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Interactive FORTRAN Programs for Micro Computers to Calculate the Thermophysical Properties of Twelve Fluids [MIPROPS]

Robert D. McCarty

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INTERACTIVE FORTRAN PROGRAMS FOR MICRO COMPUTERS TO CALCULATE THE
THERMOPHYSICAL PROPERTIES OF TWELVE FLUIDS [MIPROPS]

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The thermophysical and transport properties of selected fluids have been programmed in FORTRAN 77 which is available for micro computers. The input variables are any two of P , ρ , T (pressure, density, and temperature) in the single phase regions, and either P or T for the saturated liquid or vapor states. The output is pressure, density, temperature, internal energy, enthalpy, entropy, specific heat capacities (C_p and C_v), speed of sound and, in most cases, viscosity, thermal conductivity and dielectric constant.

The fluids included are: helium, hydrogen, nitrogen, oxygen, argon, nitrogen trifluoride, methane, ethylene, ethane, propane, iso- and normal butane. The programs give properties in both the liquid and vapor states over a wide range of temperature and pressure. Copies of the program may be obtained from the Office of Standard Reference Data, Room A320, Physics Building, National Bureau of Standards, Gaithersburg, MD 20899.

Key words: argon; computer programs; density; dielectric constant; enthalpy; entropy; equation of state; ethane, ethylene; heat capacity; helium; hydrogen; internal energy; isobutane; methane; nitrogen; nitrogen trifluoride; normal butane; oxygen; pressure; speed of sound; temperature; thermal conductivity; viscosity.

1. Introduction

Recent technological advances in the field of personal computers have made it possible and practical to run large FORTRAN programs on these machines. The programs presented here will run satisfactorily on a wide variety of personal computers on the market today.

The programs are a direct translation of those developed by Younglove [1,2], with five additional fluids added [3]. The separate program for helium originally appeared in NBS Technical Note 1025 by McCarty [4] and was, in turn, derived from an earlier evaluation of helium data [5]. The programs in the above-mentioned documents were written as interactive FORTRAN IV programs intended to run on large main frames. The programs presented here are translations of the originals to FORTRAN 77 adapted to personal computers and reproduce the calculations of the originals exactly.

All of the fluids except helium utilize the same mathematical model of the equation of state which was originally proposed by Jacobsen [6]. The model for the helium thermodynamic surface is of a different form, and a separate program was necessary for that fluid. The mathematical model of the transport properties of the fluids which have been added to those from NBS Technical Note 1048, has been improved and new routines are utilized for those fluids.

The programs produce the transport properties for all of the fluids except hydrogen, nitrogen trifluoride, ethylene, ethane and propane. The dielectric constant is also provided for all of the fluids except argon, ethylene and nitrogen trifluoride.

There is a section devoted to each fluid in Appendix A and the reader is referred to those sections for further information on an individual fluid. Listings of the source code and sample calculations may be found in Appendices B and C.

2. Uncertainties of the Calculated Properties

When calculating thermodynamic properties from an empirical equation of state, one should be aware of certain problem areas of the thermodynamic surface. In the critical region ($\rho_c \pm 0.2 \rho_c$ and $T_c \pm 0.05 T_c$), the calculated density may be in error by several percent, while the calculated pressure or temperature will not be as inaccurate. Values of specific heat capacity and thermal conductivity in the critical region become very large and no realistic estimate of the uncertainty may be made. Saturation boundaries, gas-liquid, and liquid-solid are potential areas of large uncertainties for derived thermodynamic properties, especially heat capacities. In the compressed liquid region, calculated pressures will have an uncertainty of several percent. This is a consequence of the nature of the surface and is in no way the fault of the equation of state.

In each of the sections on the individual fluids, uncertainty estimates are given for that particular fluid. These estimates do not reflect the potential large uncertainties of the problem areas outlined above.

3. Computer Routines

The thermophysical properties produced by the computer programs listed in Appendix C are all calculated using a mathematical model of the equation of state of the fluid and classical thermodynamic relationships. The reader who is interested in the thermodynamics and mathematics of the problem is referred to McCarty [7].

In general eleven or twelve significant figures are needed in the property calculations to prevent round off errors. Sample calculations for each fluid are given in Appendix A for the purpose of checking the performance of the programs on individual computers.

Upper and lower temperature and pressure limits for each fluid have been installed in the programs according to the range of validity as claimed by the original source document. All of the functions reduce to the ideal gas in the limit of zero pressure, but because of the very large exponents in some of the terms, the iterative solution for density fails at very low pressures. Because the models are empirical and cannot be trusted to give even reasonable results outside their ranges of pressure and temperature, the user is cautioned not to change the pressure or temperature limits originally set in the programs.

4. Acknowledgments

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Appendix A
Description of Individual Fluids

[PARAHYDROGEN]

The source of the hydrogen equation of state is NBSIR 75-814 by Roder and McCarty [8] and Stewart [9].

Estimated Uncertainties (%)

Property	Liquid Below T _c	Gas Below T _c	Fluid Above T _c
Pressure	5.0	0.25	0.20
Density	0.1	0.25	0.20
Temperature	0.1	0.25	0.20
Enthapy & Internal Energy	1.0	3.0	5.10
Entropy	1.0	1.0	1.0
C _p and C _v	3.0	2.0	3.0
Speed of Sound	2.0	1.0	1.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	1.2838	15.556	32.938
Triple Point Liquid	0.00743	0.06323	13.80
Triple Point Vapor	0.00743	38.2143	

Temperature Range 13.8 to 400 K

Pressure Range 0 to 120 MPa

Sample Calculations

THE TEMPERATURE RANGE FOR HYDROGEN IS 13.8 TO 400 K
 (-434.8 TO 260 F) WITH PRESSURES TO 120 MPa (17404 PSIA)
 FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
 FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
 FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
 FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
 TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
 ENTER A PRESSURE(MPA) 0 RESTARTS THE PROGRAM

.1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL ==	==	==== J/MOL-K ===	==	M/S	PA-S	MW/M-K	==	==
.100	20.23	35.144	-520.	-517.	16.1	11.4	19.4	1102.	E+6		1.22999

ENTER A PRESSURE(MPA) 0 RESTARTS THE PROGRAM

[HELIUM]

The source of the helium equation of state is McCarty [10].

Estimated Uncertainties (%)

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	10.0	0.2	0.2
Density	0.5	0.2	0.2
Temperature	0.5	0.2	0.2
Enthapy & Internal Energy	2.0	1.0	1.0
Entropy	2.0	1.0	1.0
C_p and C_v	2.0	2.0	0.5
Speed of Sound	2.0	1.0	0.5
Thermal Conductivity	10.0	10.0	10.0
Viscosity	8.0	8.0	10.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	0.2275	17.399	5.2014
Lambda Point Liquid	0.00496	36.534 3	2.172
Lambda Point Vapor	0.00496	0.2904	2.172

Temperature Range 2 - 1500 K

Pressure Range 0 - 100 MPa

Sample Calculations

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S'	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	M/S	PA-S	MW/M-K	==	E+6
. 100	4. 21	31. 291	-24.	-20.	14. 2	9. 5	19. 7	173.	31. 8	19. 6	1. 04925

[NITROGEN]

The source of the nitrogen equation of state is Jacobsen, et al. [6] and Ely and Straty [11].

Estimated Uncertainties (%)

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.3	0.3
Density	0.5	0.3	0.2
Temperature	0.5	0.3	0.2
Enthapy & Internal Energy	3.0	1.0	1.0
Entropy	2.0	1.0	1.0
C_p and C_v	5.0	5.0	5.0
Speed of Sound	2.0	0.25	1.0
Thermal Conductivity	4.0	4.0	6.0
Viscosity	2.0	2.0	2.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	3.4100	11.21	126.26
Triple Point Liquid	0.1246	30.977	63.15
Triple Point Vapor	0.1246	0.2396	63.15

Temperature Range 63.15 - 1900 K

Pressure Range 0 - 1000 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR NITROGEN IS 63.15 TO 1900 K
 WITH PRESSURES TO 1000 MPA
 FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
 FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
 FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
 FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
 TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
 ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL ==	==	==== J/MOL-K ===	===	M/S	PA-S	MW/M-K	==	==
.100	77.25	28.881	-3411.	-3407.	79.5	27.8	57.8	941.	152.2	133.8	1.43386

[OXYGEN]

The source of the oxygen equation of state is Weber [10] and Younglove [12].

Estimated Uncertainties (%)

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.25	0.15
Density	0.1	0.25	0.15
Temperature	0.1	0.20	0.10
Enthapy & Internal Energy	0.5	0.25	0.50
Entropy	0.5	0.25	0.50
C_p and C_v	3.0	5.0	3.0
Speed of Sound	2.0	0.50	0.50
Thermal Conductivity	4.0	4.0	6.0
Viscosity	2.0	2.0	2.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	5.0422	13.63	154.481
Triple Point Liquid	0.1490×10^{-3}	40.820	54.359
Triple Point Vapor	0.1490×10^{-3}	0.3275×10^{-3}	54.359

Temperature Range 54.359 to 400 K

Pressure Range 0 - 120 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR OXYGEN IS 54.359 TO 400 K
WITH PRESSURES TO 120 MPA
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

.1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	==	M/S	PA-S	MW/M-K	==
.100	90.07	35.677	-4272.	-4270.	94.1	29.6	54.2	906.	195.3	152.0	1.48734

[ARGON]

The source of the argon equation of state is Stewart, et al. [13].

Estimated Uncertainties (%)

Property	Liquid Below T _c	Gas Below T _c	Fluid Above T _c
Pressure	10.0	0.3	0.3
Density	0.25	0.3	0.3
Temperature	0.25	0.3	0.3
Enthalpy & Internal Energy	2.0	1.0	1.5
Entropy	1.0	1.0	1.0
C _p and C _v	5.0	5.0	5.0
Speed of Sound	5.0	5.0	5.0
Thermal Conductivity	4.0	4.0	6.0
Viscosity	2.0	2.0	2.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	4.8980	13.41	150.86
Triple Point Liquid	0.0689	35.40	83.8
Triple Point Vapor	0.0689	0.1015 x 10 ⁻³	83.8

Temperature Range 83.8 to 400 K

Pressure Range 0 - 100 MPa

Sample Calculations

THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K
 WITH PRESSURES TO 100 MPa
 FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
 FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
 FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
 FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
 TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
 ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	M/S	PA-S	MW/M-K	==	==
. 100	87.16	34.914	-4714.	-4711.	54.8	22.3	44.7	815.	261.2	128.5	E+6

[NITROGEN TRIFLUORIDE]

The source of the nitrogen trifluoride equation of state is Goodwin and Weber [14].

Estimated Uncertainties (%)*

Property	Liquid Below T _C	Gas Below T _C	Fluid Above T _C
Pressure	5.0	0.2	0.1
Density	0.1	0.2	0.1
Temperature	0.1	0.1	0.1
Enthapy & Internal Energy	2.0	2.0	2.0
Entropy	2.0	2.0	2.0
C _p and C _v	5.0	5.0	5.0
Speed of Sound	5.0	5.0	5.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	4.4607	7.92	234.0
Triple Point Liquid	0.1854 x 10 ⁻⁶	26.32	66.35
Triple Point Vapor	0.1854 x 10 ⁻⁶	0.33612 x 10 ⁻⁶	66.35

Temperature Range 66.36 to 500 K

Pressure Range 0 - 50 MPa

Sample Calculations

THE RANGE OF TEMPERATURE OFR NITROGEN TRIFLUORIDE IS
66.36 TO 500 K, WITH PRESSURES TO 50 MPA
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL ==	==	==== J/MOL-K ===	===	M/S		PA-S	MW/M-K	==
.100	143.92	21.669	-6846.	-6841.	147.6	40.3	72.2	759.	E+6		

*Estimates not from original source.

[METHANE]

The source of the methane equation of state is Ely, et al. [3].

Estimated Uncertainties (%)*

Property	Liquid Below T _c	Gas Below T _c	Fluid Above T _c
Pressure	5.0	0.25	0.25
Density	0.1	0.25	0.25
Temperature	0.1	0.25	0.25
Enthapy & Internal Energy	1.0	0.5	0.50
Entropy	0.5	0.5	0.50
C _p and C _v	2.0	5.0	2.00
Speed of Sound	1.0	0.3	0.3
Thermal Conductivity	5.0	5.0	4.0
Viscosity	3.0	3.0	2.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	4.599	10.23	190.55
Triple Point Liquid	0.01174	28.1511	90.68
Triple Point Vapor	0.01174	0.01569 x 10 ⁻⁶	90.68

Temperature Range 90.68 to 600 K

Pressure Range 0 - 200 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR METHANE IS 90.68 TO 600 K
WITH PRESSURES TO 200 MPa
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL ==	=== J/MOL-K ===	M/S	PA-S	MW/M-K	==	E+6		
. 100	111.47	26.355	-4629.	-4625.	79.0	32.9	55.5	1336.	117.6	188.8	1.62653

*Estimates not from original source.

[ETHYLENE]

The source of the ethylene equation of state is McCarty and Jacobsen [15].

Estimated Uncertainties (%)*

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.15	0.15
Density	0.15	0.15	0.15
Temperature	0.15	0.15	0.15
Enthapy & Internal Energy	2.0	1.0	1.0
Entropy	2.0	1.0	1.0
C_p and C_v	5.0	2.0	2.0
Speed of Sound	3.0	1.0	1.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	5.0403	7.634	282.343
Triple Point Liquid	0.12×10^{-3}	23.389	103.986
Triple Point Vapor	0.12×10^{-3}	0.14×10^{-3}	103.986

Temperature Range 104 to 400 K

Pressure Range 0 - 40 MPa

Sample Calculations

THE TEMPERATURE RANGE FOR ETHYLENE IS 104 TO 400 K
WITH PRESSURES TO 40 MPa
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	M/S	PA-S	MW/M-K	==	E+6
. 100	169.19	20.256	-8017.	-8012.	117.6	38.2	67.9	1312.			

*Estimates not from original source.

[ETHANE]

The source of the ethane equation of state is Ely, et al. [3].

Estimated Uncertainties (%)*

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.25	0.15
Density	0.1	0.25	0.15
Temperature	0.1	0.25	0.15
Enthapy & Internal Energy	1.0	1.0	1.0
Entropy	1.0	1.0	1.0
C_p and C_v	5.0	5.0	5.0
Speed of Sound	5.0	5.0	5.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	4.8714	6.8	305.33
Triple Point Liquid	0.11308×10^{-5}	21.68	90.348
Triple Point Vapor	0.11308×10^{-5}	0.1515×10^{-5}	90.348

Temperature Range 90.33 to 600 K

Pressure Range 0 - 70 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR ETHANE IS 90.35 TO 600 K
WITH PRESSURES TO 70 MPa
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPa	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	M/S	PA-S	MW/M-K	==	E+6
. 100	184.31	18.105	-8263.	-8258.	126.8	42.6	73.1	1324.			1.75728

*Estimates not from original source.

[PROPANE]

The source of the propane equation of state is Ely, et al. [3].

Estimated Uncertainties (%)*

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.25	0.15
Density	0.1	0.25	0.15
Temperature	0.1	0.25	0.15
Enthapy & Internal Energy	1.0	1.0	1.5
Entropy	1.0	1.0	1.5
C_p and C_v	5.0	5.0	5.0
Speed of Sound	5.0	5.0	5.0
Thermal Conductivity	5.0	5.0	5.0
Viscosity	3.0	3.0	3.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	4.247	5.00	369.85
Triple Point Liquid	0.1690×10^{-9}	16.630	85.47
Triple Point Vapor	0.1690×10^{-9}	0.2238×10^{-9}	85.47

Temperature Range 85.47 to 600 K

Pressure Range 0 - 100 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR PROPANE IS 85.47 TO 600 K
WITH PRESSURES TO 100 MPA
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL	
MPA	K	MOL/L	===	J/MOL	==	====	J/MOL-K	===	M/S	PA-S	MW/M-K	==
. 100	230.78	13.188	-8826.	-8818.	171.0	64.0	99.0	1160.	E+6		1.80350	

*Estimates not from original source.

[ISOBUTANE]

The source of the isobutane equation of state is Ely, et al. [3].

Estimated Uncertainties (%)*

Property	Liquid Below T _c	Gas Below T _c	Fluid Above T _c
Pressure	5.0	0.20	0.15
Density	0.1	0.20	0.15
Temperature	0.1	0.20	0.15
Enthapy & Internal Energy	1.0	1.0	1.0
Entropy	1.0	1.0	1.0
C _p and C _v	3.0	3.0	3.0
Speed of Sound	3.0	3.0	3.0
Thermal Conductivity	5.0	5.0	5.0
Viscosity	3.0	3.0	3.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	3.690	3.86	407.85
Triple Point Liquid	0.19481 x 10 ⁻⁷	12.755	113.55
Triple Point Vapor	0.19481 x 10 ⁻⁷	0.20633 x 10 ⁻⁷	113.55

Temperature Range 113.55 to 600 K

Pressure Range 0 - 35 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR ISO BUTANE IS
 113.55 TO 600 K
 WITH PRESSURES TO 35 MPA
 FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
 FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
 FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
 FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
 TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
 ENTER A PRESSURE(MPA)

.1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	===	M/S	PA-S	MW/M-K	==
.100	261.20	10.220	-7116.	-7106.	200.8	92.1	130.4	1010.	229.2	112.2	1.82016

*Estimates not from original source.

[NORMAL BUTANE]

The source of the normal butane equation of state is Ely, et al. [3].

Estimated Uncertainties (%)*

Property	Liquid Below T_c	Gas Below T_c	Fluid Above T_c
Pressure	5.0	0.20	0.15
Density	0.1	0.20	0.15
Temperature	0.1	0.20	0.15
Enthapy & Internal Energy	1.0	1.0	1.0
Entropy	1.0	1.0	1.0
C_p and C_v	3.0	3.0	3.0
Speed of Sound	3.0	3.0	3.0
Thermal Conductivity	5.0	5.0	5.0
Viscosity	3.0	3.0	3.0

Fixed Points

	Pressure, MPa	Density, M/L	Temperature, K
Critical Point	3.796	3.92	425.16
Triple Point Liquid	0.6736×10^{-6}	12.65	134.86
Triple Point Vapor	0.6736×10^{-6}	0.60071×10^{-6}	134.86

Temperature Range 134.65 to 500 K

Pressure Range 0 - 70 MPa

Sample Calculations

THE RANGE OF TEMPERATURE FOR NORMAL BUTANE IS
134.68 TO 500 K
WITH PRESSURES TO 70 MPA
FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

0
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

0
FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"

0
TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"

1
ENTER A PRESSURE(MPA)

. 1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL	==	==== J/MOL-K	===	M/S	PA-S	MW/M-K	==	E+6

. 100 272.29 10.348 -5959. -5949. 218.1 95.6 134.4 1036. 204.2 117.2 1.81181

*Estimates not from original source.

Appendix B
Sample Computer Sessions

helium

THIS PROGRAM PROVIDES THE THERMODYNAMIC PROPERTIES OF HELIUM FROM 2 TO 1500 K WITH PRESSURES TO 100 MPA

WHEN THE PROGRAM ASKS FOR A PRESSURE, DENSITY AND TEMPERATURE, ENTER ANY TWO AND A ZERO FOR THE THIRD.
TO TERMINATE THE PROGRAM ENTER ZERO FOR ALL THREE.

FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

1
FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

1
ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A TEMPERATURE INCREMENT AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"

.1,3,10,1

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL	==	====	J/MOL-K	===	M/S	PA-S	MW/M-K	==
.100	3.00	35.794	-39.	-36.	9.8	7.6	9.4	222.	38.5	18.1	1.05646
.100	4.00	32.477	-27.	-24.	13.3	9.1	16.3	185.	33.3	19.6	1.05114
.100	5.00	2.935	52.	86.	39.1	12.7	27.1	120.	13.9	11.1	1.00456
.100	6.00	2.252	67.	111.	43.7	12.5	24.0	137.	15.8	12.4	1.00350
.100	7.00	1.855	81.	135.	47.3	12.5	22.8	151.	17.6	13.8	1.00288
.100	8.00	1.586	94.	157.	50.3	12.5	22.2	163.	19.3	15.1	1.00246
.100	9.00	1.389	107.	179.	52.9	12.5	21.9	174.	21.0	16.3	1.00216
.100	10.00	1.238	120.	201.	55.2	12.5	21.7	185.	22.6	17.5	1.00192

ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A TEMPERATURE INCREMENT AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"

0,0,0,0

FOR MORE PROPERTIES ENTER 0, TO TERMINATE ENTER 1

1

Stop - Program terminated.

