURN Key -----

=======================================================================
|   Single Shot Program for Peng-Robinson Equation,                   |
|   an Application Program by F-PROPATH Ver.9.1                       |
|   Thermophysical Properties of Binary Mixtures                      |
|---------------------------------------------------------------------|
|  ## First Menu ##                                                   |
| No.                        Current                                  |
| 1 --> Go to Second Menu                                             |
| 2 --> Select Mixture     (Component1 - Component2)                  |
|                          [ R22 - R152a ]                            |
| 3 --> Read Help                                                     |
| 4 --> Set Logfile        [OFF]                                      |
| 0 --> Quit                                                          |
=======================================================================
Input No.
4

 1: Logfile ON
 2: Logfile OFF
Input No.
1
Input Filename
csdmix.log
=======================================================================
|   Single Shot Program for Peng-Robinson Equation,                   |
|   an Application Program by F-PROPATH Ver.9.1                       |
|   Thermophysical Properties of Binary Mixtures                      |
|---------------------------------------------------------------------|
|  ## First Menu ##                                                   |
| No.                        Current                                  |
| 1 --> Go to Second Menu                                             |
| 2 --> Select Mixture     (Component1 - Component2)                  |
|                          [ R22 - R152a ]                            |
| 3 --> Read Help                                                     |
| 4 --> Set Logfile        [ON] csdmix.log                            |
| 0 --> Quit                                                          |
=======================================================================
Input No.
2
```

```
===================================
| No.|  Component1 - Component2     |
|----|------------------------------|
|  1 | [ R22 - R123 ]               |
|  2 | [ R13 - R152a ]              |
|  3 | [ R22 - R12 ]                |
|  4 | [ R23 - R13 ]                |
|  5 | [ R13 - R12 ]                |
|  6 | [ R12 - R152a ]              |
|  7 | [ R22 - R114 ]               |
|  8 | [ R23 - R12 ]                |
|  9 | [ R22 - R11 ]                |
===================================
Input No.
1
======================================================================
|   Single Shot Program for Peng-Robinson Equation,                  |
|   an Application Program by F-PROPATH Ver.9.1                      |
|   Thermophysical Properties of Binary Mixtures                     |
|--------------------------------------------------------------------|
|  ## First Menu ##                                                  |
| No.                      Current                                   |
| 1 --> Go to Second Menu                                            |
| 2 --> Select Mixture    (Component1 - Component2)                  |
|                         [ R22 - R123 ]                             |
| 3 --> Read Help                                                    |
| 4 --> Set Logfile       [ON] csdmix.log                            |
| 0 --> Quit                                                         |
======================================================================
Input No.
1
=============================================================
| ## Second Menu ##                                          |
|  <Single and Two Phase States>                             |
| No.  Input                   Output                        |
| 1 --(P,T,Z)-->    H  HL HV S  SL SV V  VL VV X  Y  QUALITY  |
| 2 --(P,Z,H)--> T     HL HV S  SL SV V  VL VV X  Y  QUALITY  |
| 3 --(P,Z,S)--> T  H  HL HV    SL SV V  VL VV X  Y  QUALITY  |
| 4 --(P,Z,V)--> T  H  HL HV S  SL SV    VL VV X  Y  QUALITY  |
|-----------------------------------------------------------|
|  <Two Phase State>                                         |
| 5 --(P,Z)----> X=Z : TB HB SB VB    Y=Z : TD HD SD VD      |
| 6 --(T,Z)----> X=Z : PB HB SB VB    Y=Z : PD HD SD VD      |
| 7 --(P,T)----> Coexisting Phases: X  Y  HL HV SL SV VL VV  |
|-----------------------------------------------------------|
| 8 -----------> Fundamental Constants                       |
| 9 -----------> Conversion of Composition and Relative      |
|                Molcular Mass of Mixture                    |
|10 -----------> Change System of Unit, and Standard Values of|
|                Enthalpy and Entropy                        |
|99 -----------> Return to First Menu                        |
| 0 -----------> Quit                                        |
=============================================================
Input No.
10

=====================================================
 No.                                current
=====================================================
 1 --> Pressure and Temperature    [bar, C]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [2] IIR
 0 --> Return to Second Menu
=====================================================
Input No.
1

==============================
 No.  <Pressure> <Temperature>
==============================
 1 -->   Pa            K
```

```
 2 -->   bar          C
 3 -->   bar          K
 4 -->   Pa           C
==============================
Input No.
1

=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [ kg ]
 3 --> Standard Values of h and s  [2] IIR
 0 --> Return to Second Menu
=======================================================
Input No.
2

===========================
 No.   Amount of Substance
 1 -->   kmol
 2 -->   kg
===========================
Input No.
1

=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [2] IIR
 0 --> Return to Second Menu
=======================================================
Input No.
3

================================================
 No.   Standard States and Values of h and s
 1 --> Ideal Gas State of Pure Components
       h=0.0[kJ/kg], s=0.0[kJ/(kg*K)]
       Pure Ideal Gases at 0[C], 1.0[bar]
 2 --> Convention of International Institute of
       Refrigeration(IIR):
       h=200[kJ/kg], s=1.0[kJ/(kg*K)]
       Saturated Pure Liquids at 0[C]
================================================
Input No.
1

=======================================================
 No.                                current
=======================================================
 1 --> Pressure and Temperature    [ Pa, K]
 2 --> Amount of Substance         [kmol]
 3 --> Standard Values of h and s  [1] Ideal Gas State
 0 --> Return to Second Menu
=======================================================
Input No.
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
9

==================================================================
 Conversion of Composition and Relative Molecular Mass of Mixture
==================================================================
```

```
 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
1
Input Z[kmol/kmol]
0.5
 Z  =    .50000000[kmol/kmol]
 Z  =    .36118780[kg/kg]
 Relative Molecular Mass of Mixture =     119.69950000[kg/kmol]
 Relative Molecular Mass of [ R22 ]
    86.46800000[kg/kmol]
 Relative Molecular Mass of [ R123 ]
   152.93100000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
2
Input Z[kg/kg]
0.5
 Z  =    .50000000[kg/kg]
 Z  =    .63881220[kmol/kmol]
 Relative Molecular Mass of Mixture =     110.47360000[kg/kmol]
 Relative Molecular Mass of [ R22 ]
    86.46800000[kg/kmol]
 Relative Molecular Mass of [ R123 ]
   152.93100000[kg/kmol]


 1: [kmol/kmol] --> [kg/kg]     and Relative Molecular Mass of Mixture
 2: [kg/kg]     --> [kmol/kmol] and Relative Molecular Mass of Mixture
 0: Return to Second Menu
Input No.
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
8

=======================
 Fundamental Constants
=======================
   <Constants>               [ R22 ]           [ R123 ]
Relative Molecular Mass      86.46800000        152.93100000  [kg/kmol]
Gas Constants                96.15707000         54.36772000  [J/(kg*K)]
Critical Temperature        369.30000000        456.86000000  [K]
                             96.15001000        183.71000000  [C]
Critical Pressure            49.71000000         36.66000000  [bar]
Critical Volume            .16861500E+00       .27527600E+00  [m**3/kmol]
                           .19500280E-02       .18000010E-02  [m**3/kg]
----- Hit RETURN Key -----

================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
1

======================================
 (P,T,Z) --> H, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
======================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
```

```
Input T[K]
280.0
Input Z[kmol/kmol]
0.5
T  =     280.00000000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =   -7103.10700000[kJ/kmol]
S  =     -10.61071000[kJ/(kmol*K)]V  =    .18527250E+02[m**3/kmol]
X  =        .09671523[kmol/kmol]  Y  =        .58946680[kmol/kmol]
HL =  -32138.17000000[kJ/kmol]    HV =   -1549.20300000[kJ/kmol]
SL =     -61.69294000[kJ/(kmol*K)]SV =     721.63350000[J/(kmol*K)]
VL =    .98700080E-01[m**3/kmol]  VV =    .22615530E+02[m**3/kmol]
QUALITY =       .81843440[kmol/kmol]

Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
300.0
Input Z[kmol/kmol]
0.5
T  =     300.00000000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =     -57.29559000[kJ/kmol]
S  =       5.99217600[kJ/(kmol*K)]V  =    .24316680E+02[m**3/kmol]
Vapor Region

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                             |
 contents not shown
================================================================
Input No.
2

=====================================
 (P,Z,H) --> T, S, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input H[J/kmol]
-57295.59
T  =     300.00000000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =     -57.29559000[kJ/kmol]
S  =       5.99217600[kJ/(kmol*K)]V  =    .24316680E+02[m**3/kmol]
Vapor Region

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                             |
 contents not shown
================================================================
Input No.
3

=====================================
 (P,Z,S) --> T, H, V, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
=====================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input S[J/(kmol*K)]
5992.176
T  =     300.00000000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =     -57.29567000[kJ/kmol]
```

```
S  =       5.99217600[kJ/(kmol*K)]V  =    .24316680E+02[m**3/kmol]
Vapor Region

Input P[Pa]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
4

========================================
 (P,Z,V) --> T, H, S, QUALITY
             X, HL, SL, VL
             Y, HV, SV, VV
========================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
Input V[m**3/kmol]
24.31668
T  =     300.00010000[K]          P  =     100.00000000[kPa]
Z  =        .50000000[kmol/kmol]  H  =     -57.29181000[kJ/kmol]
S  =       5.99218900[kJ/(kmol*K)]V  =    .24316680E+02[m**3/kmol]
Vapor Region

Input P[Pa]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
5

===============================================
 (P,Z) --> X=Z : TB, HB, SB, VB
           Y=Z : TD, HD, SD, VD
===============================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input Z[kmol/kmol]
0.5
P  =     100.00000000[kPa]        Z  =        .50000000[kmol/kmol]
TB =     246.39250000[K]          TD =     284.17860000[K]
HB =  -31560.63000000[kJ/kmol]    HD =   -1315.70200000[kJ/kmol]
SB =     -67.17770000[kJ/(kmol*K)]SD =       1.72309500[kJ/(kmol*K)]
VB =    .80985700E-01[m**3/kmol]  VD =    .22921670E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
===============================================================
| ## Second Menu ##                                           |
 contents not shown
===============================================================
Input No.
6

===============================================
 (T,Z) --> X=Z : PB, HB, SB, VB
           Y=Z : PD, HD, SD, VD
===============================================
Input Z[kmol/kmol]   (Z < 0 : Second Menu)
0.5
Input T[K]
273.15
T  =     273.15000000[K]          Z  =        .50000000[kmol/kmol]
PB =     263.49430000[kPa]        PD =      62.22648000[kPa]
HB =  -28486.09000000[kJ/kmol]    HD =   -2080.65200000[kJ/kmol]
```

```
SB =     -53.59378000[kJ/(kmol*K)]SD =      -1.19924600[kJ/(kmol*K)]
VB =    .85064980E-01[m**3/kmol]  VD =    .35736690E+02[m**3/kmol]

Input Z[kmol/kmol]   (Z < 0 : Second Menu)
-1
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
7

===============================================
 (P,T) --> Coexisting Phases
           X, HL, SL, VL
           Y, HV, SV, VV
===============================================
Input P[Pa]          (P=0 : Second Menu)
100000.0
Input T[K]
273.15
T  =     273.15000000[K]          P  =     100.00000000[kPa]
X  =        .14236480[kmol/kmol]  Y  =        .70970110[kmol/kmol]
HL =  -32552.08000000[kJ/kmol]    HV =   -1889.64500000[kJ/kmol]
SL =     -63.78323000[kJ/(kmol*K)]SV =      -1.18756400[kJ/(kmol*K)]
VL =    .96228840E-01[m**3/kmol]  VV =    .22094880E+02[m**3/kmol]

Input P[Pa]          (P=0 : Second Menu)
0
================================================================
| ## Second Menu ##                                            |
 contents not shown
================================================================
Input No.
0

***** See You Again ! *****
Stop - Program terminated.
```

References

[1] G. Morrison, M. O. McLinden, Application of a hard sphere equation of state to refrigerants and refrigerant mixtures, NBS Technical Note 1226, 1986

2.3 BWR Equation

Thermodynamic properties are evaluated by the Benwdict-Webb-Rubin equation modified by Nishiumi and Saito[1]. No provision is made for transport properties at this moment.

2.3.1 The Names of Subroutine, Library File and Single Shot Program

Library File for UNIX:	`libjbwr.a`
Library File for DOS,Windows95/NT:	JBWRMX.LIB
Single Shot Program for UNIX:	Not provided
Single Shot Program for DOS,Windows95/NT:	BWRMX–SS.EXE

It should be noted that the source programs of JBWRMX.LIB are writen in both C-language and FORTRAN. Therefore user's programming environment must support mixed language programming of C and FORTRAN to use JBWRMX.LIB.

2.3.2 Reference State

By user's selecton of KSTAN, which is the first ARGUMENT of STNKAS, the reference state is determined as shown below.

Table V-2.3-1 Reference State Specified by `KSTAN`

KSTAN	Reference State	value of enthalpy and entropy
1	273.15K : saturated liquid of pure component	200kJ/kg, 1.0kJ/(kg·K)
others	same with KSTAN= 1	

2.3.3 Missing SUBPROGRAM

Of the SUBPROGRAMs listed in 1.6, the next is missing in F–PROPATH by BWR equation.

MKTABLE, START1, SUBCRT, SUBMXH, SUBM, SUBPAR, T68, T90

Also, subroutine SUBMIX with either I = 3 or 4 (see 1.7) are not supported in F–PROPATH by BWR equation.

2.3.4 Initialization by SUBROUTINE START2

By the procedure described below, user can use F–PROPATH by BWR equation for any mixture. However in that case a user has to transfer related constants of each component to F–PROPATH. They are relative molecular mass, critical constants(temperature, pressure, volume), acentric factor, coefficients of isobaric specific heat equation at ideal gas state, and interaction parameter.

A user has to write the lines shown below before he or she makes reference to any F–PROPATH by BWR equation SUBPROGRAM.

