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]	$73.15 \leq T68 \leq 1033.15$ [K] $1337.15 \leq T68 \leq 3273.15$ [K] $-200 \leq T68 \leq 630$ [°C] $1064 \leq T68 \leq 3000$ [°C]
T68(T90)	T68: Temperature by IPTS-1968 [K], [°C] T90: Temperature by ITS-1990 [K], [°C]	$73.156 \leq T90 \leq 902.841$ [K] $1337.2 \leq T90 \leq 3271.65$ [K] $-199.994 \leq T90 \leq 629.691$ [°C] $1064.05 \leq T90 \leq 2998.5$ [°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) Moist Air (Real Fluid)	`maig-ss` `marf-ss`	`libjmaig.a` `libjmarf.a`
M-PROPATH	Mixture with Ammonia and Water (Ibrahim and Klein) Mixture with Ammonia and Water (Tiller-Roth and Friend)	`awmx-ss` `awmx2-ss`	`libjawmx.a` `libjawmx2.a`

F-PROPATH	Binary Mixtures by General Equations
	Peng-Robinson Equation
	CSD Equation
	BWR Equation
		
		`prmx-ss`
		`PRMX-SS.DAT`
		`csdmx-ss`
		`CSDMX-ss.DAT`
		`----`
			
			`libjprmx.a`
			
			`libjcsdmx.a`
			
			`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 $-(\partial p)_*$.