MIPROPS

FOR INFORMATION ON HOW TO USE THIS PROGRAM, ENTER "0" OTHERWISE, ENTER "1"

0

ENTER A NUMBER TO SELECT A FLUID.
 ANY ENTRY OTHER THAN A NUMBER WILL TERMINATE THE PROGRAM.
 WHEN THE PROGRAM ASKS FOR A PRESSURE, DENSITY AND TEMPERATURE,
 ENTER ANY TWO AND A ZERO FOR THE THIRD. TO SELECT ANOTHER
 FLUID ENTER ZERO FOR ALL THREE.
 SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER

- | | | | |
|-------------|-------------------------|-------------------|-----------|
| 1=ARGON, | 2=ETHYLENE, | 3=PARA HYDROGEN, | 4=METHANE |
| 5=NITROGEN, | 6=NITROGEN TRIFLUORIDE, | 7=OXYGEN, | 8=ETHANE |
| 9=PROPANE, | 10=ISO BUTANE, | 11=NORMAL BUTANE, | 12=STOP |

1
 THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K
 WITH PRESSURES TO 100 MPA
 FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"

1
 FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"

1
 FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"

1
 ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A
 TEMPERATURE INCREMENT AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"

1, 200, 300, 20

P	T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
MPA	K	MOL/L	=== J/MOL ==	==== J/MOL-K ===	M/S	PA-S	MW/M-K	==	E+6		
1.000	200.00	.619	2384.	3999.	126.9	12.7	22.2	262.	16.3	13.2	
1.000	220.00	.559	2648.	4438.	128.9	12.6	21.8	275.	17.7	14.2	
1.000	240.00	.509	2908.	4873.	130.8	12.6	21.6	288.	19.1	15.3	
1.000	260.00	.468	3167.	5304.	132.6	12.6	21.5	301.	20.4	16.3	
1.000	280.00	.433	3423.	5732.	134.2	12.6	21.4	312.	21.8	17.3	
1.000	300.00	.403	3679.	6159.	135.6	12.5	21.3	324.	23.1	18.3	

ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A
 TEMPERATURE INCREMENT AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"

Appendix C
Program Listings

Program Listing of MIPROPS

```

IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/CONT/IF
COMMON/CRIT/EM,EOK,RM,TC,DC,X,PC,SIG
COMMON/DIEL/BX(6),PX(6)
1201 FORMAT(//' THIS PROGRAM PROVIDES THE THERMODYNAMIC PROPERTIES OF
111 FLUIDS',/,',
2'/' PARA HYDROGEN, NITROGEN, OXYGEN, ARGON
3' NITROGEN TRIFLOURIDE, METHANE, ETHANE, ETHYLENE'/
3' PROPANE, ISO BUTANE AND NORMAL BUTANE'//)
WRITE(*,1201)
WRITE(*,1202)
1202 FORMAT(' WRITTEN BY'//
A' ROBERT D. MCCARTY'/
1' THERMOPHYSICS DIVISION'/
2' CENTER FOR CHEMICAL ENGINEERING'/
3' NATIONAL BUREAU OF STANDARDS'/
4' BOULDER, COLORADO'//
5' DISTRIBUTED BY'//
A' THE OFFICE OF STANDARD REFERENCE DATA'/
6' NATIONAL BUREAU OF STANDARDS, WASHINGTON, DC'//)

1000 FORMAT(//' FOR INFORMATION ON HOW TO USE THIS PROGRAM, ENTER "0" '
A ' OTHERWISE, ENTER "1"')//)
WRITE(*,1000)
IP=3
READ(*,1010)I
IF(I.EQ.0)CALL INFO
1010 FORMAT(I1)
110 WRITE(*,1020)
WRITE(*,1030)
1020 FORMAT(' SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER',/)
1030 FORMAT(' 1=PARA HYDROGEN, 2=NITROGEN, 3=OXYGEN,'
A,/, ' 4=ARGON, 5=NITROGEN TRIFLUORIDE, 6=METHANE,
B',/, ' 7=ETHANE, 8=ETHYLENE, 9=PROPANE,
C',/, ' 10=ISO BUTANE, 11=NORMAL BUTANE, 12=STOP',/)
READ(*,*)IF
CALL FDATA(IF)
120 WRITE(*,1040)
1040 FORMAT(' FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"',/)
READ(*,1010)IU
WRITE(*,1050)
1050 FORMAT(' FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER '
A "'1"')//)
READ(*,1010)IC
WRITE(*,1060)
1060 FORMAT(' FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"',/)
READ(*,1010)IV
160 IF(IC.EQ.0)GO TO 240
IF(IV.EQ.1)GO TO 330
170 IF(IU.EQ.0)GO TO 180
WRITE(*,1080)
READ(*,*)P,D,T
GO TO 190
180 WRITE(*,1070)
1070 FORMAT(' ENTER PRESSURE(PSIA), DENSITY(LB/CU FT), AND TEMPERATURE'

```

```

A '(F)',/)
  READ(*,*)P,D,T
  P=(P/14.695949D0)*.101325D0
  D=D*16.01846371D0/EM
  T=(T-32.D0)/1.8D0+273.15D0
190 IF(P.LE.0.0D0.AND.D.LE.0.0D0)GO TO 110
  IF(P.GT.0.0D0.AND.D.GT.0.0D0)GO TO 200
  IF(P.LE.0.0D0.AND.T.NE.0.0D0)GO TO 220
1080 FORMAT(' ENTER PRESSURE(MPA), DENSITY(MOL/L), AND TEMPERATURE(K) '
A /)
  IF(P.NE.0.0D0.AND.T.NE.0.0D0)GO TO 210
  GO TO 110
200 T=FIND T(P,D)
  CALL LIMITS(P,T,IL)
  IF(IL.LE.0)GO TO 170
  GO TO 230
210 CALL LIMITS(P,T,IL)
  IF(IL.LE.0)GO TO 170
  D=FIND D(P,T)
  GO TO 230
220 P=FIND P(D,T)
  CALL LIMITS(P,T,IL)
  IF(IL.LE.0)GO TO 170
230 CALL REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
  GO TO 170
240 WRITE(*,1090)
1090 FORMAT(' FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"',/)
  READ(*,1010)IP
  IF(IV.EQ.1)GO TO 330
  WRITE(*,1095)
1095 FORMAT(' TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"',/)
  READ(*,1010)II
  IF(II.EQ.1)GO TO 290
250 IF(IU.EQ.1)GO TO 260
1100 FORMAT(' ENTER A TEMPERATURE IN DEGREES F',/)
  WRITE(*,1100)
  READ(*,*)TI
  T=(TI-32.D0)/1.8D0+273.15D0
  GO TO 270
260 WRITE(*,1110)
1110 FORMAT(' ENTER A TEMPERATURE(K) 0 RESTARTS THE PROGRAM'/)
  READ(*,*)T
270 IF(T.LT..000001D0)GO TO 110
  IF(T.GT.TCC.OR.T.LT.TTP)GO TO 280
  P=VPN(T)
  IF(IP.EQ.0)P=P+.00001D0
  D=FIND D(P,T)
  CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
  WRITE(*,1111)
1111 FORMAT(' ENTER 1 FOR MORE OR 0 TO RESTART PROGRAM'/)
  READ(*,*)ISAT
  IF(ISAT.EQ.1)GO TO 250
  GO TO 110
280 X1=(TTP-273.15D0)*1.8D0+32.D0
  X2=(TCC-273.15D0)*1.8D0+32.D0
  WRITE(*,1120)TTP,TCC,X1,X2
1120 FORMAT(' FOR SATURATION ',F6.2,' < TEMP < ',F6.2,' K',/,
A ' OR ',F7.2,' < TEMP < ',F7.2,' F',/)
  GO TO 250

```

```

290 IF(IU.EQ.1)GO TO 300
WRITE(*,1130)
1130 FORMAT(' ENTER A PRESSURE IN LB/SQ IN    0 RESTARTS THE PROGRAM'/)
READ(*,*)PI
IF(PI.LE.0.0D0)GO TO 110
P=(PI/14.695949D0)*.101325D0
GO TO 310
300 WRITE(*,1140)
1140 FORMAT(' ENTER A PRESSURE(MPA)    0 RESTARTS THE PROGRAM'/)
READ(*,*)PI
IF(PI.LE.0.0D0)GO TO 110
P=PI
310 IF(P.GT.PCC.OR.P.LT.PTP)GO TO 320
4000 FORMAT(D20.5)
T=FINN TV(P)
P=VPN(T)
IF(IP.EQ.0)P=P+.00001D0
D=FINN D(P,T)
CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
GO TO 290
320 PTPF=PTP*14.695949D0/.101325D0
PCCF=PCC*14.695949D0/.101325D0
WRITE(*,1150) PTP,PCC,PTPF,PCCF
1150 FORMAT(' YOUR INPUT PRESSURE IS OUTSIDE THE RANGE OF SATURATION'
A ' PRESSURES'/' FOR THIS FLUID THE RANGE IS ',F6.5,' TO ',F6.3,
B ' MPA'/' OR ',F6.2,' TO ',F6.1,' PSIA'/' TRY AGAIN',/)
GO TO 290
330 IF(IC.EQ.1)GO TO 370
IF(IU.EQ.1)GO TO 340
WRITE(*,1160)
1160 FORMAT(' ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE'
A '/' AND A TEMPERATURE INCREMENT, IN DEGREES F AND IN THAT ORDER'/)
READ(*,*)TS,TF,DELT
IF(DELT.LE.0.0D0)GO TO 110
TS=(TS-32.D0)/1.8D0+273.15D0
TF=(TF-32.D0)/1.8D0+273.15D0
DELT=DELT/1.8D0
IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360
GO TO 350
340 WRITE(*,1170)
1170 FORMAT(' ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE'
1/' AND A TEMPERATURE INCREMENT IN KELVINS AND IN THAT ORDER',/)
READ(*,*)TS,TF,DELT
IF(DELT.LE.0.0D0)GO TO 110
IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360
350 T=TS
P=VPN(T)
IF(IP.EQ.0.0D0)P=P+.00001D0
D=FINN D(P,T)
CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
GO TO 330
360 X1=(TTP-273.15D0)*1.8D0+32.D0
X2=(TCC-273.15D0)*1.8D0+32.D0
WRITE(*,1180)TTP,TCC,X1,X2
1180 FORMAT(' FOR SATURATION, ',F6.2,' < 'TEMP < ',F6.2,' K',/,
A ',13X,'OR, ',F7.1,' < TEMP < ',F7.1,' F. TRY AGAIN.',/)
GO TO 330