```
DIMENSION PR1(5),PR2(5),CP1(8),CP2(8)
  DATA STATEMENT for PR1,PR2,CP1,CP2
AKIJ=X
CALL KPAMES(KPA,MESS)
CALL STNKAS(KSTAN,KAS)
CALL START2(J,PR1,PR2,CP1,CP2,AKIJ)
```

PR1 and PR2 are arrays to which a user transfers constants for component 1 and 2, respectively. CP1 and CP2 are arrays to which a user trasfers coefficients of isobaric specific heat equation for component 1 and 2, respectively. AKIJ is the interaction parameter defined in reference [1].

Elements of PR1 and PR2 mean what are shown below.

PR1(1) : relative molecular mass of component 1 [kg/kmol]
PR1(2) : critical temperature of component 1 [K]
PR1(3) : dummy(critical pressure of component 1 [Pa])

PR1(4) : critical volume of component 1 [m^3/kmol]
PR1(5) : acentric factor of component 1 [-]

PR2(1) : relative molecular mass of component 2 [kg/kmol]
PR2(2) : critical temperature of component 2 [K]
PR2(3) : dummy(critical pressure of component 2 [Pa])
PR2(4) : critical volume of component 2 [m^3/kmol]
PR2(5) : acentric factor of component 2 [-]

A user is allowed to use one of the following three equations of isobaric specific heat at ideal gas state (T : temperature [K]).

(1) CP[J/(kmol·K)] $= A + BT + CT^2 + DT^3 + ET^4$, CP*(1) = 2.0
(2) CP[J/(kmol·K)] $= AT^2 + BT + C + DT + ET^2 + FT^3$, CP*(1) = 3.0

Elements of CP1 and CP2 mean what are shown below.
When CP*(1) = 1.0 or 2.0

CP1(1) : number of equation 2.0 or 3.0 for component 1.
CP1(2) : value of A for component 1
CP1(3) : value of B for component 1
CP1(4) : value of C for component 1
CP1(5) : value of D for component 1
CP1(6) : value of E for component 1
CP1(7) : lower valid bound of the equation [K]
CP1(8) : upper valid bound of the equation [K]

CP2(1) : number of equation 2.0 or 3.0 for component 2.
CP2(2) : value of A for component 2
CP2(3) : value of B for component 2
CP2(4) : value of C for component 2
CP2(5) : value of D for component 2
CP2(6) : value of E for component 2
CP2(7) : lower valid bound of the equation [K]
CP2(8) : upper valid bound of the equation [K]

When CP*(1) = 3.0

CP1(1) : number of equation 3.0 for component 1.
CP1(2) : lower valid bound of the equation [K]
CP1(3) : upper valid bound of the equation [K]
CP1(4) : value of A for component 1
CP1(5) : value of B for component 1
CP1(6) : value of C for component 1
CP1(7) : value of D for component 1
CP1(8) : value of E for component 1
CP1(9) : value of F for component 1

CP2(1) : number of equation 3.0 for component 2.
CP2(2) : lower valid bound of the equation [K]
CP2(3) : upper valid bound of the equation [K]
CP2(4) : value of A for component 2
CP2(5) : value of B for component 2
CP2(6) : value of C for component 2
CP2(7) : value of D for component 2
CP2(8) : value of E for component 2
CP2(9) : value of F for component 2

J is the error detection code. When PR1(2)>PR2(2), $T_{c1} > T_{c2}$, exchange between component 1 and 2 will occur and J= −1 will be returned. For other invalid ARGUMENT(s), J= −2 will occur.

2.3.5 Example of User's PROGRAM UNIT

Sample Program 1

```
C-----------------------------------------------------------------
C    NS-BWR Equation
C    This program calculates properties of R22-R114 mixture
C    at buble and dew point at P=2.5[bar] and Z=0.5[kg/kg].
C-----------------------------------------------------------------
C
C-------------------------------------------
C    Definition of array PR1,PR2,CP1 and CP2.
C-------------------------------------------
      DIMENSION PR1(5),PR2(5),CP1(9),CP2(9)
C
C---------------------------------------
C    T=[C],P=[bar],quantity=[kg]
C    standard state=(saturated liquid at 273.15[K])
C----------------------------------------
      call KPAMES(1,1)
      call STNKAS(1,1)
C
C---------------------------------------------------------------------------
C    Putting fundamental constants into PR1 and PR2 using DATA STATEMENT.
C    DATA(PR1(I),I=1,5)/MW1[KG/KMOL],TC1[K],dummy, VC1[M^3/KMOL],OMEGA1[-]/
C    DATA(PR2(I),I=1,5)/MW2[KG/KMOL],TC2[K],dummy, VC2[M^3/KMOL],OMEGA2[-]/
C---------------------------------------------------------------------------
      DATA(PR1(I),I=1,5)/ 86.469, 369.3,  -1.0, 0.168555, 0.205/
      DATA(PR2(I),I=1,5)/170.922, 418.78, -1.0, 0.296739, 0.234/
C
C---------------------------------------------------------------------------
C    Putting isobaric heat capacity at ideal gas state into CP1 and CP2
C    using DATA STATEMENT.
C    DATA(CP1(I),I=1,8)/EQUATION NUMBER,TMIN[K],TMAX[K], A,B,C,D,E/
C    DATA(CP2(I),I=1,8)/EQUATION NUMBER,TMIN[K],TMAX[K], A,B,C,D,E/
C---------------------------------------------------------------------------
      DATA(CP1(I),I=1,9)
     &  /3.0, 250.0, 350.0,
     &   -917.3,28.755,-2.030E-02,2.5351E-03,-2.185E-06, 7.1E-10/
C        [kJ/kg]
      DATA(CP2(I),I=1,9)
     &  /2.0, 250.0, 400.0,
     &   -0.12916, 4.7009E-03, -8.612E-06, 6.05E-09, 0.0, 0.0 /
C        [kJ/kg]
      do 10 I=4,9
C        [kJ/kg] -> [J/kmol]
         CP1(I) = CP1(I) * PR1(1) * 1000
         CP2(I) = CP2(I) * PR2(1) * 1000
 10   continue
C
C-----------------------------------------
C    Setting interaction parametar AKIJ.
C-----------------------------------------
      AKIJ=0.976
C
C-------------------------
C    Execution START2.
C-------------------------
      call START2(ECODE, PR1, PR2, CP1, CP2, AKIJ)
C
C-------------------------------------------
C   Calculation of properties at buble point and
C   dew point using SUBPB and output results.
C-------------------------------------------
      P=2.5
      Z=0.5
```

```
      CALL SUBTB(J,TB,P,Z,VB,HB,SB)
      CALL SUBTD(J,TD,P,Z,VD,HD,SD)
      WRITE(*,*) ' P[bar]     =',P
      WRITE(*,*) ' Z[kg/kg]   =',Z
      WRITE(*,1) TB, TD
      WRITE(*,2) VB, VD
      WRITE(*,3) HB/1000, HD/1000
      WRITE(*,4) SB/1000, SD/1000
 1    format('  TB[C]      =', F7.1,  '    TD =', F7.1)
 2    format('  VB[m^3/kg] =', E10.2, ' VB =', E10.2)
 3    format('  HB[kJ/kg]  =', F7.1,  '    HD =', F7.1)
 4    format('  SB[kJ/kg]  =', F7.3,  '    SD =', F7.3)
      STOP
      END
```

Output

```
 P[bar]     =  2.5
 Z[kg/kg]   =  0.5
 TB[C]      =  -14.0    TD =    3.5
 VB[m^3/kg] =  0.72E-03 VB =  0.75E-01
 HB[kJ/kg]  =  196.7    HD =  372.0
 SB[kJ/kg]  =  1.025    SD =  1.683
```

Sample Program 2

```
C------------------------------------------------------------------
C    NS-BWR Equation
C    This program calculates temperature, volume,entropy and quality
C    of R22-R114 mixture
C    at P=0.6[MPa], Z=0.5[kg/kg] and H=300[kJ/kg].
C------------------------------------------------------------------
      DIMENSION PR1(5),PR2(5),CP1(9),CP2(9)
      call KPAMES(0,1)
      call STNKAS(1,1)
      DATA(PR1(I),I=1,5)/ 86.469, 369.3,  -1.0, 0.168555, 0.205/
      DATA(PR2(I),I=1,5)/170.922, 418.78, -1.0, 0.296739, 0.234/
      DATA(CP1(I),I=1,9)
     &  /3.0, 250.0, 350.0,
     &   -917.3,28.755,-2.030E-02,2.5351E-03,-2.185E-06, 7.1E-10/
C        [kJ/kg]
      DATA(CP2(I),I=1,9)
     &  /2.0, 250.0, 400.0,
     &   -0.12916, 4.7009E-03, -8.612E-06, 6.05E-09, 0.0, 0.0 /
C        [kJ/kg]
      do 10 I=4,9
C        [kJ/kg] -> [J/kmol]
         CP1(I) = CP1(I) * PR1(1) * 1000
         CP2(I) = CP2(I) * PR2(1) * 1000
 10   continue
      AKIJ=0.976
      call START2(ECODE, PR1, PR2, CP1, CP2, AKIJ)
C
C-------------------------------------------
C   Calculation of temperature, volume, entropy and quality
C   from pressure, whole composition and enthalpy.
C-------------------------------------------
      P = 0.6E+6
      Z = 0.5
      H = 300.0*1000.0
      CALL SUBMIX(2, J, T, P, Z, V, H, S)
      Q = QMIX(T, P, Z)
      WRITE(*,*) ' P[MPa]     =', P/1e+6
      WRITE(*,*) ' Z[kg/kg]   =', Z
      WRITE(*,*) ' H[kJ/kg]   =', H/1000
      WRITE(*,*) ' T[K]       =', T
```

```
      WRITE(*,*) ' Q[kg/kg]    =', Q
      WRITE(*,*) ' V[m3/kg]    =', V
      WRITE(*,*) ' S[kJ/kg]    =', S/1000
      STOP
      END
```

Output

```
 P[MPa]     =  0.600000024
 Z[kg/kg]   =  0.5
 H[kJ/kg]   =  300.
 T[K]       =  297.011963
 Q[kg/kg]   =  0.667366326
 V[m3/kg]   =  0.00257301494
 S[kJ/kg]   =  1.34425902
```

2.3.6 Sample Output of Single Shot Program Single shot program of BWR equation is not proveided in this version of F-PROPATH.

References

[1] Nishiumi, H. and Saito, S., J. Chem. Eng. Japan, 8-5(1975), 356.

VI I-PROPATH: Ideal Gases and Ideal Gas Mixtures

I-PROPATH is a program package for the properties of ideal gases and ideal gas mixtures based on database by Daubert and Danner[1]. This package provides 11 SUBROUTINE SUBPROGRAMs and 19 FUNCTION SUBPROGRAMs for 54 substances, their mixtures, air as a mixture of ideal gases, and complete combustion-by-air products of $C_XH_YO_Z$. In addition to these SUBPROGRAMs there are 5 single shot programs (ideal gases, air, complete combustion-by-air products, Keenan-Chao-Kaye-style gas tables [2] and JANAF-style tables [3]).

In calculating the properties of air as a mixture of ideal gases and complete combustion-by-air products of $C_XH_YO_Z$, the composition of air is assumed to be that shown in reference [2] (78.03 % nitrogen, 20.99 % oxygen and 0.98 % argon by volume).

1. SUBPROGRAM REFERENCE

1.1 Initialization process

Every I-PROPATH user has to make initialization process by the following procedures.

1.1.1 Reservation of VARIABLEs (required)

A PROGRAM UNIT which is going to CALL the I-PROPATH SUBPROGRAMs should include the following LINEs before the first EXECUTABLE STATEMENT.

```
INTEGER KPA,KMOL,MESS
CHARACTER*25 ANAME
REAL GASCON
COMMON /UNIT/KPA,KMOL,MESS
COMMON /CNST/GASCON
```

`KPA` specifies the units of temperature and pressure and `KMOL` the unit of amount of substance. The system of units which a user can select and the relation between the values of `KPA` and `KMOL` specified by a user and the units are shown in Chapter 3.

`MESS` specifies whether messages to the erroneous SUBPROGRAM REFERENCE are to be printed out to the standard output device or not. I-PROPATH does not return any messages when `MESS`$=0$, while it does when `MESS`$\neq 0$.

`GASCON` is a reserved NAME as a REAL CONSTANT for the universal gas constant.

`ANAME` is a reserved NAME as a CHARACTER for the name of substance identified by the substance index of an ideal gas.

1.1.2 Initialization of the reserved CONSTANTs (required)

I-PROPATH offers the automatic initialization SUBROUTINE PROGRAM `IPINIT`. A user has to initialize parameters mentioned above by writing

```
CALL IPINIT(KPA,KMOL,MESS,KGAS,GASC)
```

before the first REFERENCE to a I-PROPATH SUBPROGRAM in the MAIN PROGRAM. See section **7.2.9**

1.1.3 Re-initialization (optional)

If a user happens to want to use other settings for parameters `KPA`, `KMOL`, `MESS` and `GASCON` in any places of his or her PROGRAM UNIT, he or she is supposed to write the similar statement as the one described in section **1.1.2** at those places.

1.2 Specification of substance

Each SUBPROGRAMs has an ARGUMENT `ISUB` or an ARRAY `ISUB(`i`)` named as **substance index(es)** for each ideal gas or ideal gas mixture. Every user has to specify the substance index when he/she wishes to make REFERENCE to the SUBPROGRAMs looking up the following table.

Table VI-1-1 List of substance indexes : ISUB

Chemical Symbol(∗)	Molecular Formula	IUPAC Name of Substance (Synonym)	**ISUB**
Ar	Ar	Argon	23
C	C	Carbon	18
CClF2H	$CHClF_2$	Chlorodifluoromethane (HCFC 22)	24
CClF3	$CClF_3$	Chlorotrifluoromethane (CFC 13)	25
CClH3	CH_3Cl	Methyl Chloride (Chloromethane)	41
CCl2FH	$CHCl_2F$	Dichlorofluoromethane (HCFC 21)	27
CCl2F2	CCl_2F_2	Dichlorodifluoromethane (CFC 12)	28
CCl2H2	CH_2Cl_2	Dichloromethane (Methylene Chloride)	29
CCl3H	$CHCl_3$	Chloroform (Trichloromethane)	26
CF4	CF_4	Carbon Tetrafluoride (Tetrafluoromethane)	30
CH4	CH_4	Methan	10
CH4O	CH_3OH	Methanol	31
CO	CO	Carbon Monoxide	8
CO2	CO_2	Carbon Dioxide	9
C2ClF2H3	CH_3CClF_2	1-Chloro-1,1-Difluoroethane (HCFC 142B)	32
C2ClH5	CH_3CH_2Cl	Ethyl Chloride (Chloroethane)	33
C2Cl2F4	$CClF_2CClF_2$	1,2-Dichlorotetrafluoroethane (CFC 114)	34
C2F2H4	CH_3CHF_2	1,1-Difluoroethane (HFC 152A)	35
C2H2	CHCH	Ethyne (Acetylene)	36
C2H4	CH_2CH_2	Ethylene (Ethene)	12
C2H4O	CH_3CHO	Acetaldehyde	42
C2H4O2	CH_3COOH	Acetic Acid	43
C2H6	CH_3CH_3	Ethane	37
C2H6O	CH_3CH_2OH	Ethanol	44
C3H6	CH_3CHCH_2	Propylene (Propene)	45
C3H6O	CH_3COCH_3	Acetone	46
C3H8	$CH_3CH_2CH_3$	Propane	11
C4H10	$CH_3(CH_2)_2CH_3$	Butane (n-Butane)	38
C4H10	$(CH_3)_3CH$	Isobutane	39
C5H12	$CH_3(CH_2)_3CH_3$	Pentane (n-Pentane)	47
C5H12	$(CH_3)_2CHCH_2CH_3$	Isopentane	40
C6H6	C_6H_6	Benzene	48
C6H14	$CH_3(CH_2)_4CH_3$	Hexane (n-Hexane)	49
C7H8	$(C_6H_5)CH_3$	Toluene (Methylbenzene)	50
C7H16	$CH_3(CH_2)_5CH_3$	Heptane (n-Heptane)	51
C8H18	$CH_3(CH_2)_6CH_3$	Octane (n-Octane)	52
C8H18	$(CH_3)_2CH(CH_2)_4CH_3$	2-Methylheptane (Iso-Octane)	53
C10H8	$(C_6H_4)(C_4H_4)$	Naphthalene	54
ClH	HCl	Hydrogen Chloride	19
Cl2	Cl_2	Chlorine	13
F2	F_2	Fluorine	20
HI	HI	Hydrogen Iodide	21
H2	H_2	Hydrogen	3
H2O	H_2O	Water	2
H3N	NH_3	Ammonia	14
He	He	Helium (Helium-4)	22
NO	NO	Nitric Oxide (Nitrogen Monoxide)	4
NO2	NO_2	Nitrogen Dioxide	5
N2	N_2	Nitrogen	1
N2O	N_2O	Nitrous Oxide (Dinitrogen Monoxide)	6
Ne	Ne	Neon	16
O2	O_2	Oxygen	7
O2S	SO_2	Sulfur Dioxide	15
O3	O_3	Ozone	17

(∗) according to the alphabetical order of elements and increasing order of number of atoms.

2. Operations to Manage Erroneous SUBPROGRAM REFERENCE

A predetermined sequence of operations will occur to process an erroneous SUBPROGRAM REFERNCE when improper SUBPROGRAM REFERENCE has been done. Erroneous SUBPROGRAM REFERENCEs are grouped into 3 levels, with the ascending severity of user's mistake. A user has committed a more serious mistake when level 3 ERROR ocurrs than when a level 2 ERROR does, for example.

2.1 Level 1 ERROR (No error)

When a I-PROPATH SUBROUTINE SUBPROGRAM returns the values of ARGUMENTs correctly to the MAIN PROGRAM, the SUBPROGRAM returns the value 0 of error detection code `IERR`.

2.2 Level 2 ERROR (Invalid ARGUMENT(s))

A level 2 ERROR will occur when the ARGUMENT(s) a user transferred to I-PROPATH SUBPROGRAM from his or her MAIN PROGRAM fail to drop in the proper range.

A level 2 ERROR is processed as below.

value of error detection cord, one of the arguments of SUBROUTINE : `IERR`$= -2$

value of FUNCTION or values of ARGUMENTs of SUBROUTINE returned to the CALLing program : -1.0E+20

output to the standard output device :

`*** OUT OF RANGE AT` (name of SUBPROGRAM CALLed) `FOR` (name of substance)

2.3 Level 3 ERROR (Substance Unavailable)

A user will encounter a level 3 ERROR when the INTEGER CONSTANT `ISUB` a user specified for the substance index fails to coincide with any of the allowable values.

The level 3 error is processed as shown below.

value of error detection cord, one of the arguments of SUBROUTINE : `IERR`$= -3$

value of FUNCTION or values of ARGUMENTs of SUBROUTINE returned to the CALLing program : -1.0E+30

output to the standard output device :

`*** SUBSTANCE INDEX * ISUB =` (value of substance index) `* IS NOT INCLUDED IN I-PROPATH ***`

3. System of Units

All REAL quantities are in the fundamental SI or in the coherent derived SI with three exceptions. Temperature can be in the unit of Kelvin [K] or degree Celsius [°C], pressure in the unit of Pascal [Pa] or bar [bar], and the amount of substance in the unit of kilomole [kmol] or kilogram [kg]. These depend on the values of INTEGER CONSTANTs, `KPA` and `KMOL`, which a user assigned to. See 1.1 and 7.2.9.

Table VI-3-1 Units of Pressure and Temperature Specified by `KPA`

`KPA`	unit of pressure	unit of temperature	
0	Pa	K	(default)
1	bar	°C	
2	bar	K	
3	Pa	°C	
others	Pa	K	

Table VI-3-2 Amount of Substance Specified by `KMOL`

`KMOL`	unit of the amount of substance	
0	kmol	(default)
1	kg	
others	kmol	

4. Reference Values of Enthalpy and Entropy

At the reference temperature of 298.15 [K] (25 [°C]), 0 is assigned to enthalpy. At the reference state of 0.1 [MPa] (1 [bar]) and 298.15 [K] (25 [°C]), the absolute entropy cited from reference [1] is assigned to the specific entropy. Thus, the value of enthalpy is relative to the reference temperature while that of entropy is absolute.

5. Reserved NAMEs of COMMON BLOCKs, FUNCTIONs and SUBROUTINEs

I-PROPATH uses a lot of NAMEs, listed below, for its own purpose. These are the NAMEs of SUBPROGRAMs, NAMED COMMON BLOCKs, and ARGUMENTs. A user is supposed to use the NAMEs of SUBPROGRAMs and COMMON BLOCKs only when he/she does so in the original meaning.

Thses are listed below. The letters in the first column are the fist LETTERs in the NAMES listed in the same line.

A	`AKG2KM`,`AKM2KG`, `AIRTP`
C	`CHOTBL`, `COMMON /CNST/`
F	`FUELML`
G	`GASCON`
I	`IDENTI`, `IDGCMM`, `IDGFND`, `IDGT`, `IDGTBL`, `IDGTP`, `IPINIT`
K	`KMOL`, `KPA`
M	`MIXCMM`, `MIXTP`, `MESS`
P	`PTSAIR`, `PTSIDG`, `PTVAIR`, `PTVIDG`
T	`T68`,`T90`, `THAIR`, `THIDG`, `TPSAIR`, `TPSIDG`, `TPVAIR`, `TPVIDG`, `TVSAIR`, `TVSIDG`, `TUAIR`, `TUIDG`
U	`COMMON /UNIT/`

6. NAMEs of FUNCTION and SUBROUTINE SUBPROGRAMs

NAMEs of FUNCTIONs and SUBROUTINEs are shown below and the full description of these SUBPROGRAMs is given in chapter 7.

6.1 FUNCTION SUBPROGRAMs

6.1.1 REAL valued FUNCTIONs (conversion of temperature scale and mole-mass conversion)

T68 = conversion from ITS-1990 to ITPS-1968
T90 = conversion from ITPS-1968 to ITS-1990
AKM2KG = conversion from mole to mass
AKG2KM = conversion from mass to mole

6.1.2 REAL valued FUNCTIONs (ideal gas)

PTSIDG = pressure as a function of temperature and entropy
PTVIDG = pressure as a function of temperature and volume
THIDG = temperature as a function of enthalpy
TPSIDG = temperature as a function of pressure and entropy
TPVIDG = temperature as a function of pressure and volume
TVSIDG = temperature as a function of volume and entropy
TUIDG = temperature as a function of internal energy

6.1.3 REAL valued FUNCTIONs (air as a mixture of ideal gases)

PTSAIR = pressure as a function of temperature and entropy
PTVAIR = pressure as a function of temperature and volume
THAIR = temperature as a function of enthalpy
TPSAIR = temperature as a function of pressure and entropy
TPVAIR = temperature as a function of pressure and volume
TVSAIR = temperature as a function of volume and entropy
TUAIR = temperature as a function of internal energy

6.1.4 CHARACTER valued FUNCTION

IDENTI = name of an ideal gas, or version number of PROPATH

6.2 SUBROUTINE SUBPROGRAMs

6.2.1 initialization and conversion

IPINIT = initialization
IDGCMM = conversion from mass to mole, or reverse, for ideal gas.
MIXCMM = conversion from mass fractions to mole fractions, or reverse, for mixture of ideal gases.

6.2.2 ideal gas

IDGFND = critical and fundamental constants
IDGT = properties of ideal gases as a function of temperature at 0.1 MPa (JANAF-style table)
IDGTBL = properties of ideal gases as a function of temperature at 0.1 MPa (Keenan-Chao-Kaye-style gas table)
IDGTP = properties of ideal gases as a function of temperature

6.2.3 mixture of ideal gases

MIXTP = properties of ideal gas mixture as a function of temperature and pressure

6.2.4 air as a mixture of ideal gases

AIRTP = properties of air (78.03 % nitrogen, 20.99 % oxygen and 0.98 % argon by volume) as a function of temperature and pressure

6.2.5 complete combustion-by-air product of $C_XH_YO_Z$

CHOTBL = properties of complete combustion-by-air products of $C_XH_YO_Z$ at 0.1 MPa (Keenan-Chao-Kaye-style gas table) as a function of temperature

FUELML = mole fractions of complete combustion-by-air products of the mixture of $C_XH_YO_Z$ fuels.

7. Descriptions of FUNCTIONs and SUBROUTINEs

Shown in alphabetical order of NAMEs.

7.1 FUNCTIONs

7.1.1 AKM2KG

mole to mass conversion for ideal gas