```

```

370 IF(IU.EQ.1)GO TO 380
    WRITE(*,1190)
1190 FORMAT(' ENTER PRESSURE(Psia), STARTING TEMPERATURE(F), FINAL '
A 'TEMPERATURE AND A '/' TEMPERATURE INCREMENT'
2' AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"',/)
    READ(*,*)PI,TS,TF,DELT
    IF(DELT.LE.0.0D0)GO TO 110
    P=(PI/14.695949D0)*.101325D0
    T=(TS-32.D0)/1.8D0+273.15D0
    TF=(TF-32.D0)/1.8D0+273.15D0
    DELT=DELT/1.8D0
    CALL LIMITS(P,T,IL)
    IF(IL.LE.0)GO TO 370
    CALL LIMITS(P,TF,IL)
    IF(IL.LE.0)GO TO 370
    GO TO 390
380 WRITE(*,1200)
1200 FORMAT(' ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A '
1'FINAL TEMPERATURE AND A '/' TEMPERATURE INCREMENT'
2' AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"',/)
    READ(*,*)PI,TS,TF,DELT
    IF(DELT.LE.0.0D0)GO TO 110
    T=TS
    P=PI
    CALL LIMITS(P,T,IL)
    IF(IL.LE.0)GO TO 370
    CALL LIMITS(P,TF,IL)
    IF(IL.LE.0)GO TO 370
390 D=FINDD(P,T)
    CALL REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
    GO TO 370
999 CONTINUE
    END
    SUBROUTINE REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
    IMPLICIT REAL*8(A-H)
    IMPLICIT REAL*8(O-Z)
    IMPLICIT INTEGER*4(I-N)
    DIMENSION G(32),VP(9)
    COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
    COMMON/CONT/IF
    COMMON/CRIT/EM,EOK,RM,TC,DC,X,PC,SIG
    COMMON/CPID/GI(11),GH(11),GL(11)
    COMMON/HAN/CR,TCI
    N=500
    IF(IV.EQ.0)TF=T-1.D0
    IF(IU.EQ.0)GO TO 100
    WRITE(*,1000)
    WRITE(*,1010)
    WRITE(*,1020)
    GO TO 110
100 WRITE(*,1000)
    WRITE(*,1030)
    WRITE(*,1040)
110 CONTINUE
    DO 210 I=1,N
    IF(I.EQ.1)GO TO 120
    IF(D.LT.DCC.OR.T.GT.TCC)GO TO 111
    D=FINDD(P,T)
    GO TO 120
111 DIN=D
    D=FINDM(P,T,DIN)

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120 H=ENTHAL(P,D,T)
    E=H-1000.DO*P/D
    S=ENTROP(D,T)
    W=SOUND(D,T)
    CPP=CP(D,T)
    CVV=CV(D,T)
    IF(IU.EQ.0)GO TO 160
    IF(IF.EQ.6.OR.IF.EQ.2.OR.IF.EQ.3) GO TO 150
    IF(IF.GT.9)GO TO 150
    IF(IF.EQ.4) GO TO 140
    IF(IF.EQ.1.OR.IF.EQ.7.OR.IF.EQ.9) GO TO 130
    WRITE(*,2000) P,T,D,E,H,S,CVV,CPP,W
    GO TO 200
130 EPS=FDIEL(P,D,T)
    WRITE(*,2010) P,T,D,E,H,S,CVV,CPP,W,EPS
    GO TO 200
140 TH=THERM(D,T)*1000.DO
    V=VISC(D,T)
    WRITE(*,2020) P,T,D,E,H,S,CVV,CPP,W,V,TH
    GO TO 200
150 V=VISC(D,T)
    TH=THERM(D,T)*1000.DO
    EPS=FDIEL(P,D,T)
    WRITE(*,2030) P,T,D,E,H,S,CVV,CPP,W,V,TH,EPS
    GO TO 200
160 H=H/(2.324445DO*EM)
    E=E/(2.324445DO*EM)
    S=S/(4.184001DO*EM)
    CPP=CPP/(4.184001DO*EM)
    CVV=CVV/(4.184001DO*EM)
    W=W*3.280840DO
    PO=(P/.101325DO)*14.695949DO
    DO=D*EM/16.01846371DO
    TO=T*1.8DO-459.67DO
    IF(IF.EQ.6.OR.IF.EQ.2.OR.IF.EQ.3) GO TO 190
    IF(IF.EQ.4) GO TO 180
    IF(IF.EQ.1) GO TO 170
    WRITE(*,3000) PO,TO,DO,E,H,S,CVV,CPP,W
    GO TO 200
170 EPS=FDIEL(P,D,T)
    WRITE(*,3010) PO,TO,DO,E,H,S,CVV,CPP,W,EPS
    GO TO 200
180 V=VISC(D,T)*.067196897DO
    TH=THERM(D,T)*.578176DO
    WRITE(*,3020) PO,TO,DO,E,H,S,CVV,CPP,W,V,TH
    GO TO 200
190 V=VISC(D,T)*.067196897DO
    TH=THERM(D,T)*.578176DO
    EPS=FDIEL(P,D,T)
    WRITE(*,3030) PO,TO,DO,E,H,S,CVV,CPP,W,V,TH,EPS
200 T=T+DELT
    IF(T.GT.TF+.01DO)GO TO 220
    IF(IC.EQ.0)P=VPN(T)
    IF(IP.EQ.0)P=P+.00001DO
210 CONTINUE
220 CONTINUE
    WRITE(*,1000)
1000 FORMAT(' ')
    RETURN

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1010 FORMAT(3X,'P',5X,'T',6X,'DEN',5X,'E',6X,'H',6X,'S',4X,'CV',4X,
A 'CP',3X,'SOUND',2X,'VISC',2X,'COND',2X,'DIEL')
1020 FORMAT(3X,'MPA',3X,'K',6X,'MOL/L',2X,'=== J/MOL ==',2X,'==== ',
A 'J/MOL-K ===',2X,'M/S',3X,'PA-S',1X,'MW/M-K',2X,'==',/,61X,'E+6')
1030 FORMAT(3X,'P',5X,'T',7X,'DENS',3X,'E',8X,'H',5X,'S',5X,'CV',
A 4X,'CP',2X,'SOUND',1X,'VISC',2X,'COND',2X,'DIEL')
1040 FORMAT(3X,'PSIA',2X,'F',7X,'LB/',3X,'==== BTU/ ===',1X,'=====',
A ' BTU/ =====',2X,'F/S',3X,'LB/',2X,'BTU/',2X,'==',/,17X,'CU FT',
B 6X,'LB',14X,'LB-F',13X,'FT-S',1X,'FT-HR-F',/,62X,'E+5')
2000 FORMAT(F8.3,F7.2,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0)
2010 FORMAT(F8.3,F7.2,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,13X,F8.5)
2020 FORMAT(F8.3,F7.2,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1)
2030 FORMAT(F8.3,F7.2,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1,F8.5)
3000 FORMAT(F8.1,F7.2,F7.3,2F7.1,3F6.3,F6.0)
3010 FORMAT(F8.1,F7.2,F7.3,2F7.1,3F6.3,F6.0,11X,F8.5)
3020 FORMAT(F8.1,F7.2,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4)
3030 FORMAT(F8.1,F7.2,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4,F8.5)
END
SUBROUTINE INFO
WRITE(*,100)
100 FORMAT('/' ENTER A NUMBER TO SELECT A FLUID.'/
*' ANY ENTRY OTHER THAN A NUMBER WILL TERMINATE THE PROGRAM.'/
*' WHEN THE PROGRAM ASKS FOR A PRESSURE, DENSITY AND TEMPERATURE, '/
*' ENTER ANY TWO AND A ZERO FOR THE THIRD. TO SELECT ANOTHER'/
*' FLUID ENTER ZERO FOR ALL THREE.')
RETURN
END
SUBROUTINE FDATA(IF)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32),VP(9),GV(9),GT(9),FV(4),FT(4),EV(8),ET(8),A(20)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
COMMON/SEN/BETA,XO,DELTA,E1,E2,AGAM
COMMON/CRIT/EM,EOK,RM,TC,DC,X,PC,SIG
COMMON/SATC/A,DTPV,EG
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/ISP/N,NW,NWW
COMMON/FIXPT/T0,S0,H0
COMMON/DIEL/BX(6),PX(6)
COMMON/B/GMW,SEOK,SSIG
COMMON/A/SE1,G1,B1,DE,BK,D1,XZ,ZZ,X1,X2,X3,X4
GO TO (3,5,7,1,6,4,8,2,9,10,11,12),IF
1 WRITE(*,200)
200 FORMAT(' THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K'
1/' (-308.8 TO 260 F) WITH PRESSURES TO 100 MPA (14504 PSIA)')
OPEN(5,FILE='ARGON.COF')
N=0
NW=0
NWW=0
GO TO 50
2 WRITE(*,201)
201 FORMAT(' THE TEMPERATURE RANGE FOR ETHYLENE IS 104 TO 400 K'
1/' (-272.4 TO 260 F) WITH PRESSURES TO 40 MPA (5801 PSIA)')
OPEN(5,FILE='C2H4.COF')
N=0
NW=0
NWW=0

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      NWW=0
      GO TO 50
3 WRITE(*,202)
202 FORMAT(' THE TEMPERATURE RANGE FOR HYDROGEN IS 13.8 TO 400 K'
1/' WITH PRESSURES TO 120 MPA')
      OPEN(5, FILE=' PH2. COF' )
      N=1
      NW=0
      NWW=0
      GO TO 50
4 WRITE(*,203)
203 FORMAT(' THE RANGE OF TEMPERATURE FOR METHANE IS 90.68 TO 600 K'
1/' WITH PRESSURES TO 200 MPA')
      OPEN(5, FILE=' METH. COF' )
      N=0
      NW=1
      NWW=0
      GO TO 50
5 WRITE(*,204)
204 FORMAT(' THE RANGE OF TEMPERATURE FOR NITROGEN IS 63.15 TO 1900 K'
1/' WITH PRESSURES TO 1000 MPA')
      OPEN(5, FILE=' N2. COF' )
      N=0
      NW=0
      NWW=0
      GO TO 50
6 WRITE(*,205)
205 FORMAT(' THE RANGE OF TEMPERATURE OFR NITROGEN TRIFLUORIDE IS'
1,/' 66.36 TO 500 K, WITH PRESSURES TO 50 MPA')
      OPEN(5, FILE=' NF3. COF' )
      N=0
      NW=0
      NWW=0
      GO TO 50
7 WRITE(*,206)
206 FORMAT(' THE RANGE OF TEMPERATURE FOR OXYGEN IS 54.359 TO 400 K'
1/' WITH PRESSURES TO 120 MPA')
      OPEN(5, FILE=' O2. COF' )
      N=0
      NW=0
      NWW=0
      GO TO 50
8 WRITE(*,207)
207 FORMAT(' THE RANGE OF TEMPERATURE FOR ETHANE IS 90.35 TO 600 K'
1/' WITH PRESSURES TO 70 MPA')
      OPEN(5, FILE=' C2H6. COF' )
      N=0
      NW=1
      NWW=0
      GO TO 50
9 WRITE(*,208)
208 FORMAT(' THE RANGE OF TEMPERATURE FOR PROPANE IS 85.47 TO 600 K'
1/' WITH PRESSURES TO 100 MPA')
      OPEN(5, FILE=' C3H8. COF' )
      N=0
      NW=1
      NWW=0
      GO TO 50
10 WRITE(*,209)
209 FORMAT(' THE RANGE OF TEMPERATURE FOR ISO BUTANE IS'
1/' 113.55 TO 600 K'
1/' WITH PRESSURES TO 35 MPA')
      OPEN(5, FILE=' ISOB. COF' )
      N=0
      NW=1
      NWW=0
      GO TO 50
11 WRITE(*,210)

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210 FORMAT(' THE RANGE OF TEMPERATURE FOR NORMAL BUTANE IS'
1/' 134.68 TO 500 K'
1/' WITH PRESSURES TO 70 MPA')
OPEN(5, FILE=' NORB. COF')
N=0
NW=1
NWW=0
GO TO 50
12 STOP
50 READ(5, 100) SIG, XO, BETA, DELTA, E1, E2, AGAM
READ(5, 100) EM, EOK, RM, TC, DC, X, PC
100 FORMAT(7E12. 6)
DO 60 I=1, 32
60 READ(5, 101) G(I)
101 FORMAT(3D20. 13)
DO 70 I=1, 20
70 READ(5, 101) A(I)
DO 75 I=1, 11
75 READ(5, 101) GI(I), GH(I), GL(I)
DO 80 I=1, 9
80 READ(5, 101) VP(I), GV(I), GT(I)
TCC=VP(8)
PTP=VP(9)
TTP=VP(7)
DO 90 I=1, 8
90 READ(5, 101) EV(I), ET(I)
DO 110 I=1, 4
110 READ(5, 101) FV(I), FT(I)
READ(5, 101) DTP, DTPV
READ(5, 101) TO, SO, HO
READ(5, 102) R, GAMMA, TUL, TLL, PUL, DCC, PCC
DO 95 I=1, 6
95 READ(5, 101) BX(I), PX(I)
IF(NW.EQ.0) GO TO 96
READ(5, 100) SE1, G1, B1, DE, BK, D1
READ(5, 100) XZ, ZZ, X1, X2, X3, X4
READ(5, 100) GMW, SEOK, SSIG, EG
EM=GMW
96 CONTINUE
CLOSE(5, STATUS=' KEEP')
102 FORMAT(F10. 8, E14. 8, 3F8. 2, 2F8. 4)
RETURN
END
SUBROUTINE LIMITS(P, T, IL)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
IF(P .GT. PUL) GO TO 10
IF(T .GT. TUL.OR. T .LT. TLL) GO TO 12
PM=PMELT(T)
IF(P .GT. PM) GO TO 20
IL=1
RETURN
10 WRITE(*, 11) PUL
11 FORMAT(' THE INPUT PRESSURE IS OUT OF THE RANGE OF THIS EQUATION '
1/' THE RANGE FOR THIS EQUATION IS FROM 0 TO ', F6.0, ' MPA')
IL=0
RETURN
12 TLLF= (TLL-273. 15D0)*1. 8D0+32. D0
TULF= (TUL-273. 15D0)*1. 8D0+32. D0
WRITE(*, 13) TLL, TUL, TLLF, TULF
13 FORMAT(' THE INPUT TEMPERATURE IS OUT OF RANGE'
A /' THE RANGE FOR THIS EQUATION IS ', F6.2, ' K TO ', F6.0, ' K', /,
B 27X, ' OR ', F8.2, ' F TO ', F6.0, ' F')
IL=0
RETURN

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20 TM=TMELT(P)
   TF=(TM-273.15D0)*1.8D0+32.D0
   WRITE(*,22) TM,TF
22 FORMAT(' SOLID PHASE DETECTED.',/, ' FOR THIS PRESSURE,   TEMP'
   A ' SHOULD EXCEED ',F8.3,' K, OR',F9.3,' F')
   IL=0
   END
   SUBROUTINE PROPS(PP,DD,TT,K)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*4(I-N)
C THE 32 TERM EQUATION OF STATE, INPUT IS DENSITY(MOLES/L),
C TEMPERATURE(K), OUTPUT (PP) IS PRESSURE(MPA), OR DP/DD IN
C LITER-MPA/MOLE OR DP/DT MPA/K OR S, H, OR CV AT ONE LIMIT OF
C INTEGRATION
   DIMENSION X(33)
   DIMENSION B(33), G(32), VP(9)
   EQUIVALENCE (B,X)
   COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
   DATA M/32/
   D=DD
   P=PP
   T=TT
   GM=GAMMA
   D2=D*D
   D3=D2*D
   D4=D3*D
   D5=D4*D
   D6=D5*D
   D7=D6*D
   D8=D7*D
   D9=D8*D
   D10=D9*D
   D11=D10*D
   D12=D11*D
   D13=D12*D
   TS=DSQRT(T)
   T2=T*T
   T3=T2*T
   T4=T3*T
   T5=T4*T
   F=DEXP(GM*D2)
   GO TO (100,200,300,400,500,600),K
C
100 B(1)=D2*T
   B(2)=D2*TS
   B(3)=D2
   B(4)=D2/T
   B(5)=D2/T2
   B(6)=D3*T
   B(7)=D3
   B(8)=D3/T
   B(9)=D3/T2
   B(10)=D4*T
   B(11)=D4
   B(12)=D4/T
   B(13)=D5
   B(14)=D6/T
   B(15)=D6/T2
   B(16)=D7/T
   B(17)=D8/T
   B(18)=D8/T2
   B(19)=D9/T2
   B(20)=D3*F/T2
   B(21)=D3*F/T3
   B(22)=D5*F/T2
   B(23)=D5*F/T4
   B(24)=D7*F/T2

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B( 25) =D7*F/T3
B( 26) =D9*F/T2
B( 27) =D9*F/T4
B( 28) =D11*F/T2
B( 29) =D11*F/T3
B( 30) =D13*F/T2
B( 31) =D13*F/T3
B( 32) =D13*F/T4
P=0
DO 101 I=1, M
101 P=P+B(I)*G(I)
P=P+R*D*T
PP=P
RETURN
C
ENTRY DPDD
200 F1=2. DO*F*GM*D
F21=3. DO*F*D2 +F1*D3
F22=5. DO*F*D4 +F1*D5
F23=7. DO*F*D6 +F1*D7
F24=9. DO*F*D8 +F1*D9
F25=11. DO*F*D10+F1*D11
F26=13. DO*F*D12+F1*D13
B( 1) =2. DO*D*T
B( 2) =2. DO*D*TS
B( 3) =2. DO*D
B( 4) =2. DO*D/T
B( 5) =2. DO*D/T2
B( 6) =3. DO*D2*T
B( 7) =3. DO*D2
B( 8) =3. DO*D2/T
B( 9) =3. DO*D2/T2
B(10) =4. DO*D3*T
B(11) =4. DO*D3
B(12) =4. DO*D3/T
B(13) =5. DO*D4
B(14) =6. DO*D5/T
B(15) =6. DO*D5/T2
B(16) =7. DO*D6/T
B(17) =8. DO*D7/T
B(18) =8. DO*D7/T2
B(19) =9. DO*D8/T2
B(20) =F21/T2
B(21) =F21/T3
B(22) =F22/T2
B(23) =F22/T4
B(24) =F23/T2
B(25) =F23/T3
B(26) =F24/T2
B(27) =F24/T4
B(28) =F25/T2
B(29) =F25/T3
B(30) =F26/T2
B(31) =F26/T3
B(32) =F26/T4
P=0
DO 201 I=1, M
201 P=P+B(I)*G(I)
P=P+R*T
PP=P
RETURN
C
ENTRY DPDT
300 X( 1) =D2
X( 2) =D2/( 2. DO*TS)
X( 3) =0. DO
X( 4) =-D2/T2
X( 5) =-2. DO*D2/T3
X( 6) =D3
X( 7) =0. DO

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X( 8) = -D3/T2
X( 9) = -2. D0*D3/T3
X(10) = D4
X(11) = 0. D0
X(12) = -D4/T2
X(13) = 0. D0
X(14) = -D6/T2
X(15) = -2. D0*D6/T3
X(16) = -D7/T2
X(17) = -D8/T2
X(18) = -2. D0*D8/T3
X(19) = -2. D0*D9/T3
X(20) = -2. D0*D3*F/T3
X(21) = -3. D0*D3*F/T4
X(22) = -2. D0*D5*F/T3
X(23) = -4. D0*D5*F/T5
X(24) = -2. D0*D7*F/T3
X(25) = -3. D0*D7*F/T4
X(26) = -2. D0*D9*F/T3
X(27) = -4. D0*D9*F/T5
X(28) = -2. D0*D11*F/T3
X(29) = -3. D0*D11*F/T4
X(30) = -2. D0*D13*F/T3
X(31) = -3. D0*D13*F/T4
X(32) = -4. D0*D13*F/T5
P=0
DO 301 I=1, M
301 P=P+G(I)*X(I)
PP=P+R*D
RETURN
C ENTRY DSDN
C PARTIAL OF ENTROPY WITH
C RESPECT TO THE G COEFFICIENTS
C S=SO-R*LOGF(D*R*T/PO)+(DSDN(D)-DSDN(0))*1000. DO +CPOS(T)
400 G1=F/(2. D0*GM)
G2=(F*D2-2. D0*G1)/(2. D0*GM)
G3=(F*D4-4. D0*G2)/(2. D0*GM)
G4=(F*D6-6. D0*G3)/(2. D0*GM)
G5=(F*D8-8. D0*G4)/(2. D0*GM)
G6=(F*D10-10. D0*G5)/(2. D0*GM)
X( 1) = -D
X( 2) = -D/(2. D0*TS)
X( 3) = 0. D0
X( 4) = +D/T2
X( 5) = 2. D0*D/T3
X( 6) = -D2/2. D0
X( 7) = 0. D0
X( 8) = D2/(2. D0*T2)
X( 9) = D2/T3
X(10) = -D3/3. D0
X(11) = 0. D0
X(12) = D3/(3. D0*T2)
X(13) = 0. D0
X(14) = D5/(5. D0*T2)
X(15) = 2. D0*D5/(5. D0*T3)
X(16) = D6/(6. D0*T2)
X(17) = D7/(7. D0*T2)
X(18) = 2. D0*D7/(7. D0*T3)
X(19) = D8/(4. D0*T3)
X(20) = 2. DG*G1/T3
X(21) = 3. D0*G1/T4
X(22) = 2. D0*G2/T3
X(23) = 4. D0*G2/T5
X(24) = 2. D0*G3/T3
X(25) = 3. D0*G3/T4
X(26) = 2. D0*G4/T3
X(27) = 4. D0*G4/T5
X(28) = 2. D0*G5/T3

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X( 29)=3. DO*G5/T4
X( 30)=2. DO*G6/T3
X( 31)=3. DO*G6/T4
X( 32)=4. DO*G6/T5
P=0
DO 401 I=1, M
401 P=P+G(I)*X(I)
PP=P
RETURN
C ENTRY DUDN
C TERMS NEEDED FOR ENTHALPY CALCULATION
C H=HO+( T*DSDN(D)-DSDN(O))*1000. +( DUDN(D-DUDN(O))*1000. +CPOH(T)
C +( P/D-R*T)*1000.
500 G1=F/( 2. DO*GM)
G2=( F*D2-2. DO*G1)/( 2. DO*GM)
G3=( F*D4-4. DO*G2)/( 2. DO*GM)
G4=( F*D6-6. DO*G3)/( 2. DO*GM)
G5=( F*D8-8. DO*G4)/( 2. DO*GM)
G6=( F*D10-10. DO*G5)/( 2. DO*GM)
X( 1)=D*T
X( 2)=D*TS
X( 3)=D
X( 4)=D/T
X( 5)=D/T2
X( 6)=D2*T/2. DO
X( 7)=D2/2. DO
X( 8)=D2/( 2. DO*T)
X( 9)=D2/( 2. DO*T2)
X(10)=D3*T/3. DO
X(11)=D3/3. DO
X(12)=D3/( 3. DO*T)
X(13)=D4/4. DO
X(14)=D5/( 5. DO*T)
X(15)=D5/( 5. DO*T2)
X(16)=D6/( 6. DO*T)
X(17)=D7/( 7. DO*T)
X(18)=D7/( 7. DO*T2)
X(19)=D8/( 8. DO*T2)
X(20)=G1/T2
X(21)=G1/T3
X(22)=G2/T2
X(23)=G2/T4
X(24)=G3/T2
X(25)=G3/T3
X(26)=G4/T2
X(27)=G4/T4
X(28)=G5/T2
X(29)=G5/T3
X(30)=G6/T2
X(31)=G6/T3
X(32)=G6/T4
P=0
DO 501 I=1, M
501 P=P+G(I)*X(I)
PP=P
RETURN
C ENTRY TDSDT
C TEMP. TIMES THE PARTIAL OF
C ENTROPY WITH RESPECT TO TEMP.
C CV=CVO+( TDSDN(/)-TDSDN(D))*1000.
600 G1=F/( 2. DO*GM)
G2=( F*D2-2. DO*G1)/( 2. DO*GM)
G3=( F*D4-4. DO*G2)/( 2. DO*GM)
G4=( F*D6-6. DO*G3)/( 2. DO*GM)
G5=( F*D8-8. DO*G4)/( 2. DO*GM)
G6=( F*D10-10. DO*G5)/( 2. DO*GM)
X( 1)=0. DO
X( 2)=-D/( 4. DO*TS)

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X( 3)=0. DO
X( 4)=2. DO*D/T2
X( 5)=6. DO*D/T3
X( 6)=0. DO
X( 7)=0. DO
X( 8)=D2/T2
X( 9)=3. DO*D2/T3
X(10)=0. DO
X(11)=0. DO
X(12)=(2. DO*D3)/(3. DO*T2)
X(13)=0. DO
X(14)=(2. DO*D5)/(5. DO*T2)
X(15)=(6. DO*D5)/(5. DO*T3)
X(16)=D6/(3. DO*T2)
X(17)=(2. DO*D7)/(7. DO*T2)
X(18)=(6. DO*D7)/(7. DO*T3)
X(19)=(3. DO*D8)/(4. DO*T3)
X(20)=6. DO*G1/T3
X(21)=12. DO*G1/T4
X(22)=6. DO*G2/T3
X(23)=20. DO*G2/T5
X(24)=6. DO*G3/T3
X(25)=12. DO*G3/T4
X(26)=6. DO*G4/T3
X(27)=20. DO*G4/T5
X(28)=6. DO*G5/T3
X(29)=12. DO*G5/T4
X(30)=6. DO*G6/T3
X(31)=12. DO*G6/T4
X(32)=20. DO*G6/T5
P=0
DO 601 I=1, M
601 P=P+G(I)*X(I)
PP=P
END
DOUBLE PRECISION FUNCTION FINDTV(POBS)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C ITERATES VAPOR PRESS EQN TO FIND TEMP(K), FOR INPUT OF PRESS(MPA).
C GIVEN AN INPUT PRESSURE(MPA)
COMMON/ DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
DIMENSION G(32), VP(9)
T=VP(8)
DO 7 I=1, 10
P=VPN(T)
IF(DABS(P-POBS)-.000001DO*POBS)8, 8, 6
6 CONTINUE
CORR=(POBS-P)/DPDTV(T, P)
7 T=T+CORR
8 CONTINUE
FINDTV=T
END
DOUBLE PRECISION FUNCTION CV(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES CV(J/(MOL*K)). INPUT DENS(MOL/L) AND TEMP(K).
DATA R/8.31434DO/
DD=D
TT=T
CALL PROPS(CD, DD, TT, 6)
DD=0.0DO
CALL PROPS(CO, DD, TT, 6)
CV=CPI(TT, 1)+(CO-CD)*1000. DO
CV=CV-R
END
FUNCTION FINDD(P, T)

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```

IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
TT=T
IF(TT.GT.VP(8)*.99999D0)GO TO 100
IF(P.GT.VPN(TT))GO TO 101
DD=SATV(TT)
GO TO 102
100 PC=PCC
X=(1.1D0/(9.D0*PC))*P+.7D0/9.D0
DD=P/(R*T*X)
IF(P/PC.GT.2D0.AND.T/VP(8).LT.2.5D0)DD=DTP
GO TO 102
101 DD=SATL(TT)
102 CONTINUE
DO 10 I=1, 50
IF(DD.LE.0.0D0.OR.DD.GT.50D0)GO TO 11
CALL PROPS(PP, DD, TT, 1)
IF(PP.LE.0.0D0)GO TO 11
P2=PP
IF(DABS(P-P2)-1.D-7*P)20, 20, 1
1 CALL PROPS(PP, DD, TT, 2)
DP=PP
CORR=(P2-P)/DP
IF(DABS(CORR)-1.D-7*DD)20, 20, 10
10 DD=DD-CORR
11 CALL REGULA(P, DD, T)
20 FINDD=DD
END
SUBROUTINE REGULA(PI, DD, TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C ITERATES EQN OF STATE FOR DENSITY WHEN SUBPROG FINDD FAILS.
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
T=TT
P=PI
D2=0.0D0
IF(T.LT.TCC)GO TO 10
DO=DCC*TCC/T
GO TO 20
10 PP=VPN(T)
IF(P.GT.PP)GO TO 15
DO=SATV(T)
DO 11 I=1, 150
CALL PROPS(PO, DO, T, 1)
IF(PO.GE.P)GO TO 12
11 DO=DO+.0001D0*DO
GO TO 42
12 D1=DO
13 CALL PROPS(P1, D1, T, 1)
IF(P1.LT.P)GO TO 14
IF(D1.LE.1D0*PTP)GO TO 42
DO=D1
Z=(P1-P)/P
IF(Z.LT.1D0)Z=.1D0
IF(Z.GT.9D0)Z=.9D0
D1=D1-Z*D1
GO TO 13
14 CALL PROPS(PO, DO, T, 1)
DO 140 I=1, 50
D=D1
P3=P1
IF(DABS(P-P1).LT.00001D0*P)GO TO 40
P2=P-P1

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D1=D1+(D1-DO)*P2/(P1-PO)
IF(DABS(D-D1).LE..00001DO*D)GO TO 40
IF(DABS(P-P1).LT..005DO*P)D2=FINDM(P,T,D1)
IF(D2.GT.0.ODO.AND.D2.LT.50.DO)D1=D2
D2=0.ODO
CALL PROPS(P1,D1,T,1)
IF(PO.GT.P.AND.P1.GT.P)GO TO 120
IF(PO.LT.P.AND.P1.LT.P)GO TO 120
GO TO 140
120 PO=P3
DO=D
140 CONTINUE
GO TO 41
15 DO=SATL(T)
DO 16 I=1,10
CALL PROPS(PO,DO,T,1)
IF(PO.LE.P)GO TO 17
16 DO=DO-.0001DO*DO
GO TO 42
17 D1=DO
18 CALL PROPS(P1,D1,T,1)
IF(D1.GE.50.DO)GO TO 42
IF(P1.GT.P)GO TO 14
DO=D1
Z=(P-P1)/P
Z=Z*10.DO
IF(T/TCC.LT..6DO)Z=1.DO
IF(Z.LT.1.DO)Z=1.DO
IF(Z.GT.9.DO)Z=9.DO
D1=D1+.01DO*D1*Z
GO TO 18
20 CALL PROPS(PO,DO,T,1)
IF(P.LE.PO)GO TO 30
D1=DO
21 CALL PROPS(P1,D1,T,1)
IF(P1.GE.P)GO TO 14
IF(D1.GE.50.DO)GO TO 42
DO=D1
Z=(P-P1)/P
Z=Z*10.DO
IF(Z.LT.1DO)Z=1.DO
IF(Z.GT.9DO)Z=9.DO
D1=D1+.1DO*D1*Z
GO TO 21
30 D1=DO
31 CALL PROPS(P1,D1,T,1)
IF(P1.LE.P)GO TO 14
IF(D1.LE..1DO*PTP)GO TO 42
DO=D1
Z=(P1-P)/P
Z=Z*10.DO
IF(Z.LT.1DO)Z=1.DO
IF(Z.GT.9DO)Z=9.DO
D1=D1-.1DO*D1*Z
GO TO 31
40 DD=D1
RETURN
41 WRITE(*,101)P,T,D
102 FORMAT(' REGULA FAILED AT P=',E11.4,' AND T=',F7.2)
101 FORMAT(' DENSITY ITERATION FAILED AT P=',F7.2,' AND T=',F7.2,
1/' DENSITY RETURNED IS',E17.8)
RETURN
42 WRITE(*,102)P,T
END
DOUBLE PRECISION FUNCTION CP(D,T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)

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```

C  CALCULATES CP(J/(MOL*K)).  INPUT DENS(MOL/L),  TEMP(K).
    CVEE=CV(D, T)
    CALL PROPS(DPT, D, T, 3)
    CALL PROPS(DPD, D, T, 2)
    CP=CVEE+( T/( D**2)*( DPT**2) /DPD) *1000. DO
    END
    DOUBLE PRECISION FUNCTION DPDTVP(TT, P)
    IMPLICIT REAL*8(A-H)
    IMPLICIT REAL*8(O-Z)
    IMPLICIT INTEGER*4(I-N)
C  CALCULATES THE DERIVATIVE OF PRESSURE WITH RESPECT TO TEMPERATURE
C  AT SATURATION.  INPUT IS TEMP(K),  OUTPUT IS DPDT(MPA/K).
    COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
    DIMENSION G( 32), VP( 9)
    T=TT
    IF(TT.GT.VP( 8))GO TO 1
    X=( 1. DO-VP( 7) /T)/( 1. DO-VP( 7) /VP( 8))
    DXDT=( VP( 7) /T**2)/( 1. DO-VP( 7) /VP( 8))
    DPDT=VP( 1)*DXDT+2. DO*VP( 2)*X*DXDT+VP( 3)*3. DO*X**2*DXDT+VP( 5)*
1( ( 1. DO-X)**VP( 6))*DXDT+VP( 5)*X*( ( 1. DO-X)**(VP( 6)-1. DO))*VP( 6)
2*( -DXDT)
    DPDTVP=DPDT*P
    RETURN
1 DPDTVP=0. 0DO
    END
    DOUBLE PRECISION FUNCTION FINDM(P, T, DD)
    IMPLICIT REAL*8(A-H)
    IMPLICIT REAL*8(O-Z)
    IMPLICIT INTEGER*4(I-N)
C  SOLVES FOR DENSITY(MOL/L) BY ITERATION.  INPUT IS PRESSURE(MPA),
C  TEMPERATURE(K),  AND A STARTING VALUE OF DENSITY.  THIS FCN IS AN
C  ALTERNATIVE FOR  FUNCTION FINDD.
    TT=T
    DO 10 I=1, 50
    CALL PROPS(PP, DD, TT, 1)
    P2=PP
    IF(DABS ( P-P2)-1. D-7*P) 20, 20, 1
1 CALL PROPS(PP, DD, TT, 1)
    DP=PP
    CORR=( P2-P) /DP
    D=DD
    IF(DABS ( CORR)-1. D-7*D) 20, 20, 10
10 DD=DD-CORR
    FINDM=0
    RETURN
20 FINDM=DD
    END
    DOUBLE PRECISION FUNCTION ENTHAL(P, D, T)
    IMPLICIT REAL*8(A-H)
    IMPLICIT REAL*8(O-Z)
    IMPLICIT INTEGER*4(I-N)
    R= . 00831434DO
    DD=D
    TT=T
    CALL PROPS(SD, DD, TT, 4)
    CALL PROPS(UD, DD, TT, 5)
    DD=0. DO
    CALL PROPS(SO, DD, TT, 4)
    CALL PROPS(UO, DD, TT, 5)
    ENTHAL=T*( SD-SO)*1000. DO+( UD-UO)*1000. DO+CPI(T, 3)+( P/D-R*T)*1000. DO
    END
    DOUBLE PRECISION FUNCTION ENTROP(D, T)
    IMPLICIT REAL*8(A-H)
    IMPLICIT REAL*8(O-Z)
    IMPLICIT INTEGER*4(I-N)
C  CALCULATES ENTROPY(J/(MOL-K)),  FROM INPUT OF DENSITY(MOL/L)  AND TEMP(K).
    R= . 00831434DO
    PO= . 101325DO
    DD=D

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TT=T
CALL PROPS( SD, DD, TT, 4)
DD=0
CALL PROPS( SO, DD, TT, 4)
ENTROP=( SD-SO) *1000. DO-R*DLOG( D*R*T/PO) *1000. DO+CPI( T, 2)
END
DOUBLE PRECISION FUNCTION SATL(TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES DENSITY(MOL/L) OF SATURATED LIQUID. INPUT IS TEMP(K).
DIMENSION A(20)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
COMMON/SATC/A, DTPV, EG
COMMON/ISP/N, NW, NWW
IF(NW.EQ.1)GO TO 30
T=TT
K=14
KK=7
10 IF(T.GE.TCC*.99999D0)GO TO 20
ITT=TCC
IF(ITT+1-T.LT.1.DO)T=ITT
X=(T-TCC)/(TTP-TCC)
D=A(K)*DLOG(X)
DO 11 I=2, KK
K=K+1
MM=I
IF(MM.GE.5)MM=MM+1
11 D=D+A(K)*(1.DO-X**((MM-5)/3.DO))
IF(K.LT.14)GO TO 12
D=DCC+DEXP(D)*(DTP-DCC)
GO TO 13
12 D=DCC+DEXP(D)*(DTPV-DCC)
13 SATL=D
IF(ITT+1-TT.LT.1)SATL=D-(D-DCC)*(TT-T)
RETURN
20 SATL=DCC
RETURN
30 CALL SSATL(DL, TT)
SATL=DL
END
DOUBLE PRECISION FUNCTION SATV(TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES DENSITY(MOL/L) OF SATURATED VAPOUR. INPUT IS TEMP(K).
DIMENSION A(20)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
COMMON/SATC/A, DTPV1, EG
COMMON/ISP/N, NW, NWW
IF(NW.EQ.1)GO TO 30
K=1
KK=13
T=TT
10 IF(T.GE.TCC*.99999D0)GO TO 20
ITT=TCC
IF(ITT+1-T.LT.1.DO)T=ITT
X=(T-TCC)/(TTP-TCC)
D=A(K)*DLOG(X)
DO 11 I=2, KK
K=K+1
MM=I
IF(MM.GE.5)MM=MM+1
11 D=D+A(K)*(1.DO-X**((MM-5)/3.DO))
IF(K.LT.14)GO TO 12
D=DCC+DEXP(D)*(DTP-DCC)
GO TO 13

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12 D=DCC+DEXP(D)*(DTPV-DCC)
13 SATV=D
   IF(ITT+1-TT.LT.1)SATV=D-(D-DCC)*(TT-T)
   RETURN
20 SATV=DCC
   RETURN
30 CALL SSATV(DV,TT)
   SATV=DV
   END
   DOUBLE PRECISION FUNCTION SOUND(D,T)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*2(I-N)
C  CALCULATES SPEED OF SOUND(M/S). INPUT IS DENSITY(MOL/L) AND TEMP(K).
   COMMON/CRIT/W,EOK, RM, TC, DC, X, PC, SIG
   CALL PROPS(DP,D,T,2)
   SOUND=((CP(D,T)/CV(D,T))*DP*1000000.DO/W)**.5DO
   END
   DOUBLE PRECISION FUNCTION VISC(DD,T)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*4(I-N)
C  CALCULATES VISCOSITY(MICRO PA*S). INPUT IS DENSITY(MOL/L) AND TEMP(K).
   COMMON/CRIT/GMW,EOK, RM, TC, DC, X, PC, SIG
   COMMON/ISP/N,NW,NWW
   IF(NW.EQ.1)GO TO 10
   D=DD*GMW/1000.DO
   VISC=DILV(T)+FDCV(D,T)+EXCESV(D,T)
   RETURN
10 VISC=VISCE(DD,T)
   END
   DOUBLE PRECISION FUNCTION THERM(DD,T)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*4(I-N)
C  RETURNS THERMAL CONDUCTIVITY(W/(M*K)). INPUT IS DENSITY(MOL/L), TEMP(K).
   COMMON/HAN/CR,TCI
   COMMON/ISP/N,NW,NWW
   COMMON/CRIT/GMW,EOK, RM, TC, DC, X, PC, SIG
   IF(NW.EQ.1)GO TO 10
   D=DD*GMW/1000.DO
   CR=CRITC(D,T)
   THER=DILT(T)+FDCT(D,T)+EXCEST(D,T)+CR
   TCI=THER-CR
   THERM=THER
   RETURN
10 THERM=THERME(DD,T)
   END
   DOUBLE PRECISION FUNCTION EXCESV(D,T)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*4(I-N)
C  CALCULATES EXCESS VISCOSITY
   COMMON/DATA1/GV,GT,FV,FT,EV,ET
   DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
   R2=D**(.5DO)*((D-EV(8))/EV(8))
   R=D**(.1DO)
   X=EV(1)+EV(2)*R2+EV(3)*R+EV(4)*R2/(T*T)+EV(5)*R/T**(.5DO)+EV(6)/T
   +EV(7)*R2/T
   X1=EV(1)+EV(6)/T
   EXCESV=DEXP(X)-DEXP(X1)
   END
   DOUBLE PRECISION FUNCTION EXCEST(D,T)
   IMPLICIT REAL*8(A-H)
   IMPLICIT REAL*8(O-Z)
   IMPLICIT INTEGER*4(I-N)
   COMMON/DATA1/GV,GT,FV,FT,EV,ET
   DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
C  CALCULATES EXCESS THERMAL CONDUCTIVITY

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R2=D**(.5D0)*((D-ET(8))/ET(8))
R=D**(.1D0)
X=ET(1)+ET(2)*R2+ET(3)*R+ET(4)*R2/(T*T)+ET(5)*R/T**(.5D0)+ET(6)/T
1+ET(7)*R2/T
X1=ET(1)+ET(6)/T
EXCEST= DEXP(X) - DEXP(X1)
END
DOUBLE PRECISION FUNCTION FDCV(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C FIRST DENSITY CORRECTION FOR VISC.
COMMON/DATA1/GV, GT, FV, FT, EV, ET
COMMON/CRIT/ GMW, EOK, RM, TC, DC, X, PC, SIG
DIMENSION GV(9), GT(9), FV(4), FT(4), EV(8), ET(8)
FDCV=(FV(1)+FV(2)*(FV(3)-DLOG(T/FV(4)))**2)*D
END
DOUBLE PRECISION FUNCTION FDCT(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C FIRST DENSITY CORRECTION FOR THERMAL COND.
COMMON/DATA1/GV, GT, FV, FT, EV, ET
DIMENSION GV(9), GT(9), FV(4), FT(4), EV(8), ET(8)
COMMON/CRIT/ GMW, EOK, RM, TC, DC, X, PC, SIG
FDCT=(FT(1)+FT(2)*(FT(3)-DLOG(T/FT(4)))**2)*D
END
FUNCTION CRITC(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES CRITICAL ENHANCEMENT FOR THERM. COND.
C INPUT UNITS ARE G/CC, K, OUTPUT IS W/(M*K).
COMMON/CRIT/ GMW, EOK, RM, TC, DC, X, PC, SIG
COMMON/CHECK/DELD, DELT, DSTAR, TSTAR
COMMON/HJM/EPSI, CPCV, RRR, AKT
COMMON/ISP/N, NW, NWW
AV=6.0225D+23
BK=1.38054D-16
DELD=DABS(D-DC)/DC
DELT=DABS(T-TC)/TC
C CALCULATE DISTANCE PARAMETER
R=(RM**2.5D0)*(D**0.5D0)*(AV/GMW)**0.5D0
R=R*(EOK**0.5D0)*X/(T**0.5D0)
RRR=R
C GENERAL EQUATION
DX=D*1000.DO/GMW
C DX IN MOL/L, D IN G/CM3.
CALL PROPS(DPT, DX, T, 3)
C DPDT IN MPA/K.
DPT=DPT*1.0D+7
C DPDT NOW IN DYNES/(CM2*K)
CALL PROPS(DPD, DX, T, 2)
C DPDD IN L*MPA/MOL.
DPD=DPD*1.0D+7*1000./GMW
C DPDD NOW IN DYNE*CM/G.
IF(DPD.LT.0.0D0)DPD=1.DO
94 VIS=VISC(DX, T)*(1.0D-05)
C VISCOSITY NOW IS G/(CM*S).
IF(DELD.GT.0.25D0)GO TO 10
8 IF(DELT.GT.0.025D0)GO TO 10
9 COMPRES=SENG(D, T)
GO TO 12
10 COMPRES=1.DO/(D*DPD)**0.5D0
12 EX=BK*T**2*(DPT**2)*COMPRES
EXB=R*((BK*T)**0.5D0)*(D**0.5D0)*((AV/GMW)**0.5D0)
CRIT=EX/(EXB*6.DO*3.14159D0*VIS)
C THERMAL COND, CRIT, IS IN ERG/(CM*SEC*K)
C PUT IN DAMPING FACTOR

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BDD=(( D-DC) / DC) **4
BTT=(( T-TC) / TC) **2
BXX= -18.66D0*BTT - 4.25D0*BDD
IF( BXX.LT. -1. D+2) BXX= -1. D+2
FACT= DEXP( BXX )
C FACT=DEXP ( -18.66D0*BTT - 4.25D0*BDD)
DELC=CRIT*FACT
CRITC=DELC/100000. D0
C THERMAL COND, CRITC, IS NOW IN W/(M*K)
AKT=COMPRES*COMPRES
EPSI=R*R*BK*T*( AV*D/GMW) *AKT
EPSI=EPSI**0.5D0
C CALC CP-CV
CPCV=T*( DPT**2) *AKT/D
END
DOUBLE PRECISION FUNCTION SENG(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C SCALED EQUATION OF STATE FOR CRITICAL REGION
COMMON/CRIT/ GMW, EOK, RM, TC, DC, X , PC, SIG
COMMON/SEN/BETA, XO, DELTA, E1, E2, AGAM
COMMON/CHECK/DELD, DELT, DSTAR, TSTAR
DSTAR= D/DC
TSTAR=T/TC
BETO=1. D0/BETA
XX=DELT/DELD**BETO
AG=AGAM-1. D0
BET2= 2. 0D0*BETA
AGB=AG/BET2
DEL1=DELTA-1. D0
AGBB=( AG-BET2) /BET2
XXO=( XX+ XO) /XO
XXB=XXO**BET2
BRAK=1. D0 + E2*XXB
BRAK1=BRAK**AGB
H=E1*XXO*BRAK1
HPRIM=( E1/XO) *BRAK1 + ( AG/XO) *E1*E2*( XXB) *( BRAK**AGBB)
RCOM=( DELD**DEL1) *( DELTA*H - ( XX/BETA) *HPRIM )
RCOMP=1. D0/( RCOM*DSTAR**2)
RCM=RCOMP/( PC*1. 0D+7)
C RCM IN CM2/DYNE, PC IN MPA
RCM=RCM**0.5D0
SENG=RCM
END
DOUBLE PRECISION FUNCTION DILV(T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C DILUTE GAS VISCOSITY
COMMON/DATA1/GV, GT, FV, FT, EV, ET
DIMENSION GV( 9) , GT( 9) , FV( 4) , FT( 4) , EV( 8) , ET( 8)
SUM=0. 0D0
TF=T**( 1. D0/3. D0)
TFF=T**( -4. D0/3. D0)
DO 10 I=1, 9
TFF=TFF*TF
10 SUM=SUM+GV( I) *TFF
DILV=SUM
END
DOUBLE PRECISION FUNCTION DILT(T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C DILUTE GAS THERMAL CONDUCTIVITY.
COMMON/DATA1/GV, GT, FV, FT, EV, ET
DIMENSION GV( 9) , GT( 9) , FV( 4) , FT( 4) , EV( 8) , ET( 8)
TF=T**( 1. D0/3. D0)
TFF=T**( -4. D0/3. D0)

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SUM=0
DO 20 I=1, 9
TFF=TFF*TF
20 SUM=SUM+GT(I)*TFF
DILT=SUM
END
DOUBLE PRECISION FUNCTION FINDP(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
DD=D
TT=T
IF(TT.LT.TCC)GO TO 10
1 CALL PROPS(PP, DD, TT, 1)
FINDP=PP
RETURN
10 P=VPN(TT)
DV=FINDD(P-.0001D0, TT)
DL=FINDD(P+.0001D0, TT)
IF(DD.LE.DV.OR.DD.GE.DL)GO TO 1
WRITE(*,100)DV, DL, DD
CALL PROPS(PP, DV, TT, 1)
FINDP=PP
D=DV
100 FORMAT(' THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO A '
1/' DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION'
2/' THE DENSITY OF THE SATURATED VAPOR IS ',F6.4,' MOLES/LITER'
3/' THE DENSITY OF THE SATURATED LIQUID IS ',F8.4,' MOLES/LITER'
4/' AND THE INPUT DENSITY IS ',F8.4,' MOLES/LITER'
5/' SATURATED VAPOR IS ASSUMED' )
END
DOUBLE PRECISION FUNCTION FINDT(P, D)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C RETURNS TEMPERATURE(K), FROM THE 32-TERM MBWR EQN OF STATE.
C INPUT IS PRESSURE(MPA) AND DENSITY(MOL/L).
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
PP=P
DD=D
IF(P.GE.PCC)GO TO 1
TSAT=FINDTV(PP)
DV=FINDD(PP-.00001D0, TSAT)
DL=FINDD(PP+.0001D0, TSAT)
IF(DD.GT.DV.AND.DD.LT.DL)GO TO 30
TT=TSAT
GO TO 2
1 TT=TCC
2 DO 10 I=1,10
CALL PROPS(P2, DD, TT, 1)
IF(DABS(PP-P2)-1, D-7*PP)20, 20, 11
11 CALL PROPS(DP, DD, TT, 3)
CORR=(P2-PP)/DP
IF(DABS(CORR)-1, D-5)20, 20, 10
10 TT=TT-CORR
20 FINDT=TT
RETURN
30 FINDT=TSAT
D=DV
WRITE(*,100)DV, DL, DD
100 FORMAT(' THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO'
1/' A DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION'
2/' DENSITY OF THE SATURATED VAPOR IS',F8.4,' MOLES/LITER'
3/' DENSITY OF THE SATURATED LIQUID IS',F8.4,' MOLES/LITER'
4/' INPUT DENSITY IS',F8.4,' MOLES/LITER'
5/' SATURATED VAPOR CONDITIONS ARE ASSUMED' )

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END
DOUBLE PRECISION FUNCTION FDIEL(P, D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C DIELECTRIC CONSTANT. INPUT P(MPA), D(MOL/L) AND T(K).
COMMON/DIEL/BX(6), PX(6)
COMMON/ISP/N, NW, NWW
IF(NW.EQ.1)GO TO 1
CM= BX(1)+ BX(2)*D+ BX(3)*D**2+ BX(4)*D**3+ BX(5)*P+ BX(6)*T
FDIEL=(1. DO+2. DO*D*CM)/(1. DO-D*CM)
RETURN
1 FDIEL=SDIEL(P, D, T)
END
DOUBLE PRECISION FUNCTION CPI(T, K)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES SPECIFIC HEAT, ENTROPY, AND ENTHALPY FOR THE IDEAL GAS.
C OUTPUT IS IN J/(MOL*K), FOR CP AND S, AND J/MOL FOR H.
C HYDROGEN, (N=1), IS TREATED AS A SPECIAL CASE AS THE COEFF. FOR
C CP ARE IN THREE TEMPERATURE RANGES. T < 40 K, 40 < T < 140 K,
C AND T > 140 K.
COMMON/CPID/G(11), GH(11), GL(11)
COMMON/ISP/N, NW, NWW
COMMON/H2/FHI, FSI
IF(N.NE.1)GO TO 15
TX1=140. DO
TX2=40. DO
DO 110 J=1, 11
110 G(J)=GH(J)
IF(T.LT.140. DO)GO TO 130
GO TO 180
130 CALL SHI(TX1)
G(10)=G(10)+FHI
G(11)=G(11)+FSI
DO 140 J=1, 8
140 G(J)=GL(J)
CALL SHI(TX1)
G(10)=G(10)-FHI
G(11)=G(11)-FSI
IF(T.LT.40. DO)GO TO 160
GO TO 180
160 CALL SHI(TX2)
G(10)=G(10)+FHI
G(11)=G(11)+FSI
DO 170 J=1, 8
170 G(J)=0. 0DO
G(4)=2. 5000315DO
CALL SHI(TX2)
G(10)=G(10)-FHI
G(11)=G(11)-FSI
180 CONTINUE
15 U=G(9)/T
EU=DEXP(U)
TS=1. DO/T**4
GO TO (20, 40, 55), K
20 CPI=G(8)*U*U*EU/(EU-1. DO)**2
DO 25 I=1, 7
TS=TS*T
25 CPI=CPI+G(I)*TS
CPI=CPI*8. 31434DO
RETURN
40 CPI=G(8)*(U/(EU-1. DO)-DLOG(1. DO-1. DO/EU))
1-G(1)*TS*T/3. DO-G(2)*TS*T*T/2. DO-G(3)/T+G(4)*DLOG(T)+G(5)*T
2+G(6)*T*T/2. DO+G(7)*T**3/3. DO
CPI=CPI*8. 31434DO+G(11)
RETURN
55 CPI=G(8)*U*T/(EU-1. DO)-G(1)/(2. DO*T*T)-G(2)/T+G(3)*DLOG(T)+G(4)*T

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1+G(5)*T*T/2.DO+G(6)*T**3/3.DO+G(7)*T**4/4.DO
CPI=CPI*8.31434DO+G(10)
END
SUBROUTINE SHI(T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
COMMON/CPID/G(11),GH(11),GL(11)
COMMON/H2/FHI,FSI
1 U=G(9)/T
EU=DEXP(U)
GHI=G(8)*U*T/(EU-1.DO)-G(1)/(2.DO*T*T)-G(2)/T+G(3)*DLOG(T)+G(4)*T
A +G(5)*T*T/2.DO+G(6)*T**3/3.DO+G(7)*T**4/4.DO
FHI=GHI*8.31434DO
U=G(9)/T
EU=DEXP(U)
TS=1.DO/T**4
GHS=G(8)*(U/(EU-1.DO)-DLOG(1.DO-1.DO/EU))-
A G(1)*TS*T/3.DO-G(2)*TS*T*T/2.DO-G(3)/T+G(4)*DLOG(T)+G(5)*T+
B G(6)*T*T/2.DO+G(7)*T**3/3.DO
FSI=GHS*8.31434DO
END
DOUBLE PRECISION FUNCTION PMELT(T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C COMPUTES MELTING PRESSURE(MPA) FOR INPUT TEMPERATURE(K).
COMMON/DIEL/BX(6),PX(6)
COMMON/ISP/N,NW,NWW
IF(N.EQ.1)GO TO 20
10 PMELT=PX(1)+PX(2)*T**PX(3)
RETURN
20 IF(T.LT.22.DO)GO TO 10
30 PMELT=PX(4)+PX(5)*T**PX(6)
END
FUNCTION TMELT(P)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C COMPUTES MELTING TEMPERATURE(K) FOR INPUT PRESSURE(MPA)
COMMON/DIEL/BX(6),PX(6)
COMMON/ISP/N,NW,NWW
IF(N.EQ.1)GO TO 20
10 TMELT=((P-PX(1))/PX(2))**(1.DO/PX(3))
RETURN
20 IF(P.LT.31.64DO)GO TO 10
30 TMELT=((P-PX(4))/PX(5))**(1.DO/PX(6))
END
DOUBLE PRECISION FUNCTION VPN(TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES VAPOR PRESSURE(MPA), INPUT IS TEMP(K).
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
T=TT
X=(1.DO-VP(7)/T)/(1.DO-VP(7)/VP(8))
VPN=VP(9)*DEXP(VP(1)*X+VP(2)*X*X+VP(3)*X**3+VP(4)*X**4+VP(5)*X*
1(1.DO-X)**VP(6))
END
SUBROUTINE SSATL(D1,T1)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C SATURATED LIQUID AND VAPOR DENSITIES.
C LIQUID DENSITIES ARE FROM R.D. MCCARTY.
C VAPOR DENSITIES ARE FROM R.D. GOODWIN.
DIMENSION G(32),VP(9),A(20)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC

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COMMON/SATC/ A, DTPV, EG
IF(T1 .GE. TCC) GO TO 20
X1=(T1-TCC)/(TTP-TCC)
Y1=A(7)*DLOG(X1)+ A(8)*(1.DO-1.DO/X1)+
A A(9)*(1.DO-X1**(-2.DO/3.DO))+ A(10)*(1.DO-X1**(-1.DO/3.DO))+
B A(11)*(1.DO-X1**(1.DO/3.DO))+ A(12)*(1.DO-X1**(2.DO/3.DO))+
C A(13)*(1.DO-X1)
D1=DCC+ (DTP-DCC)*DEXP(Y1)
RETURN
20 D1=DCC
END
SUBROUTINE SSATV(D1, T1)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9), A(20)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
COMMON/SATC/ A, DTPV, EG
TT=T1
IF(TT .GE. TCC) GO TO 20
YN=DLOG(DCC/DTPV)
X1=(TCC-TT)/(TCC-TTP)
Z1=TCC*X1/TT
Y1= A(1)*Z1+ A(2)*X1**EG+ A(3)*X1+ A(4)*X1**(4.DO/3.DO)
A +A(5)*X1**(5.DO/3.DO)+ A(6)*X1*X1
D1=DCC*DEXP(-YN*Y1)
RETURN
20 D1=DCC
END
DOUBLE PRECISION FUNCTION SDIEL(P, D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C DIELECTRIC CONSTANT. INPUT P(MPA), D(MOL/L) AND T(K).
COMMON/DIEL/BX(6), PX(6)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
DIMENSION G(32), VP(9)
CM= BX(1)+ BX(2)*D+ BX(3)*D**2+ BX(4)*DLOG(1.DO+TCC/T)+
A BX(5)*P
SDIEL=(1.DO+2.DO*D*CM)/(1.DO-D*CM)
END
DOUBLE PRECISION FUNCTION THERME(DD, TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C THERMAL CONDUCTIVITY W/(M*K).
DIMENSION GV(9), GT(9), FV(4), FT(4), EV(8), ET(8)
COMMON/DATA1/GV, GT, FV, FT, EV, ET
TI = 1.DO/TT
TRM0= ET(1)+ ET(2)*TI+ ET(3)*TI*TI
TRM1= ET(4)+ ET(5)*TI+ ET(6)*TI*TI
TRM2= ET(7)+ ET(8)*TI
BACKG = TCONDO(TT)+(TRM0+TRM1*DD)*DD/(1.DO+TRM2*DD)
THERME = BACKG + TCRIT(DD, TT)
END
DOUBLE PRECISION FUNCTION TCONDO(TT)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C THERMAL CONDUCTIVITY (W/(M*K)), TT(K).
C LOW DENSITY LIMIT.
DIMENSION GV(9), GT(9), FV(4), FT(4), EV(8), ET(8)
COMMON/DATA1/GV, GT, FV, FT, EV, ET
COMMON/B/ GMW, EOK, SIG
C R IS GAS CONSTANT IN J/(MOL*K).
R= 8.31434D0
CON1= 15.DO*R/4.DO
CON2= 2.DO*CON1/3.DO
CPO= CPI(TT, 1)

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C          CPO IS SPECIFIC HEAT IN J/(MOL*K),
C          VSCTYO IS VISCOSITY IN MICRO-PA*S.
ETAO      = VSCTYO(TT, 0. 0DO) / 1000000. DO
TS        = TT / EOK
YC        = (GT(1) + GT(2) / TS) * (CPO - CON2)
TCONDO    = 1000. DO * ETAO * (CON1 + YC) / GMW
C          FACTOR OF 1000 CONVERTS G/MOL TO KG/MOL.
END
DOUBLE PRECISION FUNCTION TCRIT(DD, TT)
C          CRITICAL ENHANCEMENT W/(M*K), INPUT MOL/L AND K.
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
COMMON/A/ E1, G1, B1, DE, BK, D1, XZ, ZZ, X1, X2, X3, X4
COMMON/B/ GMW, EOK, SIG
PC1=PCC*1. D+6
DELD=DABS(DD-DCC) / DCC
DELT=DABS(TT-TCC) / TCC
FACT= X1*DELT**4. DO + X2*DELD**4. DO
IF(FACT .GT. 100. DO) FACT=100. DO
DFACT=DEXP(-FACT)
RSTAR=DD/DCC
C          CONVERTING MICRO-PA*S TO PA*S.
VIS= 1. 0D-06*VISCE(DD, TT)
CALL PROPS(DPD, DD, TT, 2)
C          CONVERTING M-PA TO PA.
DPD=DPD*1. D+6
CALL PROPS(DPT, DD, TT, 3)
DPT=DPT*1. D+6
IF(DELD .NE. 0. 0DO) GO TO 20
C          CRITICAL ISOCHORE.
10 BGAM=XZ**G1/D1*((1. DO+E1)/E1)**((G1-1. DO)/(2. DO*B1))
CHISTAR=BGAM*(DELT)**(-G1)
GO TO 50
20 IF(DELD .LE. 0. 25DO. AND. DELT .LT. 0. 03DO) GO TO 30
GO TO 40
C          CRITICAL REGION
30 XX=DELT/DELD**(1. DO/B1)
Y=(XX+XZ) / XZ
TOP=DELD**(-G1/B1)*((1. DO+E1)/(1. DO+E1*Y**(2. DO*B1)))**((G1-1. DO
1) / (2. DO*B1))
DIV=D1*(DE+(Y-1. DO)*(DE-1. DO/B1+E1*Y**(2. DO*B1)))/(1. DO+E1*Y**(2.
1DO*B1))
CHISTAR=TOP/DIV
GO TO 50
C          NON CRITICAL REGION
40 CHISTAR=PC1*DD/(DCC**2*DPD)
50 CHI=CHISTAR**X3
UPPER=X4*BK/PC1*(TT*DPT/RSTAR)**2*CHI*DFACT
SSENG=UPPER/(ZZ*6. DO*3. 14159DO*VIS)
TCRIT=SSENG
END
DOUBLE PRECISION FUNCTION VISCE(DS, TS)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
DIMENSION GV(9), GT(9), FV(4), FT(4), EV(8), ET(8)
COMMON/DATA1/GV, GT, FV, FT, EV, ET
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
ETAO= VSCTYO(TS, DS)
TRM1= EV(3) + EV(4)*TS**(-3. DO/2. DO)
TRM2= EV(5) + EV(6)/TS + EV(7)*TS**(-2. DO)
TRMX= DEXP(EV(1) + EV(2)/TS)
R1 = DS**0. 1DO
R2 = ((DS-DCC) / DCC) * DS**0. 5DO
VISCE = TRMX*(DEXP(TRM1*R1 + TRM2*R2) - 1. DO) + ETAO

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END
DOUBLE PRECISION FUNCTION VSCTYO(TX,DX)
C      VISCOSITY THROUGH LINEAR TERM IN DENSITY IN MICRO-PA*S.
C      DENSITY IS IN MOL/L, AND TEMP IN K.
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION CO(9)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/B/ GMW,EOK,SIG
DATA CO/-3.0328138281D+00, 1.6918880086D+01,-3.7189364917D+01,
*      4.1288861858D+01,-2.4615921140D+01, 8.9488430959D+00,
*      -1.8739245042D+00, 2.0966101390D-01,-9.6570437074D-03/
TS = TX / EOK
TY = 1. DO / TS
TZ= TS**(.1 DO/3. DO)
EO=0. DO
DO 200 J=1,9
EO=EO+CO(J)*TY
200 TY=TY*TZ
OM22 = 1. DO / EO
C      ETA0 IS VISCOSITY AT THE LOW DENSITY LIMIT.
ETA0 = 2.6693DO *DSQRT(GMW * TX) / (SIG*SIG * OM22)
ETA1= FV(1) + FV(2)*(FV(3)-DLOG(TX/FV(4)))**2
VSCTYO=(ETA0+ETA1*DX)
END

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. 329700E+01 . 183000E+00 . 355000E+00 . 435200E+01 . 227000E+01 . 287000E+00 . 11
9000E+01
. 399480E+02 . 152800E+03 . 366900E-07 . 150725E+03 . 533000E+00 . 171240E+01 . 486190
E+01
-. 6569731294000D-04
. 1822957801000D-01
-. 3649470141000D+00
. 1232012107000D+02
-. 8613578274000D+03
. 7978579691000D-05
-. 2911489110000D-02
. 7581821758000D+00
. 8780488169000D+03
. 1423145989000D-07
. 1674146131000D-03
-. 3200447909000D-01
. 2561766372000D-05
-. 5475934941000D-04
-. 4505032058000D-01
. 2013254653000D-05
-. 1678941273000D-07
. 4207329271000D-04
-. 5444212996000D-06
-. 8004855011000D+03
-. 1319304201000D+05
-. 4954923930000D+01
. 8092132177000D+04
-. 9870104061000D-02
. 2020441562000D+00
-. 1637417205000D-04
-. 7038944136000D-01
-. 1154324539000D-07
. 1555990117000D-05
-. 1492178536000D-10
-. 1001356071000D-08
. 2933963216000D-07
-. 2702629237770D+02
. 1310402418660D+00
-. 2674864381280D+01
. 3001768044060D+02
-. 8758991493260D+02
-. 4082674364560D+02
. 1042680664510D+03
-. 6712785553790D+02
. 1510029357010D+02
-. 3312435366370D+02
. 6331462125810D+02
-. 4271497068990D+02
. 1005999000300D+02
. 1376820849000D+02
-. 6646303631910D-01
. 1333687827300D+01
-. 1443714632440D+02
. 6019384720000D+02
-. 2308884638870D+02
. 4653183588870D+01
0. 0. 0.
0. 0. 0.
0. 0. 0.
. 2500000000000D+01 0. 0.
0. 0. 0.
0. 0. 0.
0. 0. 0.
0. 0. 0.
0. 0. 0.
. 2500000000000D+01 0. 0.

- . 8011774999613D+00	0.	0.
. 3630410930969D+02	0.	0.
. 3415111551900D+01	. 6114547278700D+04	. 6277770374200D+01
. 1191081251900D+01	- . 1039439031200D+05	- . 9609637663700D+01
- . 3407632334000D+00	. 6759461461900D+04	. 5888754919100D+01
0.	- . 2253650938000D+04	- . 1892092632000D+01
. 8955585525100D+00	. 4259395013800D+03	. 3488657143700D+00
. 1500000000000D+01	- . 4725267109300D+02	- . 3801678619300D-01
. 8380000000000D+02	. 3179527542500D+01	. 2520728316700D-02
. 1508600000000D+03	- . 1162908378000D+00	- . 9109874447800D-04
. 6890606625000D-01	. 1804301059200D-02	. 1399084294200D-05
- . 1231357908600D+02	- . 3332702733200D+02	
. 2069468571200D+00	0.	
. 1602914512200D+02	. 3069485997100D+02	
. 1171746135100D+04	0.	
- . 5699589878000D+03	. 2295655167400D+04	
. 4013607193300D+02	- . 3555941584800D+03	
. 3987012240300D+02	0.	
. 5370000000000D+00	. 1000000000000D+01	
. 1465365243300D+00	. 2414210327000D-01	
- . 7748742496500D-01	. 7569623425500D-02	
. 1400000000000D+01	. 1000000000000D+01	
. 1528000000000D+03	. 1528000000000D+03	
. 3540027619188D+02	. 1029227022329D+00	
. 2981500000000D+03	. 1547335000000D+03	. 6196500000000D+04
. 00831434-	. 55542372E-02	400.00 83.80 100.00 13.4100 4.9058
0.	- . 2105621650000D+03	
0.	. 1777605270000D+00	
0.	. 1598178680000D+01	
0.	0.	
0.	0.	
0.	0.	

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0.	0.	0.	0.	0.	0.	0.
. 201594E+010.	0.	0.	0.	0.	. 171240E+010.	0.
. 4675528393416D-04						
. 4289274251454D-02						
- . 5164085596504D-01						
. 2961790279801D+00						
- . 3027194968412D+01						
. 1908100320379D-05						
- . 1339776859288D-03						
. 3056473115421D-01						
. 5161197159532D+01						
. 1999981550224D-07						
. 2896367059356D-04						
- . 2257803939041D-02						
- . 2287392761826D-06						
. 2446261478645D-05						
- . 1718181601119D-03						
- . 5465142603459D-07						
. 4051941401315D-09						
. 1157595123961D-06						
- . 1269162728389D-08						
- . 4983023605519D+01						
- . 1606676092098D+02						
- . 1926799185310D-01						
. 9319894638928D+00						
- . 3222596554434D-04						
. 1206839307669D-03						
- . 3841588197470D-07						
- . 4036157453608D-05						
- . 1250868123513D-10						
. 1976107321888D-09						
- . 2411883474011D-13						
- . 4127551498251D-13						

N2. COF

. 354000E+01 . 164000E+00 . 355000E+00 . 435200E+01 . 217000E+01 . 287000E+00 . 119000
E+01
. 280160E+02 . 118000E+03 . 393300E-07 . 126240E+03 . 313900E+00 . 167108E+01 . 344300
E+01
. 1380297474657D-03
. 1084506501349D-01
-. 2471324064362D+00
. 3455257980807D+01
-. 4279707690666D+03
. 1064911566998D-04
-. 1140867079735D-02
. 1444902497287D-04
. 1871457567553D+04
. 8218876886831D-08
. 2360990493348D-03
-. 5144803081201D-01
. 4914545013668D-05
-. 1151627162399D-03
-. 7168037246650D-01
. 7616667619500D-05
-. 1130930066213D-06
. 3736831166831D-04
-. 2039851507581D-06
-. 1719662008990D+04
-. 1213055199748D+05
-. 9881399141428D+01
. 5619886893511D+04
-. 1823043964118D-01
-. 2599826498477D+00
-. 4191893423157D-04
-. 2596406670530D-01
-. 1258683201921D-07
. 1049286599400D-05
-. 5458369305152D-10
-. 7674511670597D-09
. 5931232870994D-08
-. 1584534655070D+02
. 4191369114230D-01
-. 1019653716600D+01
. 1347637437990D+02
-. 1099303990870D+03
. 9255188354970D+02
-. 9562338313200D+02
. 1001043667100D+03
-. 7018579373980D+02
. 9000769986470D+01
. 2869811203470D+02
-. 2167676017800D+02
. 4965582264710D+01
. 2183079284770D+02
-. 1264933098070D+00
. 2415441886330D+01
-. 2452568717940D+02
. 9359252071240D+02
-. 3609382516320D+02
. 7574532719890D+01
-. 7352104011573D+03 0.
. 3422399804120D+02 0.
-. 5576482845676D+00 0.
. 3504042283088D+01 0.
-. 1733901850810D-04 0.
. 1746508497665D-07 0.
-. 3568920335443D-11 0.
. 1005387228088D+01 0.
. 3353406100000D+04 0.
. 1491235932073D+02 0.

. 2553079069000D+02 0. 0.
 . 5111319209400D+01 -. 1822424000000D+05 -. 2002957397200D+02
 . 6482667539000D+00 . 1991532737400D+05 . 4976574668400D+01
 -. 1510873091600D+00 -. 9154232449400D+04 . 8018895937800D+01
 0. . 2325548405900D+04 -. 5502271688800D+01
 . 7402849334200D+00 -. 3630721422800D+03 . 1536373896500D+01
 . 1500000000000D+01 . 3645750681100D+02 -. 2297473725700D+00
 . 6315000000000D+02 -. 2226188081700D+01 . 1936054734600D-01
 . 1262600000000D+03 . 7805390489500D-01 -. 8567738576800D-03
 . 1246297500000D-01 -. 1189402910400D-02 . 1556467093500D-04
 -. 1212815412900D+02 -. 3861329162700D+02
 . 5715609213900D+00 0.
 . 1609461114800D+02 . 3720174333300D+02
 . 3695408615800D+04 0.
 -. 8088980118000D+03 -. 3901350907900D+02
 . 6846443564000D+02 -. 3182610948500D+02
 -. 2124113591200D+01 0.
 . 3150000000000D+00 . 1000000000000D+01
 -. 1121773962300D+00 . 5387566663700D-01
 . 3291231724400D-01 . 6102791110400D-02
 . 1400000000000D+01 . 1200000000000D+01
 . 1180000000000D+03 . 1180000000000D+03
 . 3097717741477D+02 . 2428220857100D-01
 0. 0. 0.
 . 00831411-. 56000000E-02 1900. 00 63. 15 1000. 00 11. 2100 3. 3991
 . 4399383600000D-02 -. 1600002810000D+03
 . 1893209600000D-05 . 9385755020000D-01
 0. . 1795000000000D+01
 -. 3145017800000D-08 0.
 -. 2859270300000D-06 0.
 -. 4466603400000D-07 0.

02. COF

. 343700E+01 . 183000E+00 . 355000E+00 . 435200E+01 . 221000E+01 . 287000E+00 . 119000
 E+01
 . 319988E+02 . 113000E+03 . 388960E-07 . 154575E+03 . 436200E+00 . 221064E+01 . 504290
 E+01
 -. 4365859650000D-04
 . 2005820677000D-01
 -. 4197909916000D+00
 . 1878215317000D+02
 -. 1287473398000D+04
 . 1556745888000D-05
 . 1343639359000D-03
 -. 2228415518000D+00
 . 4767792275000D+03
 . 4790846641000D-07
 . 2462611107000D-03
 -. 1921891680000D-01
 -. 6978320847000D-06
 -. 6214145909000D-04
 -. 1860852567000D-01
 . 2609791417000D-05
 -. 2447611408000D-07
 . 1457743352000D-04
 -. 1726492873000D-06
 -. 2384892520000D+03
 -. 2301807796000D+05
 -. 2790303526000D+01
 . 9400577575000D+04
 -. 4169449637000D-02
 . 2008497853000D+00
 -. 1256076520000D-04
 -. 6406362964000D-01
 -. 2475580168000D-08
 . 1346309703000D-05
 -. 1161502470000D-10

-. 1034699798000D-08
 . 2365936964000D-07
 . 5813947530760D+02
 -. 4902411961330D-01
 . 1683288932520D+01
 -. 3251612233980D+02
 . 5503009898720D+03
 -. 5109685061150D+03
 . 3150915590490D+03
 -. 2325666592580D+02
 -. 4884254793590D+02
 -. 1506242175230D+03
 . 2804416038510D+03
 -. 1766938968610D+03
 . 4032477474490D+02
 . 2521986883650D+01
 -. 1360983164720D-01
 . 2823161594030D+00
 -. 2866459053410D+01
 . 6170242122840D+01
 -. 8102207954620D+00
 -. 2796010689690D+00
 -. 4981998537119D+04 0.
 . 2302477799952D+03 0.
 -. 3455653235107D+01 0.
 . 3521876773671D+01 0.
 -. 4354202160244D-04 0.
 . 1346353450132D-07 0.
 . 1620598259591D-10 0.
 . 1031468515726D+01 0.
 . 2239181050000D+04 0.
 . 1238529263264D+03 0.
 . 3816718907989D+02 0.
 . 7568956000000D+01 -. 9707637859300D+04 -. 2039505219300D+03
 . 5004836000000D+01 . 8280125420100D+04 . 2408814170900D+03
 -. 2137460000000D+01 -. 2466875880300D+04 -. 1201417518300D+03
 0. . 2132436024300D+03 . 3295494919000D+02
 . 3454481000000D+01 . 3785104952200D+02 -. 5424423959800D+01
 . 1514000000000D+01 -. 1048721609000D+02 . 5473486554000D+00
 . 5435900000000D+02 . 1113444130400D+01 -. 3285482153900D-01
 . 1545810000000D+03 -. 5367609375700D-01 . 1075357210300D-02
 . 1479953000000D-03 . 1027937964100D-02 -. 1461098682000D-04
 -. 1445497211000D+02 -. 2152074113700D+02
 -. 3142172899400D+00 0.
 . 1820116146800D+02 . 1679950426100D+02
 . 2739042952500D+03 0.
 -. 2749895694800D+04 -. 2994487872100D+04
 . 2434068966700D+03 . 4735050878800D+03
 . 1191150410400D+03 0.
 . 4350000000000D+00 . 1000000000000D+01
 . 4352651515300D+00 . 3060000000000D-01
 -. 2036126387800D+00 . 2785000000000D-01
 . 1400000000000D+01 . 1120000000000D+01
 . 1000000000000D+03 . 1000000000000D+03
 . 4081997364372D+02 . 3318894767078D-03
 0. 0. 0.
 . 00831411-. 56000000E-02 1500. 00 54. 36 120. 00 13. 6300 5. 0430
 . 3960810000000D-02 -. 2672268540000D+03
 . 2970000000000D-06 . 2276063480000D+00
 -. 4130000000000D-07 . 1769000000000D+01
 0.
 0.
 -. 2140000000000D-07 0.

NF3. COF

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. 710190E+020.			. 234000E+03	. 792000E+01	. 171240E+010.
. 1774353868000D-02					
- . 5409379418000D-01					
. 3976634466000D+00					
- . 5209476694000D+02					
- . 3286322888000D+04					
- . 5990517411000D-04					
. 9217525601000D-01					
- . 4848977075000D+02					
- . 4235892691000D+06					
- . 9824248063000D-06					
. 5432235989000D-02					
- . 1462388500000D+01					
- . 3366180440000D-03					
. 2801374599000D-01					
. 8435288597000D+00					
- . 1324421452000D-02					
. 1875604377000D-04					
. 2959643991000D-01					
- . 7009976870000D-03					
. 4365820912000D+06					
- . 1111397536000D+07					
. 2411866612000D+04					
. 3179136276000D+06					
. 6166849090000D+01					
. 4260854720000D+01					
. 1090598789000D-01					
- . 3340951059000D+01					
. 8597429644000D-05					
. 1240544214000D-03					
. 1286224248000D-07					
- . 8941104276000D-07					
. 3353054595000D-05					
. 1312851816360D+03					
- . 2269985555360D+01					
. 3847083894980D+02					
- . 3098272682390D+03					
- . 6353485266350D+03					
. 9269790283570D+03					
. 3714980112590D+03					
- . 1822916544700D+04					
. 1055924038530D+04					
. 1216738953440D+04					
- . 2072089283230D+04					
. 1134633947100D+04					
- . 2266421371400D+03					
. 1050872951730D+01					
- . 1316864742460D-02					
. 3901413319000D-01					
- . 5877965979750D+00					
. 4009005210170D+01					
- . 2033853869770D+01					
. 4004343644240D+00					
. 7427518245951D+06	0.				0.
- . 4389825372134D+05	0.				0.
. 1012629224351D+04	0.				0.
- . 7140693612211D+01	0.				0.
. 5481339146452D-01	0.				0.
- . 7677196006769D-04	0.				0.
. 4203630864340D-07	0.				0.
- . 6328752997967D+00	0.				0.
. 3000000000000D+04	0.				0.
- . 3493688822979D+05	0.				0.
. 5145589888845D+03	0.				0.

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.1159387949200D+02 0. 0.
.9654850231200D+01 0. 0.
-.2872773281500D+01 0. 0.
-.1379770070000D+01 0. 0.
.7311244167300D+01 0. 0.
.1500000000000D+01 0. 0.
.6636000000000D+02 0. 0.
.2340000000000D+03 0. 0.
.1853782700000D-06 0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
.2632000000000D+02 .3361200000000D-08
0. 0.
0.00831441-.56000000E-02 500.00 66.36 50.00 7.9200 4.4607
0. -.1909399710000D+03
0. .8137501940000D-01
0. .1850000000000D+01
0. 0.
0. 0.
0. 0.

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METH. COF

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.9898937956000D-05
.2199608275000D-01
-.5322788000000D+00
.2021657962000D+02
-.2234398926000D+04
.1067940280000D-04
.1457922469000D-03
-.9265816666000D+00
.2915364732000D+03
.2313546209000D-06
.1387214274000D-03
.4780467451000D-02
.1176103833000D-04
-.1982096730000D-03
-.2512887756000D-01
.9748899826000D-05
-.1202192137000D-06
.4128353939000D-04
-.7215842918000D-06
.5081738255000D+03
-.9198903192000D+05
-.2732264677000D+01
.7499024351000D+05
.1114060908000D-02
.1083955159000D+01
-.4490960312000D-04
-.1380337847000D+01
-.2371902232000D-07
.3761652197000D-04
-.2375166954000D-09
-.1237640790000D-07
.6766926453000D-06

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. 4436658614060D+00
. 6172912655850D+00
-. 1714092038860D+01
. 2664891756670D+01
-. 2006798722650D+01
. 5054513976350D+00
-. 1255990487150D+01
. 1374552965910D-02
-. 6643534109710D-01
. 1277137136070D+01
-. 8438642963590D+01
. 3101115288610D+01
-. 5753632727380D+00
0.
0.
0.
0.
0.
0.
0.
-. 1804475050700D+07 0.
. 7742666639300D+05 0.
-. 1324165875400D+04 0.
. 1543814959500D+02 0.
-. 5147900525700D-01 0.
. 1080917219600D-03 0.
-. 6550178343700D-07 0.
-. 6749005617100D+01 0.
. 3000000000000D+04 0.
. 4869146318103D+05 0.
-. 4861658943347D+03 0.
. 4779399530000D+01 0.
. 1757393941000D+01 0.
-. 5665073910000D+00 0.
0. 0.
. 1326326855000D+01 0.
. 1500000000000D+01 0.
. 9068000000000D+02 0.
. 1905550000000D+03 0.
. 1174300000000D-01 0.
-. 1620427429000D+02 . 2325800819000D-02
. 4270589027000D+03 -. 2477927999000D+00
. 1402596278000D+02 . 3880593713000D+02
-. 3916837745000D+04 -. 1579519146000D-06
-. 3477099090000D-01 . 3717991328000D-02
. 2136542674000D+02 -. 9616989434000D+00
. 1436802482000D+04 -. 3017352774000D-01
0. . 4298153386000D+00
. 1696985927100D+00 0.
-. 1333723450800D-01 0.
. 1400000000000D+01 0.
. 1680000000000D+03 0.
. 2814700000000D+02 . 1567900000000D-01
0. 0.
. 00831434-. 97066175E-02 600. 00 90. 68 200. 00 10. 1500 4. 5980
. 6570101800000D-02 -. 1909269420000D+03
. 6383501300000D-05 . 4565597600000D-01
-. 1871872800000D-06 . 1850000000000D+01
-. 5313482000000D-04 0.
-. 9471173500000D-06 0.
0. 0.
. 287000E+00 . 119000E+01 . 355000E+00 . 435200E+01 . 138054E-22 . 217000E+01
. 164000E+00 . 651271E-09 . 374237E+02 . 316714E+01 . 780350E+00 . 601030E+00
. 160420E+02 . 168000E+03 . 368000E+01 . 520000E+00

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C2H4. COF

0.	0.	0.	0.	0.	0.
. 280540E+020.		0.	0.	0.	. 167108E+010.
- . 2146684366683D-02					
. 1791433722534D+00					
- . 3675315603930D+01					
. 3707178934669D+03					
- . 3198282566709D+05					
. 5809379774732D-04					
- . 7895570824899D-01					
. 1148620375835D+02					
. 2713774629193D+05					
- . 8647124319107D-05					
. 1617727266385D-01					
- . 2731527496271D+01					
- . 2672283641459D-03					
- . 4752381331990D-02					
- . 6255637346217D+01					
. 4576234964434D-03					
- . 7534839269320D-05					
. 1638171982209D-01					
- . 3563090740740D-03					
- . 1833000783170D+05					
- . 1805074209985D+07					
- . 4794587918874D+03					
. 3531948274957D+07					
- . 2562571039155D+01					
. 1044308253292D+03					
- . 1695303363659D-01					
- . 1710334224958D+03					
- . 2054114462372D-04					
. 6727558766661D-02					
- . 1557168403328D-06					
- . 1229814736077D-04					
. 4234325938573D-04					
- . 6096215155940D+02					
. 2031853127020D-01					
- . 9254412658130D+00					
. 2436307958880D+02					
- . 8547456228880D+03					
. 1239278681830D+04					
- . 1427107117890D+04					
. 8373586704050D+03					
. 4322036965520D+03					
- . 1379175411610D+04					
. 1268586001240D+04					
- . 5715523217130D+03					
. 1060122343600D+03					
- . 4790470601830D+01					
. 1513813452830D-01					
- . 4034560794450D+00					
. 5086839202250D+01					
- . 2467119979870D+02					
. 9800309152470D+01					
- . 2168465161220D+01					
. 5603615762000D+06	0.			0.	
- . 2141069802000D+05	0.			0.	
. 2532008897000D+03	0.			0.	
. 3554495281000D+01	0.			0.	
- . 9951927478000D-02	0.			0.	
. 5108931070000D-04	0.			0.	
- . 1928667482000D-07	0.			0.	
- . 2061703241000D+02	0.			0.	
. 3000000000000D+04	0.			0.	
- . 1054840584320D+05	0.			0.	
. 6447430891887D+02	0.			0.	


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. 1099839659870D+00
. 1371418636620D+00
-. 9801225235070D+00
. 1338489436060D+01
-. 8076017312800D+00
-. 1884527431980D+01
. 4486631930080D-02
-. 1248903769190D+00
. 1797380770930D+01
-. 1375304922580D+02
. 6941377045750D+01
-. 1932968312710D+01
0.
0.
0.
0.
0.
0.
0.
-. 6934140690900D+06 0. 0.
. 3153483413500D+05 0. 0.
-. 6103375287000D+03 0. 0.
. 9950792245900D+01 0. 0.
-. 2865787794800D-01 0. 0.
. 9092289782100D-04 0. 0.
-. 5275010991500D-07 0. 0.
-. 1424359341100D+02 0. 0.
. 3000000000000D+04 0. 0.
. 2176008367499D+05 0. 0.
-. 2165173422429D+03 0. 0.
. 8900377023000D+01 0. 0.
. 1155950893100D+02 0. 0.
-. 4009244950000D+01 0. 0.
-. 1175263997000D+01 0. 0.
. 7918066027000D+01 0. 0.
. 1600000000000D+01 0. 0.
. 9034800000000D+02 0. 0.
. 3053300000000D+03 0. 0.
. 1130842618000D-05 0. 0.
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0. 0.
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0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
0. 0.
. 2102436247000D+01 0.
-. 1065920192000D+01 0.
. 1400000000000D+01 0.
. 3053300000000D+03 0.
. 2168000000000D+02 . 1515400000000D-05
0. 0. 0.
. 00831434-. 21157025E-01 600.00 90.35 70.00 6.8750 4.8714
. 1114210000000D-01 -. 2559650000000D+03
. 2066220000000D-04 . 1400342000000D-01
-. 1359820000000D-05 . 2179000000000D+01
. 6304320000000D-04 0.
-. 1456830000000D-06 0.
0. 0.
. 287000E+00 . 119000E+01 . 355000E+00 . 435200E+01 . 138054E-22 . 232000E+01
. 168000E+00 . 742399E-090. 0. 0. 0.
. 300701E+02 . 240000E+03 . 440110E+01 . 350000E+00

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C3H8. COF

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0.	0.	0.	0.	0.	0.	0.
- . 2804337729000D-03						
. 1180666107000D+00						
- . 3756325860000D+01						
. 5624374521000D+03						
- . 9354759605000D+05						
- . 4557405505000D-04						
. 1530044332000D+00						
- . 1078107476000D+03						
. 2218072099000D+05						
. 6629473971000D-05						
- . 6199354447000D-02						
. 6754207966000D+01						
. 6472837570000D-03						
- . 6804325262000D-01						
- . 9726162355000D+01						
. 5097956459000D-02						
- . 1004655900000D-03						
. 4363693352000D-01						
- . 1249351947000D-02						
. 2644755879000D+05						
- . 7944237270000D+07						
- . 7299920845000D+03						
. 5381095003000D+08						
. 3450217377000D+01						
. 9936666689000D+03						
- . 2166699036000D+00						
- . 1612103424000D+05						
- . 3633126990000D-03						
. 1108612343000D+01						
- . 1330932838000D-04						
- . 3157701101000D-02						
. 1423083811000D+00						
. 2776096607720D+00						
. 9963162115260D-01						
- . 9351030114790D-01						
- . 3931811933810D+00						
. 7803933323340D+00						
- . 5946726552360D+00						
- . 1703537178580D+02						
. 8507185809450D-01						
- . 1698995082710D+01						
. 1842068338990D+02						
- . 8153344355910D+02						
. 3306123402780D+02						
- . 7376365110310D+01						
0.						
0.						
0.						
0.						
0.						
0.						
0.						
0.						
. 3125245009900D+07	0.			0.		
- . 1141525363800D+06	0.			0.		
. 1497165072000D+04	0.			0.		
- . 5404120433800D+01	0.			0.		
. 3921545289700D-01	0.			0.		
- . 2173891392600D-04	0.			0.		
. 4827454130300D-08	0.			0.		
. 3190701634900D+01	0.			0.		
. 1500000000000D+04	0.			0.		
- . 5905992207939D+05	0.			0.		
. 4723601648251D+03	0.			0.		

. 1541015327200D+02	0.					. 1422605000000D+01
. 1187073361500D+02	0.					-. 1797490000000D+00
-. 8749583550000D+00	0.					0.
-. 2448971934000D+01	0.					0.
. 1140096225900D+02	0.					0.
. 1200000000000D+01	0.					0.
. 8547000000000D+02	0.					0.
. 3698500000000D+03	0.					0.
. 1689532516000D-09	0.					0.
-. 1411329489600D+02	. 3113890422000D-02					
. 9682294015300D+03	-. 2257559730000D+00					
. 1368654503200D+02	. 5674370999000D+02					
-. 1251162837800D+05	-. 7840963643000D-04					
. 1689108640000D-01	. 2291785465000D-01					
. 4352710944400D+02	-. 2527939890000D+01					
. 7659454347200D+04	-. 6265334654000D-01					
0.	. 2518064809000D+01					
0.	0.					
0.	0.					
. 1120000000000D+01	0.					
. 3590000000000D+03	0.					
. 1663600000000D+02	. 2377500000000D-09					
0.	0.					0.
. 00831434-. 40000000E-01	600.00	85.47	100.00	5.0000	4.2477	
. 1556263100000D-01	-. 7180000000000D+03					
. 7716282000000D-04	. 2385650000000D+01					
-. 6039908400000D-05	. 1283000000000D+01					
. 5107405100000D-03	0.					
-. 4514118100000D-06	0.					
0.	0.					
0.	0.	0.	0.	. 138054E-220.		
0.	0.	0.	0.	0.	0.	
. 440972E+02	. 359000E+030.			. 390000E+00		

ISOB. COF

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
. 1307325972000D-02						
. 3927802742000D-01						
-. 3185427394000D+01						
. 7608825192000D+03						
-. 1753919859000D+06						
-. 2090019755000D-03						
. 8959557971000D+00						
-. 6816710130000D+03						
-. 1111271045000D+06						
. 3248737572000D-04						
-. 1046526456000D+00						
. 6536598969000D+02						
. 3726503734000D-02						
. 8553649395000D+00						
. 2109987236000D+03						
-. 1401267363000D+00						
. 5213089327000D-02						
-. 1925026382000D+01						
. 7640067895000D-01						
. 3425854273000D+06						
-. 3373475924000D+08						
. 1180683444000D+05						
. 1529683738000D+09						
. 3323837416000D+03						
. 6423169487000D+04						
. 3891706042000D+01						
-. 1494755736000D+06						
-. 1720240173000D-02						
. 2894195375000D+02						
. 2005086329000D-03						

-. 4448393005000D-01
 . 8028488415000D+01
 . 3432512286730D+00
 . 4828577762610D-01
 . 5484324610530D+00
 -. 1884263998340D+01
 . 2028124065780D+01
 -. 9734823703320D+00
 -. 9587205839600D+01
 . 3912955870750D-01
 -. 8482763798650D+00
 . 9883018121350D+01
 -. 4930250474110D+02
 . 2097730743050D+02
 -. 4921886633430D+01
 0.
 0.
 0.
 0.
 0.
 0.
 0.
 . 1702791900600D+08 0. 0.
 -. 4726972473700D+06 0. 0.
 . 4730140658100D+04 0. 0.
 -. 1723172327800D+02 0. 0.
 . 5849134429100D-01 0. 0.
 . 8944035188600D-05 0. 0.
 -. 1827459919700D-07 0. 0.
 -. 1928302196200D+02 0. 0.
 . 3000000000000D+04 0. 0.
 -. 1977633864428D+06 0. 0.
 . 1076385671262D+04 0. 0.
 . 1264889651000D+02 0. . 1449797353000D+01
 . 1074641516000D+02 0. -. 1685643887000D+00
 -. 2191129109000D+01 0. 0.
 -. 2155822575000D+01 0. 0.
 . 8832766439000D+01 0. 0.
 . 1400000000000D+01 0. 0.
 . 1135500000000D+03 0. 0.
 . 4078500000000D+03 0. 0.
 . 1948100000000D-07 0. 0.
 -. 2055498053000D+02 . 4307008989000D-02
 . 1357076181000D+04 -. 1509010974000D+01
 . 1893774336000D+02 . 4693712392000D+03
 -. 1822277344000D+05 -. 3554280979000D-03
 -. 4599387773000D-02 . 1841552874000D+00
 . 6305247065000D+02 -. 3892338766000D+02
 . 1282253921000D+05 -. 9354624917000D-01
 0. . 7114330590000D+01
 . 1687838652000D+01 0.
 0. 0.
 . 1400000000000D+01 0.
 . 4078500000000D+03 0.
 . 1275500000000D+02 . 2063400000000D-07
 0. 0. 0.
 . 00831434-. 67115896E-01 600.00 113.55 35.00 3.8600 3.6400
 . 1986702600000D-01 -. 4300000000000D+02
 . 1760005300000D-03 . 1373820000000D-10
 -. 1526737200000D-04 . 6080000000000D+01
 . 9947290400000D-03 0.
 -. 5637502400000D-06 0.
 0. 0.
 . 287000E+00 . 119000E+01 . 355000E+00 . 435200E+01 . 138054E-22 . 207000E+01
 . 140000E+00 . 910218E-09 . 347138E-02 . 101207E+02 . 466392E+00 . 100344E+01
 . 581243E+02 . 418000E+03 . 509217E+01 . 250000E+00

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0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
. 1537401046030D-02						
- . 1609800346110D-01						
- . 9797824590100D+00						
. 4996606745040D+02						
- . 1021156076870D+06						
. 2360321477560D-03						
- . 1374757570930D+00						
- . 9070387338650D+02						
. 3854217482130D+05						
- . 3494537107000D-05						
. 1573611227140D-01						
. 1023014740680D+02						
. 1823357373310D-02						
- . 4041143077870D+00						
. 1879798557830D+00						
. 3620887950400D-01						
- . 7387622482660D-03						
- . 2186185905630D+00						
. 1188027290270D-01						
. 7068541987130D+05						
- . 2194698857960D+08						
- . 1824543612680D+04						
. 2067903772770D+09						
. 1117575501450D+02						
. 5587799259860D+04						
- . 1595790540260D+01						
- . 1480342146220D+06						
- . 2452063282010D-01						
. 2183052593090D+02						
- . 9239906273380D-05						
- . 2052677766390D+00						
. 3876390448200D+01						
. 4041621499070D+00						
. 9607640867320D-01						
. 3404715226650D+00						
- . 1729592472230D+01						
. 2214509591330D+01						
- . 1195654636800D+01						
- . 5007387533220D+01						
. 9593278394870D-02						
- . 2995224440540D+00						
. 4457489568490D+01						
- . 3041854550990D+02						
. 1424771122650D+02						
- . 3608627293560D+01						
0.						
0.						
0.						
0.						
0.						
0.						
0.						
0.						
. 3880231019400D+06	0.			0.		
- . 1544429689000D+06	0.			0.		
. 2845508223900D+04	0.			0.		
- . 1349151137600D+02	0.			0.		
. 6614259535300D-01	0.			0.		
- . 2430796502800D-04	0.			0.		
. 1504424842900D-09	0.			0.		
- . 8393342346700D+01	0.			0.		
. 3000000000000D+04	0.			0.		
- . 1090160645491D+06	0.			0.		
. 8662371372633D+03	0.			0.		

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-. 7645674906000D+01 0. .1530992335000D+01
. 2457845942700D+02 0. -. 2114511021000D+00
-. 1096617182000D+01 0. 0.
-. 2890833730000D+00 0. 0.
. 2516192927700D+02 0. 0.
. 1030000000000D+01 0. 0.
. 1348600000000D+03 0. 0.
. 4251600000000D+03 0. 0.
. 6735758052000D-06 0. 0.
-. 2724386845000D+02 . 4024170074000D-02
. 8012766611000D+03 . 1561435847000D+01
. 2503978646000D+02 -. 6004381127000D+03
-. 1309704275000D+05 -. 7547260841000D-03
-. 8313305258000D-01 -. 2069676662000D-01
. 6636975027000D+02 . 9382534978000D+02
. 9849317662000D+04 -. 1711371457000D+00
0. . 3647724935000D+02
. 1630521851000D+01 0.
0. 0.
. 1400000000000D+01 0.
. 4251600000000D+03 0.
. 1265000000000D+02 . 6007200000000D-06
0. 0. 0.
. 00831434-. 65077051E-01 500.00 134.86 70.00 3.9200 3.7960
. 2069763100000D-01 -. 3634000000000D+03
. 6734573100000D-04 . 7134170000000D-02
-. 6611178500000D-05 . 2210000000000D+01
-. 1115193300000D-03 0.
-. 1202982000000D-05 0.
0. 0.
. 287000E+00 . 119000E+01 . 355000E+00 . 435200E+01 . 138054E-22 . 207000E+01
. 140000E+00 . 910218E-09 . 769608E-03 . 132533E+02 . 485554E+00 . 101021E+01
. 581243E+02 . 440000E+03 . 503103E+01 . 320000E+00

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Program Listing of HELIUM

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PROGRAM HELIUM
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4 (I-N)
COMMON/LIM/TUL,TLL,PUL,TCC,DCC,PCC
1000 FORMAT(//'      THIS PROGRAM PROVIDES THE THERMODYNAMIC PROPERTIES
1 OF HELIUM',/,',      FROM 2 TO 1500 K (-456 TO 2240 F)'
A,/'      WITH PRESSURES TO 100 MPA (14503 PSIA)'/)
WRITE(*,1000)
CALL INFO
IP=3
CALL FDATA
TTP=TLL
PTP=.005D0
EM=4.0026
1010 FORMAT(I1)
1 CONTINUE
120 WRITE(*,1040)
1040 FORMAT(' FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"',/)
READ(*,1010)IU
WRITE(*,1050)
1050 FORMAT(' FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER '
A '"1"',/)
READ(*,1010)IC
WRITE(*,1060)
1060 FORMAT(' FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"',/)
READ(*,1010)IV
160 IF(IC.EQ.0)GO TO 240
IF(IV.EQ.1)GO TO 330
170 IF(IU.EQ.0)GO TO 180
WRITE(*,1080)
READ(*,*)PI,D,T
GO TO 190
180 WRITE(*,1070)
1070 FORMAT(' ENTER PRESSURE(PSIA), DENSITY(LB/CU FT), AND TEMPERATURE'
A '(F)',/)
READ(*,*)P,D,T
PI=(P/14.695949D0)*.101325
D=D*16.01846371D0/EM
T=(T-32.D0)/1.8D0+273.15D0
190 IF(PI.LE.0.0D0.AND.D.LE.0.0D0)GO TO 110
IF(PI.GT.0.0D0.AND.D.GT.0.0D0)GO TO 200
IF(PI.LE.0.0D0.AND.T.NE.0.0D0)GO TO 220
IF(PI.NE.0.0D0.AND.T.NE.0.0D0)GO TO 210
GO TO 1
1080 FORMAT(' ENTER PRESSURE(MPA), DENSITY(MOL/L), AND TEMPERATURE(K)'
A ')
200 P=PI/.101325
T=FINDD T(P,D)
CALL LIMITS(PI,T,IL)
IF(IL.LE.0)GO TO 170
GO TO 230
210 P=PI/.101325
CALL LIMITS(PI,T,IL)
IF(IL.LE.0)GO TO 170
D=FINDD D(P,T)

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GO TO 230
220 P=FIND P(D,T)
    PI=P*.101325
    CALL LIMITS(PI,T,IL)
    IF(IL.LE.0)GO TO 170
230 CALL REPRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
    GO TO 170
240 WRITE(*,1090)
1090 FORMAT(' FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"',/)
    READ(*,1010)IP
    IF(IV.EQ.1)GO TO 330
    WRITE(*,1095)
1095 FORMAT(' TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"',/)
    READ(*,1010)II
    IF(II.EQ.1)GO TO 290
    250 IF(IU.EQ.1)GO TO 260
1100 FORMAT(' ENTER A TEMPERATURE IN DEGREES F, ENTER 0 FOR RESTART',/)
    WRITE(*,1100)
    READ(*,*)TI
    IF(TI.EQ.0.0D0)GO TO 110
    T=(TI-32.D0)/1.8D0+273.15D0
    GO TO 270
    260 WRITE(*,1110)
1110 FORMAT(' ENTER A TEMPERATURE(K) ,ENTER 0 FOR RESTART',/)
    READ(*,*)T
    270 IF(T.LT..000001D0)GO TO 110
    IF(T.GT.TCC.OR.T.LT.TTP)GO TO 280
    P=VPN(T)
    IF(IP.EQ.0)P=P+.00001D0
    IF(IP.EQ.1)P=P-.00001D0
    D=FIND D(P,T)
    PI=P*.101325
    CALL RE PRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
    GO TO 250
    280 X1=(TTP-273.15D0)*1.8D0+32.D0
    X2=(TCC-273.15D0)*1.8D0+32.D0
    WRITE(*,1120)TTP,TCC,X1,X2
1120 FORMAT(' FOR SATURATION ',F6.2,' < TEMP < ',F6.2,' K',/,
A ' OR ',F7.2,' < TEMP < ',F7.2,' F',/)
    GO TO 250
    290 IF(IU.EQ.1)GO TO 300
    WRITE(*,1130)
1130 FORMAT(' ENTER A PRESSURE IN LB/SQ IN    0 RESTRATS PROGRAM',/)
    READ(*,*)P
    PI=(P/14.695949D0)*.101325D0
    P=PI/.101325D0
    IF(PI.LE.0.0D0)GO TO 110
    GO TO 310
    300 WRITE(*,1140)
1140 FORMAT(' ENTER A PRESSURE(MPA)    0 RESTARTS PROGRAM',/)
    READ(*,*)PI
    IF(PI.LE.0.0D0)GO TO 110
    P=PI/.101325
    310 IF(PI.GT.PCC.OR.PI.LT.PTP)GO TO 320
    T=FIND TV(P)
    P=VPN(T)
    IF(IP.EQ.1)P=P-.00001D0
    IF(IP.EQ.0)P=P+.00001D0
    D=FIND D(P,T)
    PI=P*.101325
    CALL RE PRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
    GO TO 290

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320 PTPF=PTP*14.695949/.101325
    PCCF=PCC*14.695949/.101325
    WRITE(*,1150) PTP,PCC,PTPF,PCCF
1150 FORMAT(' YOUR INPUT PRESSURE IS OUTSIDE THE RANGE OF SATURATION'
    A ' PRESSURES'/' FOR THIS FLUID THE RANGE IS ',F6.5,' TO ',F6.3,
    B ' MPA,'/' OR ',F6.5,' TO ',F6.3,' PSIA'/' TRY AGAIN',/)
    GO TO 290

330 IF(IC.EQ.1)GO TO 370
    IF(IU.EQ.1)GO TO 340
    WRITE(*,1160)
1160 FORMAT(' ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE'
    A '/' AND A TEMPERATURE INCREMENT, IN DEGREES F AND IN THAT ORDER',/
    B ' ENTER 0,0,0 TO RESTART'/)
    READ(*,*)TS,TF,TDEL
    IF(TDEL.LE.0.0D0)GO TO 110
    TS=(TS-32.D0)/1.8D0+273.15D0
    TF=(TF-32.D0)/1.8D0+273.15D0
    TDEL=TDEL/1.8D0
    IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
    IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360
    GO TO 350

340 WRITE(*,1170)
1170 FORMAT(' ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE'
    1/' AND A TEMPERATURE INCREMENT IN KELVINS AND IN THAT ORDER',/
    2' ENTER 0,0,0 TO RESTART PROGRAM'/)
    READ(*,*)TS,TF,TDEL
    IF(TDEL.LE.0.0D0)GO TO 110
    IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
    IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360

350 T=TS
    P=VPN(T)
    IF(IP.EQ.0)P=P+.00001D0
    IF(IP.EQ.1)P=P-.00001D0
    D=FIND D(P,T)
    PI=P*.101325
    CALL RE PRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
    GO TO 330

360 X1=(TTP-273.15D0)*1.8D0+32.D0
    X2=(TCC-273.15D0)*1.8D0+32.D0
    WRITE(*,1180)TTP,TCC,X1,X2
1180 FORMAT(' FOR SATURATION, ',F6.2,' < TEMP < ',F6.2,' K',/,/
    A ',13X,'OR, ',F7.1,' < TEMP < ',F7.1,' F. TRY AGAIN.',/)
    GO TO 330

370 IF(IU.EQ.1)GO TO 380
    WRITE(*,1190)
1190 FORMAT(' ENTER PRESSURE(PSIA), STARTING TEMPERATURE(F), FINAL '
    A 'TEMPERATURE(F)'/' AND A TEMPERATURE INCREMENT, IN THAT ORDER',/
    B ' ENTER 0,0,0,0 TO RESTART PROGRAM'/)
    READ(*,*)P,TS,TF,TDEL
    IF(TDEL.LE.0.0D0)GO TO 110
    PI=(P/14.695949D0)*.101325D0
    T=(TS-32.D0)/1.8D0+273.15D0
    TF=(TF-32.D0)/1.8D0+273.15D0
    TDEL=TDEL/1.8D0
    P=PI/.101325
    CALL LIMITS(PI,T,IL)
    IF(IL.LE.0)GO TO 370
    CALL LIMITS(PI,TF,IL)
    IF(IL.LE.0)GO TO 370
    GO TO 390

380 WRITE(*,1200)
1200 FORMAT(' ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A '

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1 'FINAL TEMPERATURE AND A '/' TEMPERATURE INCREMENT'
2 ' AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"',/)
  READ(*,*)PI,TS,TF,TDEL
  IF(TDEL.LE.0.0D0)GO TO 110
  T=TS
  P=PI/.101325
  CALL LIMITS(PI,T,IL)
  IF(IL.LE.0)GO TO 370
  CALL LIMITS(PI,TF,IL)
  IF(IL.LE.0)GO TO 370
390 D=FIND D(P,T)
  CALL RE PRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
  GO TO 370
110 CONTINUE
  WRITE(*,1210)
1210 FORMAT(//' FOR MORE PROPERTIES ENTER 0, TO TERMINATE ENTER 1')
  READ(*,1010)IM
  IF(IM.EQ.0)GO TO 1
999 CONTINUE
  STOP
  END
  SUBROUTINE REPRO(PI,D,T,IU,IV,IC,IP,TF,TDEL)
  IMPLICIT REAL*8(A-H)
  IMPLICIT REAL*8(O-Z)
  IMPLICIT INTEGER*4(I-N)
  N=500
  EM=4.0026
  P=PI/.101325
  IF(IV.EQ.0)TF=T-1.D0
  IF(IU.EQ.0)GO TO 100
  WRITE(*,1000)
  WRITE(*,1010)
  WRITE(*,1020)
  GO TO 110
100 WRITE(*,1000)
  WRITE(*,1030)
  WRITE(*,1040)
110 CONTINUE
  DO 210 I=1,N
  IF(I.EQ.1)GO TO 120
  D=FIND D(P,T)
120 H=ENTHAL(P,D,T)
  E=H-101.325D0*P/D
  S=ENTROP(D,T)
  W=SOUND(D,T)
  CPP=CP(D,T)
  CVV=CV(D,T)
150 V=VISC(D,T)
  TH=THERM(D,T)*100.D0
  EPS=FDIEL(D)
  IF(IU.EQ.0)GO TO 160
  PO=P*.101325
  WRITE(*,2030) PO,T,D,E,H,S,CVV,CPP,W,V,TH,EPS
  GO TO 200
160 H=H/(2.324445D0*EM)
  E=E/(2.324445D0*EM)
  S=S/(4.184001D0*EM)
  CPP=CPP/(4.184001D0*EM)
  CVV=CVV/(4.184001D0*EM)
  W=W*3.280840D0
  PO=P*14.695949D0
  DO=D*EM/16.01846371D0

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      TO=T*1.8D0-459.67D0
190  V=VISC(D,T)*.0067196897D0
      TH=THERM(D,T)*.000578176D0
      EPS=FDIEL(P,D,T)
      WRITE(*,3030) PO,TO,DO,E,H,S,CVV,CPP,W,V,TH,EPS
200  T=T+TDEL
      IF(T.GT.TF+.01D0)GO TO 220
      IF(IC.NE.0)GO TO 210
      P=VPN(T)
      IF(IP.EQ.0)P=P+.00001D0
      IF(IP.EQ.1)P=P-.00001D0
210  CONTINUE
220  CONTINUE
      WRITE(*,1000)
1000 FORMAT(' ')
      RETURN
1010 FORMAT(3X,'P',5X,'T',6X,'DEN',5X,'E',6X,'H',6X,'S',4X,'CV',4X,
      A 'CP',3X,'SOUND',2X,'VISC',2X,'COND',2X,'DIEL')
1020 FORMAT(3X,'MPA',3X,'K',6X,'MOL/L',2X,'=== J/MOL ==',2X,'==== ',
      A 'J/MOL-K ===',2X,'M/S',3X,'PA-S',1X,'MW/M-K',2X,'==',/,61X,'E+6')
1030 FORMAT(3X,'P',5X,'T',7X,'DENS',3X,'E',8X,'H',5X,'S',5X,'CV',
      A 4X,'CP',2X,'SOUND',1X,'VISC',2X,'COND',2X,'DIEL')
1040 FORMAT(3X,'PSIA',2X,'F',7X,'LB/',3X,'==== BTU/ ===',1X,'=====',
      A ' BTU/ =====',2X,'F/S',3X,'LB/',2X,'BTU/',2X,'==',/,17X,'CU FT',
      B 6X,'LB',14X,'LB-F',13X,'FT-S',1X,'FT-HR-F',/,62X,'E+5')
2030 FORMAT(F8.3,F7.2,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1,F8.5)
3030 FORMAT(F8.1,F7.2,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4,F8.5)
      END
      SUBROUTINE INFO
      WRITE(*,101)
101  FORMAT('
      A'                               WRITTEN BY'//
      1'                               ROBERT D. MCCARTY'/
      2'                               THERMOPHYSICS DIVISION'/
      3'                               CENTER FOR CHEMICAL ENGINEERING'/
      4'                               NATIONAL BUREAU OF STANDARDS'/
      5'                               BOULDER, COLORADO'//
      6'                               DISTRIBUTED BY'//
      A'                               THE OFFICE OF STANDARD REFERENCE DATA'/
      B'                               NATIONAL BUREAU OF STANDARDS, WASHINGTON, DC'//
      WRITE(*,100)
100  FORMAT(/ ' WHEN THE PROGRAM ASKS FOR A PRESSURE, DENSITY AND'
      * ' TEMPERATURE,'/ ' ENTER ANY TWO AND A ZERO FOR THE THIRD.'/
      * ' TO TERMINATE THE PROGRAM ENTER ZERO FOR ALL THREE.'/)
      RETURN
      END