```
REAL FUNCTION AKM2KG(ISUB,Z)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `Z` : mole [kmol]

Returned
REAL `AKM2KG` : mass [kg]

7.1.2 AKG2KM

mass to mole conversion for ideal gas

```
REAL FUNCTION AKG2KM(ISUB,Z)
```

Input
INTEGER `ISUB` : substance index of gas
REAL `Z` : mass [kg]

Returned
REAL `AKG2KM` : mole [kmol]

7.1.3 IDENTI

name of an ideal gas, or version number

```
CHARACTER*25 FUNCTION IDENTI(ISUB,A)
```

Input
INTEGER `ISUB` : substance index
CHARACTER*1 `A` : a character to control output

Returned
`IDENTI` : name of substance when `A='S'`, or version number when `A≠'S'`

7.1.4 PTSAIR

pressure of air as a function of temperature and entropy

```
REAL FUNCTION PTSAIR(T,S)
```

Input
REAL `T` : temperature [K],[°C]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `PTSAIR` : pressure [Pa], [bar]

7.1.5 PTSIDG

pressure of ideal gas as a function of temperature and entropy

```
REAL FUNCTION PTSIDG(ISUB,T,S)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `T` : temperature [K],[°C]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `PTSIDG` : pressure [Pa],[bar]

7.1.6 PTVAIR
pressure of air as a function of temperature and volume

```
REAL FUNCTION PTVAIR(T,V)
```

Input
REAL `T` : temperature [K],[°C]
REAL `V` : volume [m^3/kmol], [m^3/kg]

Returned
REAL `PTVAIR` : pressure [Pa],[bar]

7.1.7 PTVIDG
pressure of ideal gas as a function of temperature and volume

```
REAL FUNCTION PTVIDG(ISUB,T,V)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `T` : temperature [K],[°C]
REAL `V` : volume [m^3/kmol], [m^3/kg]

Returned
REAL `PTVIDG` : pressure [Pa],[bar]

7.1.8 THAIR
temperature of air as a function of enthalpy

```
REAL FUNCTION THAIR(H)
```

Input
REAL `H` : enthalpy [J/kmol], [J/kg]

Returned
REAL `THAIR` : temperature [K],[°C]

7.1.9 THIDG
temperature of ideal gas as a function of enthalpy

```
REAL FUNCTION THIDG(ISUB,H)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `H` : enthalpy [J/kmol], [J/kg]

Returned
REAL `THIDG` : temperature [K],[°C]

7.1.10 TPSAIR
temperature of air as a function of pressure and entropy

```
REAL FUNCTION TPSAIR(P,S)
```

Input
REAL `P` : pressure [Pa],[bar]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `TPSAIR` : temperature [K],[°C]

7.1.11 TPSIDG
temperature of ideal gas as a function of pressure and entropy

```
REAL FUNCTION TPSIDG(ISUB,P,S)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `P` : pressure [Pa],[bar]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `TPSIDG` : temperature [K],[°C]

7.1.12 TPVAIR
temperature of air as a function of pressure and volume

```
REAL FUNCTION TPVAIR(P,V)
```

Input
REAL `P` : pressure [Pa],[bar]
REAL `V` : volume [m^3/kmol],[m^3/kg]

Returned
REAL `TPVAIR` : temperature [K],[°C]

7.1.13 TPVIDG
temperature of ideal gas as a function of pressure and volume

```
REAL FUNCTION TPVIDG(ISUB,P,V)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `P` : pressure [Pa],[bar]
REAL `V` : volume [m^3/kmol],[m^3/kg]

Returned
REAL `TPVIDG` : temperature [K],[°C]

7.1.14 TVSAIR
temperature of air as a function of volume and entropy

```
REAL FUNCTION TVSAIR(V,S)
```

Input
REAL `V` : volume [m^3/kmol],[m^3/kg]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `TVSAIR` : temperature [K],[°C]

7.1.15 TVSIDG
temperature of ideal gas as a function of volume and entropy

```
REAL FUNCTION TVSIDG(ISUB,V,S)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `V` : volume [m^3/kmol],[m^3/kg]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

Returned
REAL `TVSIDG` : temperature [K],[°C]

7.1.16 TUAIR
temperature of air as a function of internal energy

```
REAL FUNCTION TUAIR(U)
```

Input
REAL `U` : internal energy [J/kmol], [J/kg]

Returned
REAL `TUAIR` : temperature [K],[°C]

7.1.17 TUIDG
temperature of ideal gas as a function of internal energy

```
REAL FUNCTION TUIDG(ISUB,U)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `U` : internal energy [J/kmol], [J/kg]

Returned
REAL `TUIDG` : temperature [K],[°C]

7.2 SUBROUTINEs

7.2.1 AIRTP
properties of air as a function of temperature and pressure

```
SUBROUTINE AIRTP(IERR,AMM,T,P,V,CP,CV,W,U,H,S)
```

Input
REAL `T` : temperature [K],[°C]
REAL `P` : pressure [Pa],[bar]

Output
INTEGER `IERR` : error detection code
0 : no error
-2 : invalid ARGUMENT(s)
REAL `AMM` : molar mass [kg/kmol]
REAL `V` : volume [m^3/kmol], [m^3/kg]
REAL `CP` : isobaric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `CV` : isochoric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `W` : speed of sound [m/s]
REAL `U` : internal energy [J/kmol], [J/kg]
REAL `H` : enthalpy [J/kmol], [J/kg]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

7.2.2 CHOTBL
properties of comlplete combustion-by-air product of $C_XH_YO_Z$ at 0.1MPa, Keenan-Chao-Kaye-style gas table.

```
SUBROUTINE CHOTBL(IERR,X,Y,Z,AF,AMM,T,H,PR,U,VR,SO)
```

Input
REAL `AF` : air factor (≥ 1)
REAL `T` : temperature [K],[°C]
REAL `X` : value of `X`
REAL `Y` : value of `Y`
REAL `Z` : value of `Z`

Output

INTEGER `IERR` : error detection code

0 : no error

-2 : invalid ARGUMENT(s)

REAL `AMM` : molar mass [kg/kmol]

REAL `H` : enthalpy [J/kmol], [J/kg]

REAL `PR` : relative pressure, $= \exp\left(\dfrac{1}{R}\displaystyle\int_{T_{ref}}^{T} \dfrac{c_p}{T} dt\right)$ [-]

REAL `U` : internal energy [J/kmol], [J/kg]

REAL `VR` : relative volume, $= \exp\left(-\dfrac{1}{R}\displaystyle\int_{T_{ref}}^{T} \dfrac{c_v}{T} dt\right)$ [-]

REAL `SO` : entropy function, $= \displaystyle\int_{Tref}^{T} \dfrac{c_p}{T} dT$ [J/(kmol·K)], [J/(kg·K)]

where T_{ref} is the reference temperature 298.15K(25°C).

7.2.3 FUELML

mole fractions of comlplete combustion-by-moist-air products of the mixture of $C_XH_YO_Z$ fuels.

```
SUBROUTINE FUELML(IERR,A,IR,AF,XW,XC,XH,XN,XO)
```

Input

REAL ARRAY `A(1:4,1:IR)` : parameters for a component fuel of the mixture of $C_XH_YO_Z$ fuels.

REAL ARRAY `A(1,I)` : mole fraction of the ith component fuel

REAL `A(2,I)` : value of `X` of the ith component fuel

REAL `A(3,I)` : value of `Y` of the ith component fuel

REAL `A(4,I)` : value of `Z` of the ith component fuel

INTEGER `IR` : number of component fuels of the mixture

REAL `AF` : air factor (≥ 1)

REAL `XW` : absolute humidity of the moist air [kg/kg of dry air]

Output

INTEGER `IERR` : error detection code

0 : no error

-2 : invalid ARGUMENT(s)

REAL `XC` : mole fraction of CO_2 in the combustion products [-]

REAL `XH` : mole fraction of H_2O in the combustion products [-]

REAL `XN` : mole fraction of N_2 in the combustion products [-]

REAL `XO` : mole fraction of O_2 in the combustion products [-]

7.2.4 IDGCMM

conversion from mole to mass, or reverse, for ideal gas

```
SUBROUTINE IDGCMM(IERR,ITRNS,ISUB,X,Y)
```

Input

INTEGER `ITRNS` : direction of conversion

$= 0$: conversion from mole to mass

$\neq 0$: conversion from mass to mole

INTEGER `ISUB` : substance index of the gas

REAL `X`: mole (for `ITRNS` $= 0$) or mass (for `ITRNS`$\neq 0$)

Output

INTEGER `IERR` : error detection code

0 : no error

-3 : invalid substance index `ISUB` specified

REAL `Y` : mass (for `ITRNS` $= 0$) or mole (for `ITRNS` $\neq 0$)

7.2.5 IDGFND

critical fundamental constants

```
SUBROUTINE IDGFND(IERR,ISUB,C,ANAME)
```

Input
INTEGER `ISUB` : substance index

Output
INTEGER `IERR` : error detection code
0 : no error
-3 : invalid substance index `ISUB` specified
REAL ARRAY `C(1:10)`
`C(1)` : molar mass [kg/kmol]
`C(2)` : critical temperature [K], [°C]
`C(3)` : critical pressure [Pa], [bar]
`C(4)` : critical volume [m^3/kmol], [m^3/kg]
`C(5)` : ideal gas absolute entropy at reference state of 0.1MPa and 25°C, [J/(kmol· K)], [J/(kg · K)]
`C(6)` : ideal gas enthalpy of formation at reference state of 0.1MPa and 25°C, [[J/kmol], [J/kg]
`C(7)` : ideal gas Gibbs energy of formation at reference state of 0.1MPa and 25°C, [J/(kmol· K)], [J/(kg · K)]
`C(8)` : lower bound of temperature for the ideal gas isobaric specific heat equation [K], [°C]
`C(9)` : upper bound of temperature for the ideal gas isobaric specific heat equation [K], [°C]
`C(10)` : type of state
= 10 : ideal gas and reference state
= 11 : ideal gas
= 19 : ideal gas (not included in JANAF Table [3])
CHARACTER*25 `ANAME` : name of substance

7.2.6 IDGT

properties of ideal gases at 0.1 MPa, JANAF-style table

```
SUBROUTINE IDGT(IERR,ISUB,T,A,ANAME)
```

Input
INTEGER `ISUB` : substance index
REAL `T` : temperature [K],[°C]

Output
INTEGER `IERR` : error detection code
0 : no error
-2 : invalid ARGUMENT(s)
-3 : invalid substance index `ISUB` specified
REAL ARRAY `A(1:4)`
`A(1)` : isobaric specific heat [J/(kmol·K)], [J/(kg·K)]
`A(2)` : absolute entropy [J/(kmol·K)], [J/(kg·K)]
`A(3)` : $-gref^\circ(T) = -\dfrac{g^\circ(T) - h^\circ(T_{ref})}{T}$ [J/(kmol·K)], [J/(kg·K)]
where $g^\circ(T)$ and $h^\circ(T_{ref})$ are the Gibbs free energy at a temperature T and the enthalpy at the reference temperature of 298.15K, respectively.
`A(4)` : enthalpy [J/kmol], [J/kg]
CHARACTER*25 `ANAME` : name of substance

7.2.7 IDGTBL

properties of ideal gases at 0.1MPa, Keenan-Chao-Kaye-style gas table

```
SUBROUTINE IDGTBL(IERR,ISUB,T,H,PR,U,VR,SO)
```

Input
INTEGER `ISUB` : substance index of the gas
REAL `T` : temperature [K],[°C]

Output
INTEGER `IERR` : error detection code
0 : no error
-2 : invalid ARGUMENT(s)

-3 : invalid substance index `ISUB` specified
REAL `AMM` : molar mass [kg/kmol]
REAL `H` : enthalpy [J/kmol], [J/kg]
REAL `PR` : relative pressure = $\exp\left(-\frac{1}{R}\int_{T_{ref}}^{T}\frac{c_p}{T}dt\right)$ [-]
REAL `U` : internal energy [J/kmol], [J/kg]
REAL `VR` : relative volume = $\exp\left(-\frac{1}{R}\int_{T_{ref}}^{T}\frac{c_v}{T}dt\right)$ [-]
REAL `S0` : entropy function, = $\int_{Tref}^{T}\frac{c_p}{T}dT$ [J/(kmol·K)], [J/(kg·K)]
where T_{ref} is the reference temperature 298.15K.

7.2.8 IDGTP

properties of ideal gas as a function of temperature and pressure.

```
SUBROUTINE IDGTP(IERR,ISUB,T,P,V,CP,CV,WS,U,H,S,ANAME)
```

Input
INTEGER `ISUB` : substance index
REAL `T` : temperature [K],[°C]
REAL `P` : pressure [Pa],[bar]

Output
INTEGER `IERR` : error detection code
0 : no error
-2 : invalid ARGUMENT(s)
-3 : invalid substance index `ISUB` specified
REAL `AMM` : molar mass [kg/kmol]
REAL `V` : volume [m^3/kmol], [m^3/kg]
REAL `CP` : isobaric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `CV` : isochoric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `W` : speed of sound [m/s]
REAL `U` : internal energy [J/kmol], [J/kg]
REAL `H` : enthalpy [J/kmol], [J/kg]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]
CHARACTER*25 `ANAME` : name of substance

7.2.9 IPINIT

Initialization

```
SUBROUTINE IPINIT(K1,K2,K3,KGAS,GASC)
```

Input
INTEGER `K1` : value of `KPA` for the units of pressure and temperature
INTEGER `K2` : value of `KMOL` for the unit of amount of substance
INTEGER `K3` : value of `MESS` for error message
INTEGER `KGAS` : universal gas constant = 8.31451×10^3 J/(kmol·K) (built-in value) when `KGAS`=0
REAL `GASC` : universal gas constant = `GASC` (user's selection) when `KGAS`$\neq 0$

Output
The values of `KPA`, `KMOL`, `MESS` and `GASCON` are sent to COMMON BLOCK `UNIT` and `CNST`. See section 1.1 and chapter 3.

7.2.10 MIXCMM

conversion from mass fraction to mole, or reverse, for mixture of ideal gases

```
SUBROUTINE MIXCMM(IERR,ITRNS,ISUBNO,ISUB,X,Y)
```

Input
INTEGER `ITRNS` : direction to conversion
$= 0$: mole fraction to mass fraction
$\neq 0$: mass fraction to mole fraction
INTEGER `ISUBNO` : number of component gases
INTEGER ARRAY `ISUB(1:ISUBNO)` : substance index of the `ISUBNO` components
REAL ARRAY `X(1:ISUBNO)` : mole fraction (for `ITRNS`=0) or mass fraction (for `ITRNS` $\neq 0$) of the ith component

Output
INTEGER `IERR` : error detection code
0 : no error
-3 : invalid substance index, or invalid number of components
REAL ARRAY `Y(1:ISUBNO)` : mass fraction (for `ITRNS`=0) or mole fraction (for `ITRNS` $\neq 0$) of the ith component

7.2.11 MIXTP

properties of a mixture of ideal gases as a function of temperature and pressure

```
SUBROUTINE MIXTP(IERR,ISUBNO,ISUB,AM,AMM,TI,PI,V,CP,CV,W,U,H,S)
```

Input
REAL `T` : temperature [K],[°C]
REAL `P` : pressure [Pa],[bar]
INTEGER `ISUBNO` : number of component gases
INTEGER ARRAY `ISUB(1:ISUBNO)` : substance index of the `ISUBNO` components
REAL ARRAY `AM(1:ISUBNO)` : molar fraction of the `ISUBNO` components

Output
INTEGER `IERR` : error detection code
0 : no error
-2 : invalid ARGUMENT(s)
-3 : invalid substance index `ISUB` specified
REAL `AMM` : molar mass [kg/kmol]
REAL `V` : volume [m^3/kmol], [m^3/kg]
REAL `CP` : isobaric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `CV` : isochoric specific heat [J/(kmol·K)], [J/(kg·K)]
REAL `W` : speed of sound [m/s]
REAL `U` : internal energy [J/kmol], [J/kg]
REAL `H` : enthalpy [J/kmol], [J/kg]
REAL `S` : absolute entropy [J/(kmol·K)], [J/(kg·K)]

8. Application Programs

8.1 Single Shot Programs

I-PROPATH offers the following five single shot programs.
(1) IPROPAIR calculates properties of air as a mixture of ideal gases.
(2) IPROPCHO calculates properties of complete combustion-by-air products of $C_X H_Y O_Z$.
(3) IPROPIDG calculates properties of ideal gases.
(4) IPROPJNF calculates properties by JANAF-style table.
(5) IPROPKCK calculates properties by Keenan-Chao-Kaye-style gas table.

8.2 Sample Output of IPROPIDG

```
Do you need ERROR MESSAGES ? NO->0 : YES->1 = 1
This program can calculate properties of the following 54 ideal gases.

ISUB : Name of substance           | ISUB : Name of substance
   1 : NITROGEN N2                 |    2 : WATER H20
   3 : HYDROGEN H2                 |    4 : NITRIC MONOXIDE NO
   5 : NITROGEN DIOXIDE NO2        |    6 : DINITROGEN MONOXIDE N2O
   7 : OXYGEN O2                   |    8 : CARBON MONOXIDE CO
   9 : CARBON DIOXIDE CO2          |   10 : METHANE CH4
  11 : PROPANE C3H8                |   12 : ETHYLENE C2H4
  13 : CHLORINE CL2                |   14 : AMMONIA H3N (NH3)
  15 : SULFUR DIOXIDE O2S (SO2)    |   16 : NEON NE
  17 : OZONE O3                    |   18 : CARBON C
  19 : HYDROGEN CHLORIDE HCL       |   20 : FLUORINE F2
  21 : HYDROGEN IODIDE HI          |   22 : HELIUM-4 HE
  23 : ARGON AR                    |   24 : HCFC22 CHCLF2
  25 : CFC13 CCLF3                 |   26 : CHLOROFORM CHCL3
  27 : HCFC21 CHCL2F               |   28 : CFC12 CCL2F2
  29 : METHYLENE CLORIDE CH2CL2    |   30 : CARBON TETRAFLUORIDE CF4
  31 : METHANOL CH3-OH             |   32 : HCFC142B CH3-CCLF2
  33 : ETHYL CHLORIDE C2H5CL       |   34 : CFC114 CCLF2-CCLF2
  35 : HFC152A CH3-CHF2            |   36 : ACETYLENE C2H2
  37 : ETHANE C2H6                 |   38 : n-BUTANE C4H10
  39 : ISOBUTANE C4H10             |   40 : ISOPENTANE C5H12
  98 : other substances
 Select one of ISUBs (1-40) or (98) = 98
ISUB : Name of substance           | ISUB : Name of substance
  41 : METHYL CHLORIDE CH3CL       |   42 : ACETALDEHYDE C2H4O
  43 : ACETIC ACID C2H4O2          |   44 : ETHANOL C2H6O
  45 : PROPYLENE C3H6              |   46 : ACETONE C3H6O
  47 : n-PENTANE C5H12             |   48 : BENZENE C6H6
  49 : n-HEXANE C6H14              |   50 : TOLUENE C7H8
  51 : n-HEPTANE C7H16             |   52 : n-OCTANE C8H18
  53 : ISO-OCTANE C8H18            |   54 : NAPHTHALENE C10H8
  98 : other substances            |   99 : Stop.
 Select one of ISUBs (41-54) or (98-99) = 50
 Name of Substance : TOLUENE C7H8

  KPA  PRESSURE  TEMPERATURE
   0      Pa         K
   1      bar        C
   2      bar        K
   3      Pa         C
 others   Pa         K
------------------------------
 Select one set of units for pressure and temperature : KPA = 0
 KMOL    Amount of Substance
   0         kmol
```

```
    1         kg
   others     kmol
  ------------------------------
  Select kmol or kg for amount of substance : KMOL = 0
  You can select one from the following 8 patterns of calculation
  1 : (P,T) >>> V, CP, H, S, etc |   2 : (P,V) >>> T, CP, H, S, etc
  3 : (T,V) >>> P, CP, H, S, etc |   4 : (P,S) >>> T, V, CP, H, etc
  5 : (T,S) >>> P, V, CP, H, etc |   6 : (V,S) >>> P, T, CP, H, etc
  7 : (P,H) >>> T, V, CP, S, etc |   8 : (P,U) >>> T, V, CP, S, etc
  Input INDEX for pattern of calculation (1-8) = 1
  Name of Substance : TOLUENE C7H8

  INPUT P[Pa]  = 1.0E+06
  INPUT T[K] = 500
   AMM=    92.14100[kg/kmol]    T  =     500.000[K]
   P  = 0.10000E+07[Pa]         V  = 0.41573E+01[m^3/kmol]
   CP = 0.17078E+06[J/(kmol*K)] CV = 0.16246E+06[J/(kmol*K)]
   W  = 0.21778E+03[m/s]        S  = 0.37141E+06[J/(kmol*K)]
   H  = 0.28222E+08[J/kmol]     U  = 0.24065E+08[J/kmol]
   ---------------------------------------------------------
   1 : CONTINUE                 2 : SELECT PATTERN OF CALCULATION
   3 : SELECT SYSTEM OF UNITS   4 : SELECT SUBSTANCE
   5 : STOP
  What do you wish to do next ? Input (1-5) = 2
  You can select one from the following 8 patterns of calculation
  1 : (P,T) >>> V, CP, H, S, etc |   2 : (P,V) >>> T, CP, H, S, etc
  3 : (T,V) >>> P, CP, H, S, etc |   4 : (P,S) >>> T, V, CP, H, etc
  5 : (T,S) >>> P, V, CP, H, etc |   6 : (V,S) >>> P, T, CP, H, etc
  7 : (P,H) >>> T, V, CP, S, etc |   8 : (P,U) >>> T, V, CP, S, etc
  Input INDEX for pattern of calculation (1-8) = 6
  Name of Substance : TOLUENE C7H8

  INPUT V[m^3/kmol] = 4.1573
  INPUT S[J/(kmol*K)] = 0.37141E+06
   AMM=    92.14100[kg/kmol]    T  =     500.009[K]
   P  = 0.10000E+07[Pa]         V  = 0.41573E+01[m^3/kmol]
   CP = 0.17078E+06[J/(kmol*K)] CV = 0.16246E+06[J/(kmol*K)]
   W  = 0.21778E+03[m/s]        S  = 0.37141E+06[J/(kmol*K)]
   H  = 0.28223E+08[J/kmol]     U  = 0.24066E+08[J/kmol]
   ---------------------------------------------------------
   1 : CONTINUE                 2 : SELECT PATTERN OF CALCULATION
   3 : SELECT SYSTEM OF UNITS   4 : SELECT SUBSTANCE
   5 : STOP
  What do you wish to do next ? Input (1-5) = 5
Stop - Program terminated.
```

8.3 Example of User's PROGRAM UNIT (IPROPJNF.FOR)

Source program

```
C *****
C  This propram calculates properties of ideal gases
C  in order to produce a JANAF style gas table
      CHARACTER*25 ANAME,IDENTI
      INTEGER IERR,ISUB
      REAL T
      REAL C(1:10)
      REAL A(1:4)
      COMMON /UNIT/KPA,KGM,MESS
      COMMON /CNST/GASCON
      CHARACTER*25 AANAME(54)
      INTEGER IP(54)
      ISUBNO=54
      IDISP=40
```