```

```

SUBROUTINE FDATA(IF)
  IMPLICIT REAL*8(A-H)
  IMPLICIT REAL*8(O-Z)
  IMPLICIT INTEGER*4(I-N)
  DIMENSION B(27,3)
  COMMON/COEF/B
  COMMON/LIM/TUL,TLL,PUL,TCC,DCC,PCC
  OPEN(5,FILE='HELIUM.COF')
  DO 60 J=1,3
  DO 60 I=1,27
60 READ(5,101)B(I,J)
101 FORMAT(D20.13)
  READ(5,102)TUL,TLL,PUL,TCC,DCC,PCC
  CLOSE(5,STATUS='KEEP')
102 FORMAT(F10.8,E14.8,3F8.2,2F8.4)
  RETURN
  END
SUBROUTINE LIMITS(PI,T,IL)
  IMPLICIT REAL*8(A-H)
  IMPLICIT REAL*8(O-Z)
  IMPLICIT INTEGER*4(I-N)
  COMMON/LIM/TUL,TLL,PUL,TCC,DCC,PCC
  P=PI/.101325
  IF(PI.GT. PUL)GO TO 10
  IF(T .GT. TUL.OR.T .LT. TLL)GO TO 12
  PM=PMELT(T)
  IF(P .GT. PM) GO TO 20
  IL=1
  RETURN
10 PULF=PUL*14.6959496/.101325
  WRITE(*,11)PUL,PULF
11 FORMAT(' THE INPUT PRESSURE IS OUT OF THE RANGE OF THIS EQUATION '
1/' THE RANGE FOR THIS EQUATION IS FROM 0 TO ',F6.0,' MPA'
2/' OR ',F7.0,' PSIA')
  IL=0
  RETURN
12 TLLF=(TLL-273.15D0)*1.8D0+32.D0
  TULF=(TUL-273.15D0)*1.8D0+32.D0
  WRITE(*,13) TLL,TUL,TLLF,TULF
13 FORMAT(' THE INPUT TEMPERATURE IS OUT OF RANGE'
A /' THE RANGE FOR THIS EQUATION IS ',F6.2,' K TO ',F6.0,' K',/,
B 27X,' OR ',F8.2,' F TO ',F6.0,' F')
  IL=0
  RETURN
20 TM=TMELT(P)
  TF=(TM-273.15D0)*1.8D0+32.D0
  WRITE(*,22) TM,TF
22 FORMAT(' SOLID PHASE DETECTED.',/, ' FOR THIS PRESSURE, TEMP'
A ' SHOULD EXCEED ',F8.3,' K, OR',F9.3,' F')
  IL=0
  END
DOUBLE PRECISION FUNCTION CV(D,T)
  IMPLICIT REAL*8(A-H)
  IMPLICIT REAL*8(O-Z)
  IMPLICIT INTEGER*4(I-N)
C CALCULATES CV(J/(MOL*K)). INPUT DENS(MOL/L) AND TEMP(K).
  CALL PROPS(PP,D,T,6)
  CV=PP
  END
DOUBLE PRECISION FUNCTION ENTHAL(P,D,T)
  IMPLICIT REAL*8(A-H)
  IMPLICIT REAL*8(O-Z)
  IMPLICIT INTEGER*4(I-N)