```
      WRITE(6,2200)
 2200 FORMAT(1H ,' Do you need ERROR MESSAGES ? NO->0 : YES->1 = ')
      READ(5,*) IM
      CALL IPINIT(0,0,IM,0,0.0)
      DO 10 I=1,ISUBNO
      IP(I)=I
      AANAME(I)=IDENTI(I,'S')
   10 CONTINUE
  100 WRITE(6,2100) ISUBNO
 2100 FORMAT(1H ,' This program can calculate properties of ',
     1 'the following ',I2,' ideal gases.'//
     2 1h ,1X,'ISUB : Name of substance',10X,
     3      '| ISUB : Name of substance')
      DO 20 I=1,IDISP,2
      WRITE(6,2110) IP(I),AANAME(I),IP(I+1),AANAME(I+1)
 2110 FORMAT(1H ,2X,I3,' : ',A25,'  |  ',I3,' : ',A25)
   20 CONTINUE
      WRITE(6,2120) IDISP
 2120 FORMAT(1H ,3X,'98 : other substances'
     1/3X,'Select one of ISUBs (1-',I2,') or (98) = ')
      READ(5,*) ISUB
      IF (ISUB .LT. 1 .OR. ISUB .GT. IDISP) THEN
      WRITE(6,2140)
 2140 FORMAT(2X,'ISUB : Name of substance',10X,
     1      '| ISUB : Name of substance')
      DO 30 I=IDISP+1,ISUBNO,2
      WRITE(6,2110) IP(I),AANAME(I),IP(I+1),AANAME(I+1)
   30 CONTINUE
      WRITE(6,2160) IDISP+1,ISUBNO
 2160 FORMAT(1H ,3X,'98 : other substances',11X,
     1 '|   99 : Stop.'/
     2 3X,'Select one of ISUBs (',I2,'-',I2,') or (98-99) = ')
      READ(5,*) ISUB
      ENDIF
      ANAME=IDENTI(ISUB,'S')
      IF (ISUB .LT. 1 .OR. ISUB .GT. ISUBNO) THEN
        IF (ISUB .EQ. 98) THEN
          GOTO 100
        ELSE
          STOP
        ENDIF
      ENDIF
      WRITE(6,2000) ANAME
 2000 FORMAT(1H , ' Name of Substance : ',A25)
      CALL IDGFND(IERR,ISUB,C,ANAME)
      AMM=C(1)
      WRITE(6,2300) AMM,C(2),C(3),C(4)
      AKF=-C(7)/(298.15*GASCON)/ALOG(10.0)
      WRITE(6,2320) C(5),C(6),C(7),ANAME,AKF
 2300 FORMAT(3X,'  Molecular weight     = ', F13.4/
     1 3X,'  Critical temperature = ',F13.3, '[K]'/
     2 3X,'  Critical pressure    = ',E13.5, '[Pa]'/
     3 3X,'  Critical volume      = ',E13.5, '[m**3/kmol]')
 2320 FORMAT(1H ,' At reference state of 0.1MPa and 298.15 K'/
     1 3X,'  Absolute entropy          = ',E13.5,'[J/(kmol*K)]'/
     1 3X,'  Enthalpy of formation     = ',E13.5,'[J/kmol]'/
     1 3X,'  Gibbs energy of formation = ',E13.5,'[J/kmol]'/
     1 3X,'  Logarithm of the equilibrium constant of the reaction '/
     1 3X,'  for the formation of ',A25/
     1 3X,'  from the elements:log(Kf) = ',F10.4/)
  200 WRITE(6,*) ' INPUT T [K] = '
      READ(5,*) T
      CALL IDGT(IERR,ISUB,T,A,ANAME)
      CP=A(1)
      CV=CP-GASCON
      WSOUND=SQRT(CP/CV*GASCON/AMM*T)
      S=A(2)
      GREF=A(3)
      H=A(4)
      U=H-GASCON*T
```

```
      WRITE(6,1000) ANAME,T,CP,S,GREF,H,CV,WSOUND
 1000 FORMAT(1H ,' Substance : ',A25/
     1 3X,'                   T  = ',F12.3,'[K]'/
     2 3X,'                CP(T) = ',E12.6,'[J/(kmol*K)]'/
     2 3X,'                S0(T) = ',E12.6,'[J/(kmol*K)]'/
     3 3X,'-(G0(T)-H0(298.15K))/T = ',E12.6,'[J/(kmol*K)]'/
     4 3X,'      H(T)-H(298.15K)  = ',E12.6,'[J/kmol]'/
     5 3X,'                CV(T) = ',E12.6,'[J/(kmol*K)]'/
     6 3X,'                W     = ',E12.6,'[m/s]'/
     7 3X,'---------------------------------------------')
      WRITE(6,*) ' 1:CONTINUE  |  2:SELECT SUBSTANCE  |  3:STOP '
      WRITE(6,*) ' What do you wish to do next ? Input (1-3) =  '
      READ(5,*) INUM
      IF (INUM .EQ. 1) THEN
        GOTO 200
      ELSEIF (INUM .EQ. 2) THEN
        GOTO 100
      ENDIF
      STOP
      END
```

Sample output

```
 Do you need ERROR MESSAGES ? NO->0 : YES->1 = 1
 This program can calculate properties of the following 54 ideal gases.

 ISUB : Name of substance          | ISUB : Name of substance
    1 : NITROGEN N2                |    2 : WATER H20
    3 : HYDROGEN H2                |    4 : NITRIC MONOXIDE NO
    5 : NITROGEN DIOXIDE NO2       |    6 : DINITROGEN MONOXIDE N2O
    7 : OXYGEN O2                  |    8 : CARBON MONOXIDE CO
    9 : CARBON DIOXIDE CO2         |   10 : METHANE CH4
   11 : PROPANE C3H8               |   12 : ETHYLENE C2H4
   13 : CHLORINE CL2               |   14 : AMMONIA H3N (NH3)
   15 : SULFUR DIOXIDE O2S (SO2)   |   16 : NEON NE
   17 : OZONE O3                   |   18 : CARBON C
   19 : HYDROGEN CHLORIDE HCL      |   20 : FLUORINE F2
   21 : HYDROGEN IODIDE HI         |   22 : HELIUM-4 HE
   23 : ARGON AR                   |   24 : HCFC22 CHCLF2
   25 : CFC13 CCLF3                |   26 : CHLOROFORM CHCL3
   27 : HCFC21 CHCL2F              |   28 : CFC12 CCL2F2
   29 : METHYLENE CLORIDE CH2CL2   |   30 : CARBON TETRAFLUORIDE CF4
   31 : METHANOL CH3-OH            |   32 : HCFC142B CH3-CCLF2
   33 : ETHYL CHLORIDE C2H5CL      |   34 : CFC114 CCLF2-CCLF2
   35 : HFC152A CH3-CHF2           |   36 : ACETYLENE C2H2
   37 : ETHANE C2H6                |   38 : n-BUTANE C4H10
   39 : ISOBUTANE C4H10            |   40 : ISOPENTANE C5H12
   98 : other substances
  Select one of ISUBs (1-40) or (98) = 2
 Name of Substance : WATER H20
    Molecular weight     =       18.0150
    Critical temperature =       647.130[K]
    Critical pressure    =   0.22055E+08[Pa]
    Critical volume      =   0.55950E-01[m**3/kmol]
 At reference state of 0.1MPa and 298.15 K
    Absolute entropy          =   0.18872E+06[J/(kmol*K)]
    Enthalpy of formation     =  -0.24181E+09[J/kmol]
    Gibbs energy of formation =  -0.22859E+09[J/kmol]
    Logarithm of the equilibrium constant of the reaction
    for the formation of WATER H20
    from the elements:log(Kf) =    40.0470

 INPUT T [K] = 300
 Substance : WATER H20
                      T  =      300.000[K]
                   CP(T) = 0.335859E+05[J/(kmol*K)]
                   S0(T) = 0.188928E+06[J/(kmol*K)]
```

```
 -(G0(T)-H0(298.15K))/T = 0.188721E+06[J/(kmol*K)]
       H(T)-H(298.15K)  = 0.621280E+05[J/kmol]
                  CV(T) = 0.252714E+05[J/(kmol*K)]
                  W     = 0.428969E+03[m/s]
 -----------------------------------------------
1:CONTINUE  |  2:SELECT SUBSTANCE  |  3:STOP
What do you wish to do next ? Input (1-3) =  1
INPUT T [K] = 500
Substance : WATER H2O
                    T  =      500.000[K]
                  CP(T) = 0.352270E+05[J/(kmol*K)]
                  S0(T) = 0.206414E+06[J/(kmol*K)]
 -(G0(T)-H0(298.15K))/T = 0.192569E+06[J/(kmol*K)]
       H(T)-H(298.15K)  = 0.692221E+07[J/kmol]
                  CV(T) = 0.269125E+05[J/(kmol*K)]
                  W     = 0.549600E+03[m/s]
 -----------------------------------------------
1:CONTINUE  |  2:SELECT SUBSTANCE  |  3:STOP
What do you wish to do next ? Input (1-3) =  2
This program can calculate properties of the following 54 ideal gases.

ISUB : Name of substance          | ISUB : Name of substance
   1 : NITROGEN N2                |    2 : WATER H2O
   3 : HYDROGEN H2                |    4 : NITRIC MONOXIDE NO
   5 : NITROGEN DIOXIDE NO2       |    6 : DINITROGEN MONOXIDE N2O
   7 : OXYGEN O2                  |    8 : CARBON MONOXIDE CO
   9 : CARBON DIOXIDE CO2         |   10 : METHANE CH4
  11 : PROPANE C3H8               |   12 : ETHYLENE C2H4
  13 : CHLORINE CL2               |   14 : AMMONIA H3N (NH3)
  15 : SULFUR DIOXIDE O2S (SO2)   |   16 : NEON NE
  17 : OZONE O3                   |   18 : CARBON C
  19 : HYDROGEN CHLORIDE HCL      |   20 : FLUORINE F2
  21 : HYDROGEN IODIDE HI         |   22 : HELIUM-4 HE
  23 : ARGON AR                   |   24 : HCFC22 CHCLF2
  25 : CFC13 CCLF3                |   26 : CHLOROFORM CHCL3
  27 : HCFC21 CHCL2F              |   28 : CFC12 CCL2F2
  29 : METHYLENE CLORIDE CH2CL2   |   30 : CARBON TETRAFLUORIDE CF4
  31 : METHANOL CH3-OH            |   32 : HCFC142B CH3-CCLF2
  33 : ETHYL CHLORIDE C2H5CL      |   34 : CFC114 CCLF2-CCLF2
  35 : HFC152A CH3-CHF2           |   36 : ACETYLENE C2H2
  37 : ETHANE C2H6                |   38 : n-BUTANE C4H10
  39 : ISOBUTANE C4H10            |   40 : ISOPENTANE C5H12
  98 : other substances
 Select one of ISUBs (1-40) or (98) = 98
ISUB : Name of substance          | ISUB : Name of substance
  41 : METHYL CHLORIDE CH3CL      |   42 : ACETALDEHYDE C2H4O
  43 : ACETIC ACID C2H4O2         |   44 : ETHANOL C2H6O
  45 : PROPYLENE C3H6             |   46 : ACETONE C3H6O
  47 : n-PENTANE C5H12            |   48 : BENZENE C6H6
  49 : n-HEXANE C6H14             |   50 : TOLUENE C7H8
  51 : n-HEPTANE C7H16            |   52 : n-OCTANE C8H18
  53 : ISO-OCTANE C8H18           |   54 : NAPHTHALENE C10H8
  98 : other substances           |   99 : Stop.
 Select one of ISUBs (41-54) or (98-99) = 52
Name of Substance : n-OCTANE C8H18
   Molecular weight     =      114.2310
   Critical temperature =       568.700[K]
   Critical pressure    =   0.24900E+07[Pa]
   Critical volume      =   0.48600E+00[m**3/kmol]
At reference state of 0.1MPa and 298.15 K
   Absolute entropy          =   0.46723E+06[J/(kmol*K)]
   Enthalpy of formation     =  -0.20875E+09[J/kmol]
   Gibbs energy of formation =   0.16000E+08[J/kmol]
   Logarithm of the equilibrium constant of the reaction
   for the formation of n-OCTANE C8H18
   from the elements:log(Kf) =    -2.8031

INPUT T [K] = 500
Substance : n-OCTANE C8H18
                    T  =      500.000[K]
                  CP(T) = 0.287545E+06[J/(kmol*K)]
```