```

```

DD=D
TT=T
CALL PROPS(UD, DD, TT, 5)
ENTHAL=(UD)
END
DOUBLE PRECISION FUNCTION ENTROP(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C CALCULATES ENTROPY(J/(MOL-K)), FROM INPUT OF DENSITY(MOL/L) AND TEMP(K).
DD=D
TT=T
CALL PROPS(SD, DD, TT, 4)
ENTROP=(SD)
END
DOUBLE PRECISION FUNCTION FINDP(D, T)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
DD=D
TT=T
IF(TT.LT.TCC)GO TO 10
1 CALL PROPS(PP, DD, TT, 1)
FINDP=PP
RETURN
10 P=VPN(TT)
DV=FINDD(P-.0001D0, TT)
DL=FINDD(P+.0001D0, TT)
IF(DD.LE.DV.OR.DD.GE.DL)GO TO 1
WRITE(*,100)DV, DL, DD
CALL PROPS(PP, DV, TT, 1)
FINDP=PP
D=DV
100 FORMAT(' THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO A '
1/' DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION'
2/' THE DENSITY OF THE SATURATED VAPOR IS ',F6.4,' MOLES/LITER'
3/' THE DENSITY OF THE SATURATED LIQUID IS ',F8.4,' MOLES/LITER'
4/' AND THE INPUT DENSITY IS ',F8.4,' MOLES/LITER'
5/' SATURATED VAPOR IS ASSUMED')
END
DOUBLE PRECISION FUNCTION FINDT(P, D)
IMPLICIT REAL*8(A-H)
IMPLICIT REAL*8(O-Z)
IMPLICIT INTEGER*4(I-N)
C RETURNS TEMPERATURE(K), FROM THE 32-TERM MBWR EQN OF STATE.
C INPUT IS PRESSURE(MPA) AND DENSITY(MOL/L).
DIMENSION G(32), VP(9)
COMMON/DATA/G, R, GAMMA, VP, DTP, PCC, PTP, TCC, TTP, TUL, TLL, PUL, DCC
PP=P
DD=D
IF(P.GE.PCC)GO TO 1
TSAT=FINDTV(PP)
DV=FINDD(PP-.00001D0, TSAT)
DL=FINDD(PP+.0001D0, TSAT)
IF(DD.GT.DV.AND.DD.LT.DL)GO TO 30
TT=TSAT
GO TO 2
1 TT=TCC
2 DO 10 I=1, 10
CALL PROPS(P2, DD, TT, 1)
IF(DABS(PP-P2)-1.D-7*PP)20, 20, 11
11 CALL PROPS(DP, DD, TT, 3)
CORR=(P2-PP)/DP
IF(DABS(CORR)-1.D-5)20, 20, 10
10 TT=TT-CORR
20 FINDT=TT

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```

RETURN
30 FINDT=TSAT
D=DV
WRITE(*,100)DV,DL,DD
100 FORMAT(' THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO'
1/' A DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION'
2/' DENSITY OF THE SATURATED VAPOR IS',F8.4,' MOLES/LITER'
3/' DENSITY OF THE SATURATED LIQUID IS',F8.4,' MOLES/LITER'
4/' INPUT DENSITY IS',F8.4,' MOLES/LITER'
5/' SATURATED VAPOR CONDITIONS ARE ASSUMED' )
END
DOUBLE PRECISION FUNCTION FIND D(PI, TI)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
T=TI
P=PI
IF(T.LT.5.2D0)GO TO 6
PM=1001.D0
PM=1.0D+5
IF(T.LT.15.D0)PM=PMELT(T)
IF(PM.LT.P)GO TO 30
IF(T.GT.100.D0)GO TO 1
PC=2.2449D0+(T-5.2014D0)*1.76D0
IF(P.LT.PC)GO TO 1
PM=200.D0+(T-5.2D0)*12.31D0
D=17.399D0+((PM-PC)/(PM-PC+1.D0))*2.33D0*17.399D0
GO TO 7
2 D=.0001D0
IF(T.LT.4.2D0)GO TO 7
1 VB=VIRB(T)
RT=0.0820558D0*T
P1=RT/P
D=1./(P1+VB)
GO TO 7
6 IF(P.LT.VPN(T))GO TO 2
DS=46.18D0+(T-2.D0)*4.02D0
DL=SATL(T)*1000.D0/4.0026D0
DEL=DS-DL
PM=PMELT(T)
IF(P.GT.PM)GO TO 30
D=DL+DEL*P/PM
7 DO 10 I=1,50
CALL PROPS(P2,D,T,1)
IF(DABS(P-P2)-1.D-7*P)20,20,8
8 CALL PROPS(DP,D,T,2)
CORR=(P2-P)/DP
IF(DABS(CORR)-1.D-7*D)20,20,10
10 D=D-CORR
FIND D=0.D0
RETURN
20 FIND D=D
RETURN
30 FIND D=0.D0
RETURN
END
SUBROUTINE PROPS(PP,DD,TT,ICON)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION A(26),B(27,3)
COMMON/COEF/B
GO TO(1000,3000,2000,4000,5000,6000)ICON
1000 KP=1
GO TO 10
C ENTRY DPDT
2000 KP=2
GO TO 10

```

```

C      ENTRY DPDD
3000  KP=3
      GO TO 10
C      ENTRY ENTROP
4000  KP=4
      GO TO 10
C      ENTRY ENTHAL
5000  KP=5
      GO TO 10
C      ENTRY CV
6000  KP=6
      10 K1=0
          KH=1
          K=1
          KK=1
          K4=1
          IF(ID. NE. 0) GO TO 20
          IF(TT. GE. 15. D0) GO TO 20
          IF(TT. GT. 10. D0) GO TO 30
          IF(DD. GT. 17. 3987D0) GO TO 40
11    I=1
          T=TT
          D=DD
      8  GO TO ( 9, 100, 200, 300, 400, 500) KP
      9  D2=D*D
          D3=D2*D
          D4=D3*D
          D5=D4*D
          GAMMA=B( 27, I)
          EX=DEXP( D2*GAMMA)
          EXD3=EX*D3
          EXD5=EX*D5
          M=I
          N=1
          A( N) =D5*D
          N=N+1
          A( N) =A( N-1) / T
          N=N+1
          DO 2 I=1, 6
              FI=I
              A( N) =D5*T**(. 75D0-FI/ 4. D0)
      2  N=N+1
          DO 3 I=1, 4
              FI=I
              A( N) =D4*T** ( 1. 5D0-FI)
      3  N=N+1
          DO 1 I=1, 8
              FI=I
              A( N) =D3*T** ( 1. 5D0-FI/ 2. D0)
          N=N+1
      1  CONTINUE
          DO 4 I=1, 3
              FI=I
              A( N) =EXD3*T** ( 1. D0-FI)
      4  N=N+1
          DO 5 I=1, 3
              FI=I
              A( N) =EXD5*T** ( 1. D0-FI)
      5  N=N+1
          N=N-1
          I=M
      7  P=0. D0
          DO 15 J=1, N
      15  P=P+B( J, I) *A( J)
          P=P+. 0820558D0*D*T*( 1. +VIRB( T) *D)
          IF( KH. LT. 1) GO TO 413
          GO TO( 50, 50, 30, 40) K
100   D2=D*D