```
                 S0(T) = 0.588724E+06[J/(kmol*K)]
  -(G0(T)-H0(298.15K))/T = 0.492094E+06[J/(kmol*K)]
        H(T)-H(298.15K)  = 0.483151E+08[J/kmol]
                 CV(T) = 0.279231E+06[J/(kmol*K)]
                 W     = 0.193590E+03[m/s]
  ----------------------------------------------
 1:CONTINUE  |  2:SELECT SUBSTANCE  |  3:STOP
 What do you wish to do next ? Input (1-3) =  3
Stop - Program terminated.
```

References

[1] Daubert, T. E. and Danner, R.P., Physical and Thermodynamic Properties of Pure Chemicals, data compilation, Design Institute for Physical Property Data Americal Institute of Chemical Engineers, Hemisphere, (1991).

[2] Keenan, J. P., Chao, J. and Kaye, J, Gas Tables, 2nd. ed. (SI Units), Wiley, (1983).

[3] Chase, Jr.,M.W. et al., JANAF Thermochemical Tables, 3rd ed., J. Physical and Chemical Reference Data, Vol.14(1985), supplement No.1.

VII E-PROPATH:
Libraries for MS-Excel

E-PROPATH is a collection of Library FILEs and Import FILEs for MS-Excel. Using this PROPATH facility, one may use PROPATH SUBPROGRAMs described in PartII through VI while working in MS-Excel. However, reference to PROPATH SUBPROGRAM is limited to PROPATH FUNCTION SUBPROGRAMs in PartII (P–PROPATH) and III (A–PROPATH) at this moment.

1. System on Units

The units tabulated in table VII–1 can be used in E–PROPATH.

Table VII–1 Units used in E–PROPATH

temperature	[°C]
pressure	[bar]
specific volume	[m^3/kg]
specific enthalpy	[J/kg]
specific entropy	[J/(kg·K)]
amount of substance	[kg]
composition	[kg/kg]

2. Functions Available

All FUNCTIONs in P–PROPATH and A–PROPATH, except IDENTF FUNCTION.

3. Operation to Manage Erroneous FUNCTION REFERENCE

The same is done as in SUBPROGRAMs in P–PROPATH and A–PROPATH, though no error messge appears.

4. How to Use E-PROPATH

4.1 How to Use a Single Library FILE

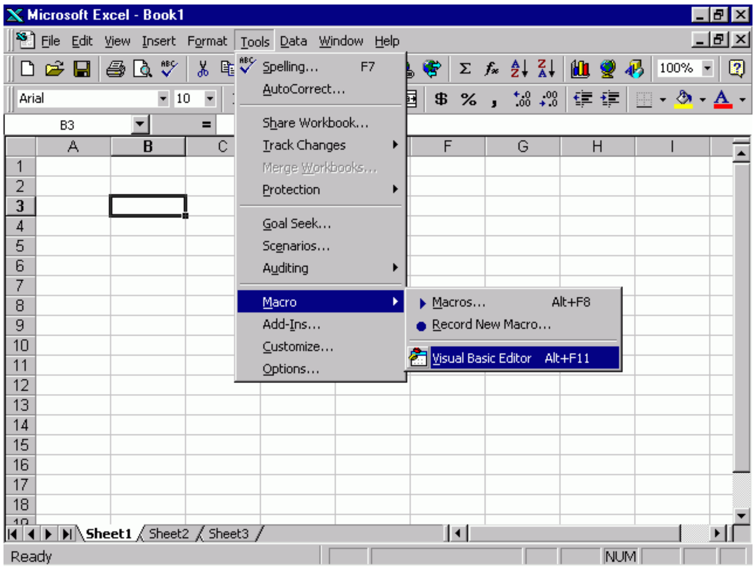
As an example, the procedure to use water Library FILE in MS-Excel are illustrated. The files required are JH2O.DLL and JH2O.BAS. The procedure to use other Library FILE is similar. In the following explanations, the word enclosed with square bracket means the menu item of MS-Excel.

1. Copy JH2O.DLL and JH2O.BAS to the hard disk drive on your computer. The destination directory of JH2O.BAS is a free choice(example: `C:\PROPATH\IMPORT`), whereas that of JH2O.DLL must be one of following directories;

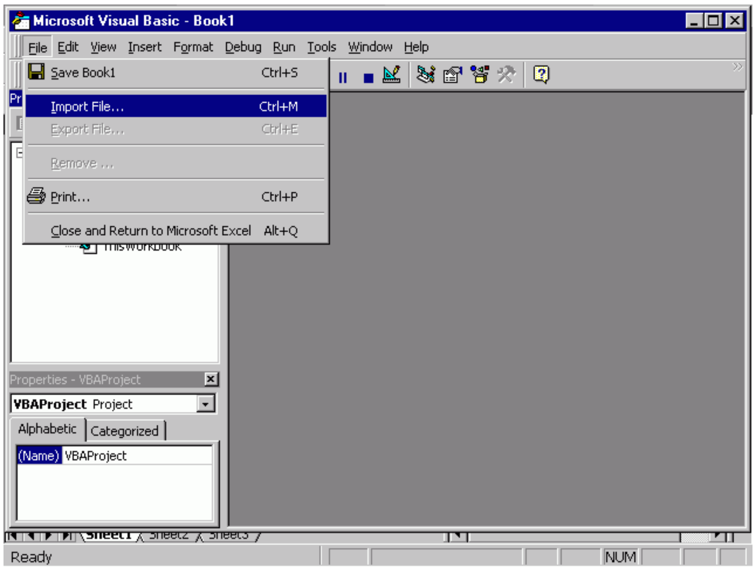
    - Windows directory(example: `C:\WINDOWS`)
    - Windows system directory(example: `C:\WINDOWS\SYSTEM`)
    - Directories specified by enviromental variable `PATH`

    Copying Library FILEs to PATH directory is recommended (example: `C:\PROPATH\WINLIB`), because a conflict of file name may occur in case of copying to Windows directory or Windows system directory.

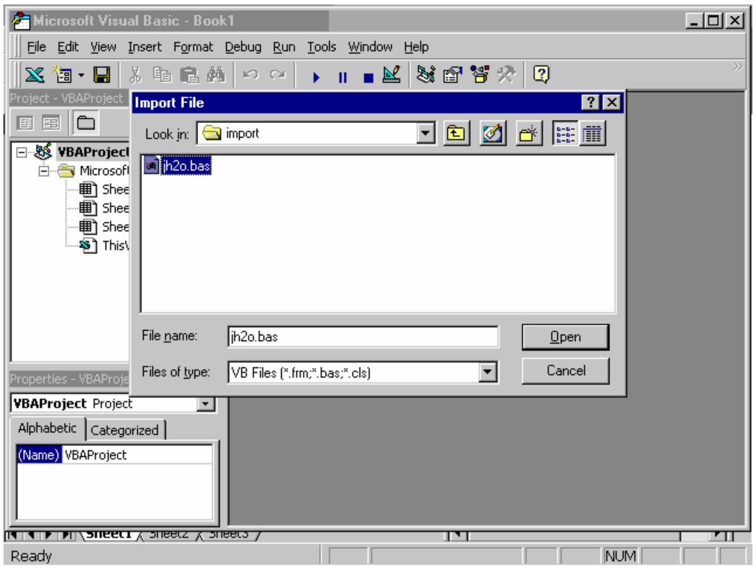
2. Start Microsoft Excel. Select [Tools] - [Macro] - [Visual Basic Editor], then VISUAL BASIC EDITOR starts.



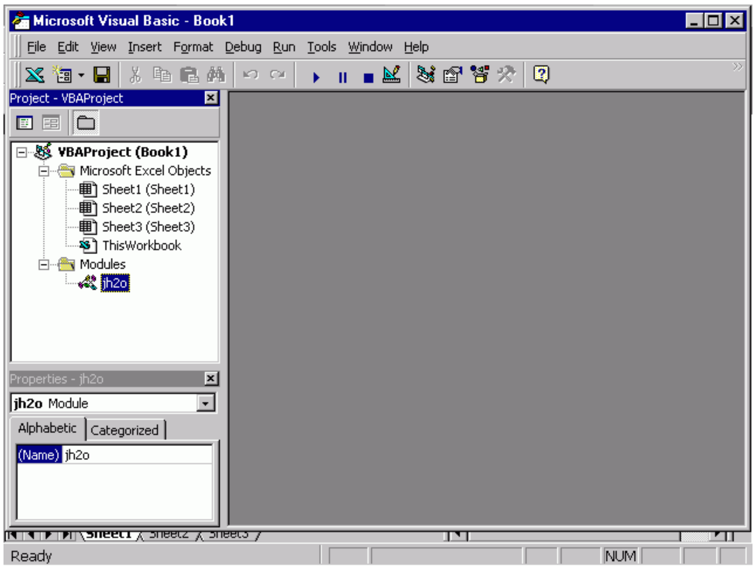
3. On VISUAL BASIC EDITOR, Select [File] - [Import File...].



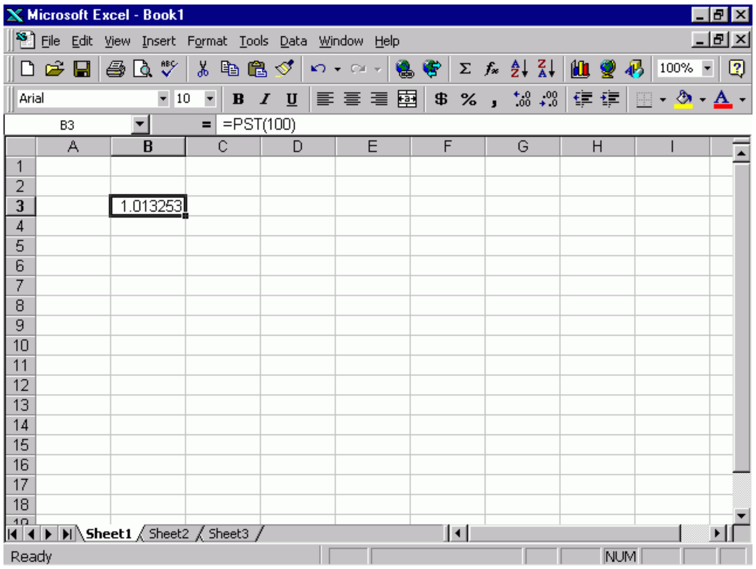
4. Select JH2O.BAS copied to your hard disk drive and press [Open] button.



5. If the "jh2o" module appears in Project Explorer on VISUAL BASIC EDITOR, JH2O.BAS is imported to MS–Excel successfully.

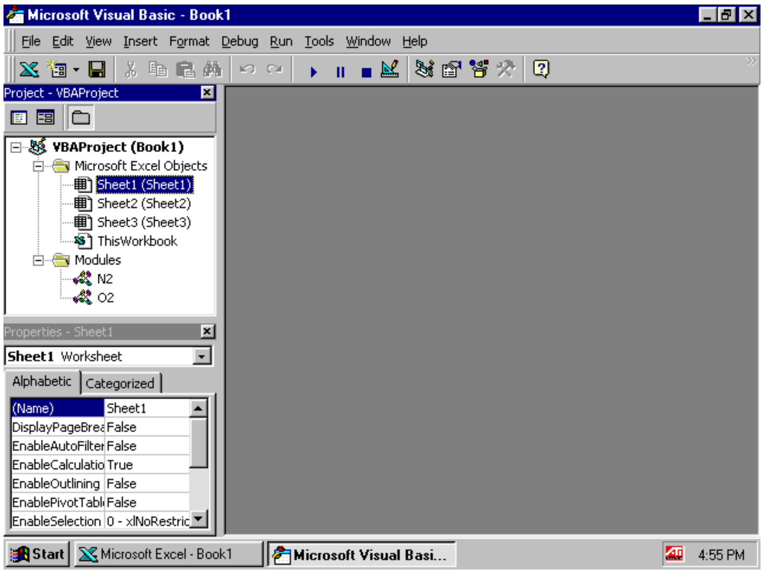


6. On VISUAL BASIC EDITOR, select [File] - [Close and Return to Microsoft Excel] to return MS–Excel. One can call any FUNCTION exported from JH2O.DLL. For example, if one calculates vapor pressure at 100 °C, input "=PST(100)" to any cell on MS–Excel and press the return key. Then the result "1.013253" will be shown in the cell. If `"#VALUE!"` is shown, make sure that JH2O.DLL exists in the prescribed directories.

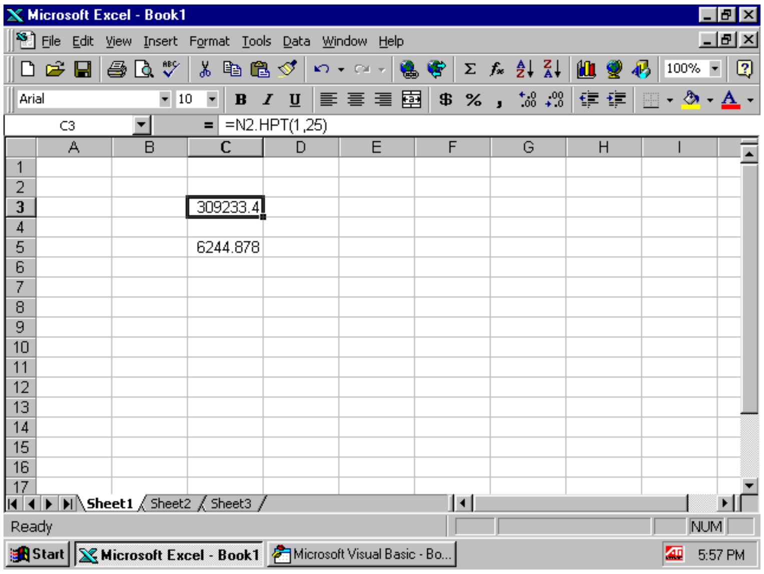


4.2 How to Use More Than Two Library FILEs