```

```

D3=D**3
D4=D3*D
D5=D4*D
D6=D5*D
T2=T*T
T3=T2*T
T4=T**4
M=I
GAMMA=B( 27, M)
EX=DEXP( D2*GAMMA)
N=1
R=. 0820558D0
A( N)=0. 0D0
N=N+1
A( N)=(-1. D0) *D6/T2
N=N+1
DO 102 I=1, 6
FI=I
A( N)=D5*T**(. 75D0-FI/4. D0-1. D0) *(. 75D0-FI/4. D0)
102 N=N+1
DO 103 I=1, 4
FI=I
A( N)=D4*T**(. 5D0-FI/1. D0-1. D0) *(. 5D0-FI)
103 N=N+1
DO 101 I=1, 8
FI=I
A( N)=D3*T**(. 5D0-FI/2. D0-1. D0) *(. 5D0-FI/2. D0)
101 N=N+1
DO 104 I=1, 3
FI=I
A( N)=EX*D3*T**(. 1. D0-FI-1. D0) *(. 1. D0-FI)
104 N=N+1
DO 105 I=1, 3
FI=I
A( N)=EX*D5*T**(. 1. D0-FI-1. D0) *(. 1. D0-FI)
105 N=N+1
N=N-1
P=0
DO 115 J=1, N
115 P=P+A( J) *B( J, M)
P=P+R*D*( 1. D0+VIRB( T) *D) +R*D*T*DBDT( T) *D
I=M
GO TO( 50, 50, 30, 40) K
200 D2=D*D
D3=D2*D
D4=D3*D
D5=D4*D
M=I
GAMMA=B( 27, M)
EX=DEXP( D2*GAMMA)
DEX=GAMMA*2. D0*D*EX
N=1
R=0. 0820558D0
A( N)=6. D0*D5
N=N+1
A( N)=A( N-1) /T
N=N+1
DO 202 I=1, 6
FI=I
A( N)=5. D0*D4*T**(. 75D0-FI/4. D0)
202 N=N+1
DO 203 I=1, 4
FI=I
A( N)=D3*4. D0*T**(. 5D0-FI)
203 N=N+1
DO 201 I=1, 8
FI=I
A( N)=D2*3. D0*T**(. 5D0-FI/2. D0)