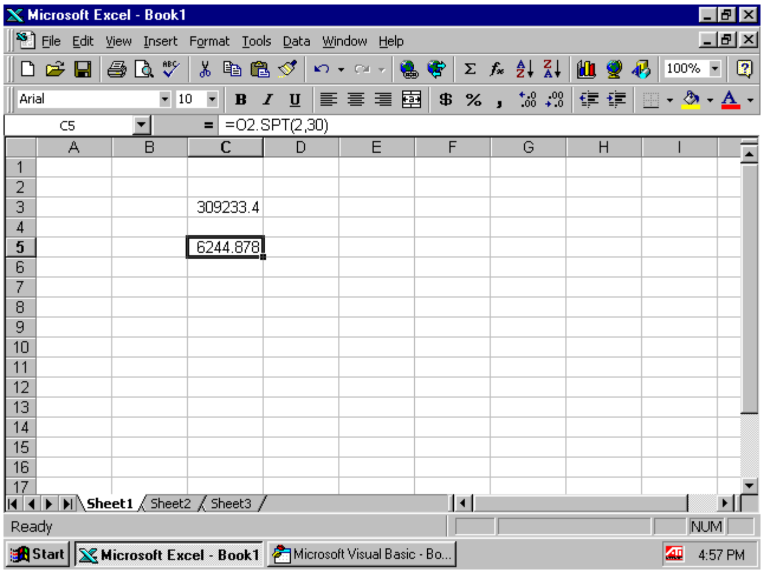
1. One may use more than two Library FILEs at the same time. If one use Library FILEs of nitrogen and oxgen, the files used are JN2.DLL, JO2.DLL, JN2.BAS, and JO2.BAS. One copies these files to priscribed directory and imports both JN2.BAS and JO2.BAS by the the procedure illustrated at previous section.



2. If one caluculates spcecific enthalpy at 1bar and 25°Cof nitrogen, input "=JN2.HPT(1,25)".



3. And if one calculates specific entropy at 2bar and 30°Cof oxgen, input "=JO2.SPT(2,30)".



Thus, in case of importing more than two Library FILEs, input "J+(SUBSTANCE NAME).(FUNCTION NAME).

VIII W-PROPATH: Single Shot P-PROPATH on Internet Web Page

W-PROPATH is a single shot program for P-PROPATH that is operated by CGI(Common Gateway Interface). Properties of pure substances which are provided by P-PROPATH are available through the Internet using a web browser. (A frames compatible web browser is required.)

1. System of Units

In W-PROPATH, users can directly change the unit of pressure, temperature, enthalpy, entropy, specific volume, thermal conductivity, viscosity, surface tension, Laplace coefficient, sonic velocity and Joule-Thomson coefficient, while the units of other properties are automatically changed according to the user's selection of units above.

2. Functions Available

All FUNCTIONs in PartII (P-PROPATH) are available.

3. Operation to Manage Erroneous FUNCTION REFERENCE

Though no error message appears explicitly, users can get the information about "no convergence" and "out of range" by means of the value displayed, such as -1.0×10^{10} and -1.0×10^{20} respectively.

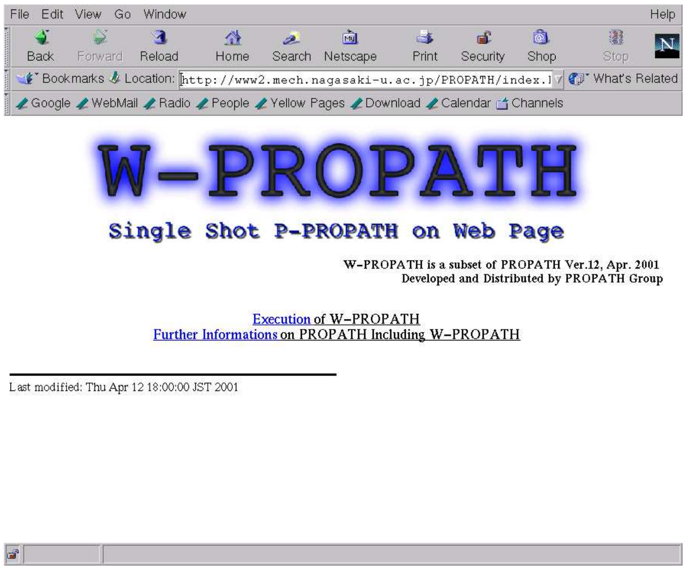
4. How to Use W-PROPATH

The URL of W-PROPATH is as follows.

`http://www2.mech.nagasaki-u.ac.jp/PROPATH/`

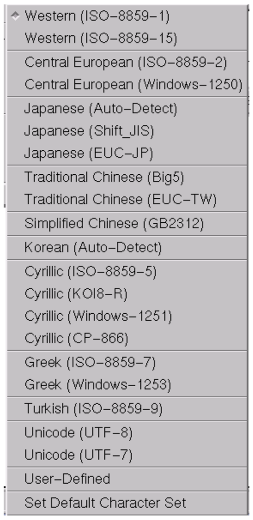
In this section, the words enclosed with the pair of square brackets means the menu item or clickable words in the W-PROPATH web page.

1. Access the above URL with your frames compatible web browser.

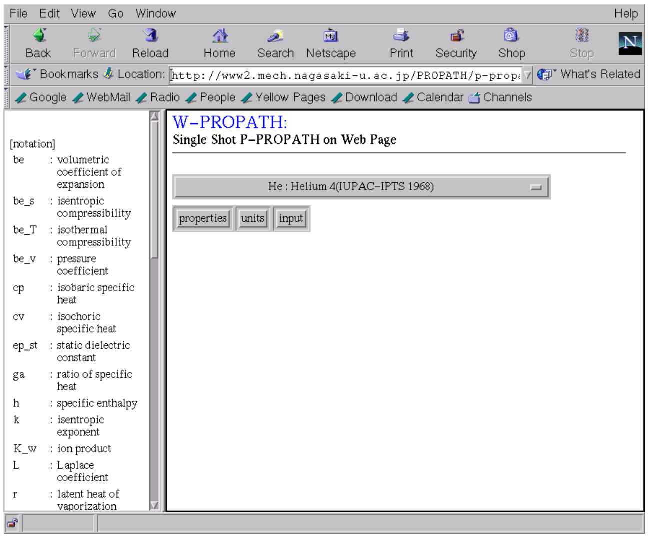


2. Set the "Character Set" to Western.

Example in the Linux Netscape browser



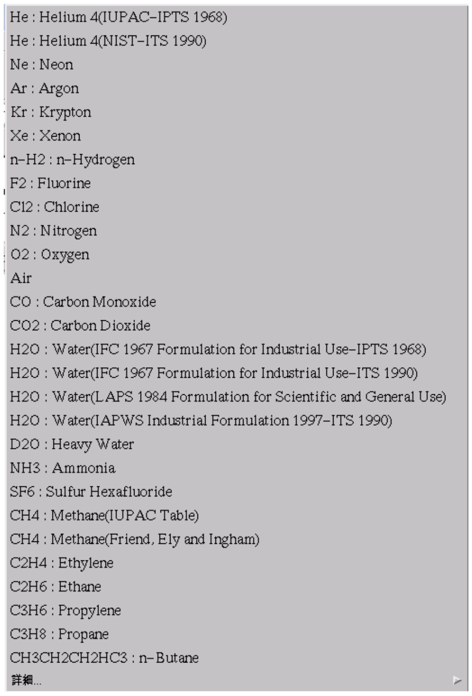
3. Click on [Execution of W-PROPATH]. The substance selection page is displayed.



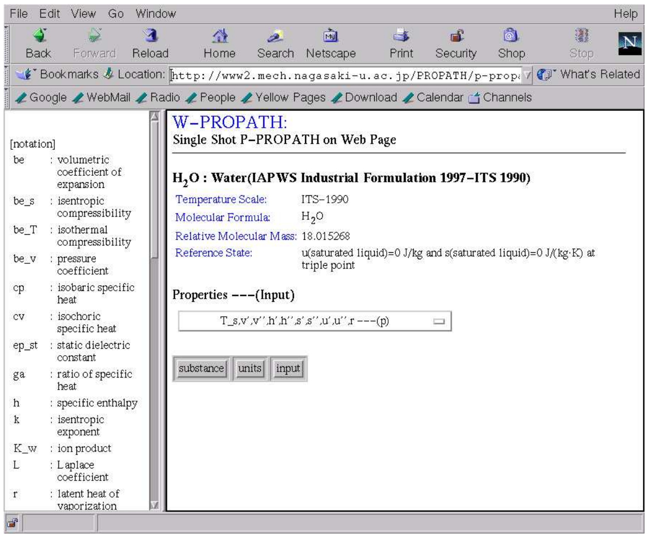
The nomenclature for W-PROPATH is shown in the left frame. Particular symbols are used in W-PROPATH such as "`mu`" for "μ". Refer to the left frame when you find symbols you don't understand in the right frame.

You select a substance in the right frame. Clicking on the long horizontal bar, you get the substances pull-down list and you select a substance from the list. If you click on [Properties] or [Units], the properties selection page or the units selection page appears respectively. [Input(s)] leads you to the page for data input.

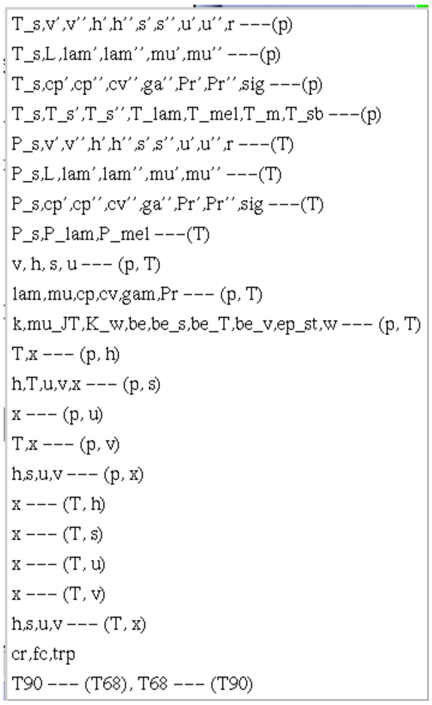
4. Select a substance from the pull-down list in the right frame.



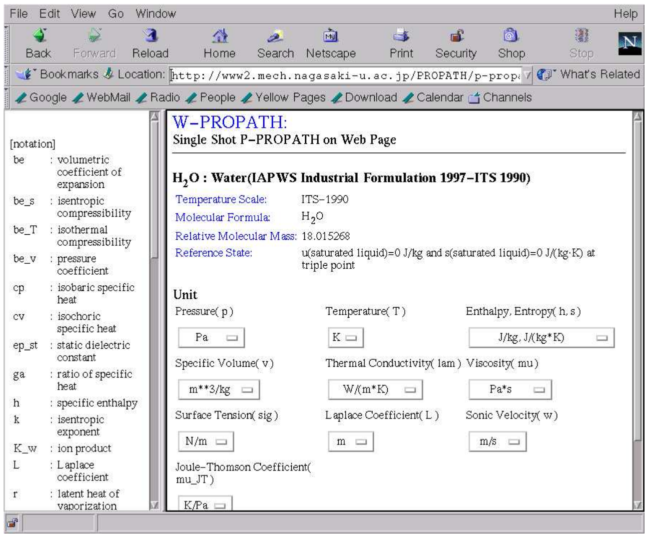
5. Click on [Properties]. The properties selection page appears. You can select properties in the pull-down list. Clicking on [Substances] brings you back to the substance selection page.



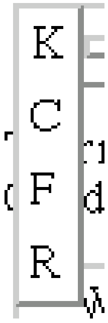
6. Select a property, or properties, from the pull-down list.



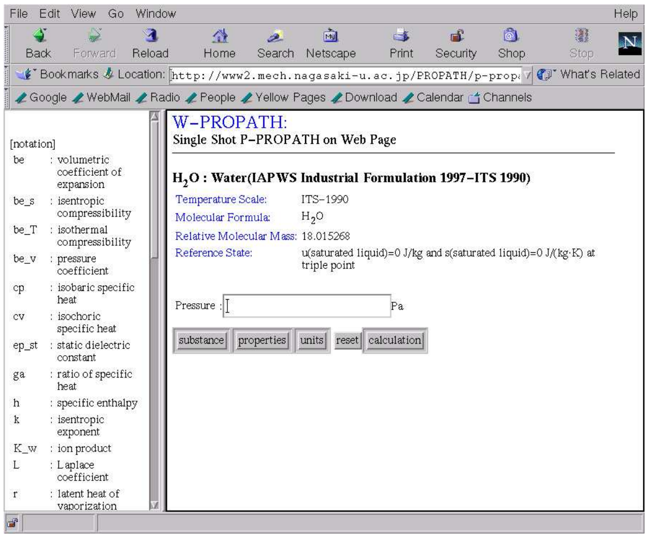
7. Click on [Units]. The units selection page appears. You can select one from listed units. Clicking on [defaults] resets all units to defaults.



8. For example, the unit pull-down list for temperature looks as below. You can choose K(Kelvin), °C(Celsius), F(Fahrenheit) or R(Rankine).



9. Click on [Input]. The page for data input and calculation appears.



10. Input the required value from the server and click on [calculation]. Then the results page is then displayed.