```

```

201 N=N+1
    DO 204 I=1, 3
        FI=I
        A(N)=(DEX*D3+3. DO*D2*EX)*T**(1. DO-FI)
204 N=N+1
    DO 205 I=1, 3
        FI=I
        A(N)=(DEX*D5+5. DO*D4*EX)*T**(1. DO-FI)
205 N=N+1
    N=N-1
    P=0
    DO 215 J=1, N
215 P=P+A(J)*B(J, M)
    I=M
    P=P+R*T*(1. DO+2. DO*D*VIRB(T))
    GO TO(50, 50, 30, 40) K
300 D2=D*D
    D3=D2*D
    D4=D3*D
    N=1
    R=.0820558D0
    M=I
    GAMMA=B(27, M)
    EX=DEXP(D2*GAMMA)
    A(N)=0.0D0
    N=N+1
    A(N)=(D4*D/5. DO)*T**(-2. DO)*(-1. DO)
    N=N+1
    DO 302 I=1, 6
        FI=I
        A(N)=(D4/4. DO)*T**(.75D0-FI/4. DO-1. DO)*(.75D0-FI/4. DO)
302 N=N+1
    DO 303 I=1, 4
        FI=I
        A(N)=(D3/3. DO)*T**(1.5D0-FI-1. DO)*(1.5D0-FI)
303 N=N+1
    DO 301 I=1, 8
        FI=I
        A(N)=(D2/2. DO)*T**(1.5D0-FI/2. DO-1. DO)*(1.5D0-FI/2. DO)
301 N=N+1
    DO 304 I=1, 3
        FI=I
        A(N)=(EX/(2. DO*GAMMA))*T**(1. DO-FI-1. DO)*(1. DO-FI)
304 N=N+1
    DO 305 I=1, 3
        FI=I
        A(N)=(D2*EX/(2. DO*GAMMA)-EX/(2. DO*GAMMA**2))*
1T**(1. DO-FI-1. DO)*(1. DO-FI)
305 N=N+1
    N=N-1
    SINT=D*R*(VIRB(T)+T*DBDT(T))
    DO 306 I=1, N
306 SINT=SINT+B(I, M)*A(I)
    N=21
    EX=1. DO
    D2=0.0D0
    DO 310 I=1, 3
        FI=I
        A(N)=(EX/(2. DO*GAMMA))*T**(1. DO-FI-1. DO)*(1. DO-FI)
310 N=N+1
    DO 311 I=1, 3
        FI=I
        A(N)=(D2*EX/(2. DO*GAMMA)-EX/(2. DO*GAMMA**2))*
1T**(1. DO-FI-1. DO)*(1. DO-FI)
311 N=N+1
    N=N-1
    DO 312 I=21, N
312 SINT=SINT-B(I, M)*A(I)

```



```

P=( 9. 371658D0+5. 193043D0*DLOG( T/4. 2144D0) -25. 31469D0
1*( SINT+R*DLOG( R*T*D) ) )
P=P*4. 0026D0
I=M
GO TO( 50, 50, 30, 40) K
400 KH=0
GO TO 9
413 PP=P
KH=1
D2=D*D
D3=D*D2
D4=D3*D
N=1
R=. 0820558D0
M=I
GAMMA=B( 27, M)
EX=DEXP( D2*GAMMA)
A( N)=( D4*D) /5. DO
N=N+1
A( N)=( D4*D/5. DO) *( 2. DO/T)
N=N+1
DO 402 I=1, 6
FI=I
A( N)=( D4/4. DO) *( T**(. 75D0-FI/4. DO) -T**(. 75D0-FI/4. DO)
1*( . 75D0-FI/4. DO) )
402 N=N+1
DO 403 I=1, 4
FI=I
A( N)=( D3/3. DO) *( T**( 1. 5D0-FI) -T**( 1. 5D0-FI) *( 1. 5D0-FI) )
403 N=N+1
DO 401 I=1, 8
FI=I
A( N)=( D2/2. DO) *( T**( 1. 5D0-FI/2. DO) -T**( 1. 5D0-FI/2. DO)
1*( 1. 5D0-FI/2. DO) )
401 N=N+1
DO 404 I=1, 3
FI=I
A( N)=( EX/( 2. DO*GAMMA) ) *( T**( 1. DO-FI) -T**( 1. DO-FI) *( 1. DO-FI) )
404 N=N+1
DO 405 I=1, 3
FI=I
A( N)=( D2*EX/( 2. DO*GAMMA) -EX/( 2. DO*GAMMA**2) )
1*( T**( 1. DO-FI) -T**( 1. DO-FI) *( 1. DO-FI) )
405 N=N+1
N=N-1
HINT=R*T*T*D*DBDT( T) *(-1. DO)
DO 406 I=1, N
406 HINT=HINT+B( I, M) *A( I)
N=21
D2=0. 0D0
EX=1. DO
DO 410 I=1, 3
FI=I
A( N)=( EX/( 2. DO*GAMMA) ) *( T**( 1. DO-FI) -T**( 1. DO-FI) *( 1. DO-FI) )
410 N=N+1
DO 411 I=1, 3
FI=I
A( N)=( D2*EX/( 2. DO*GAMMA) -EX/( 2. DO*GAMMA**2) ) *( T**( 1. DO-FI)
1-T**( 1. DO-FI) *( 1. -FI) )
411 N=N+1
N=N-1
DO 412 I=21, N
412 HINT=HINT-B( I, M) *A( I)
P=21. 8228D0+5. 193043D0*( T-4. 2144D0) +25. 31469D0
1*( HINT+PP/D-R*T)
P=P*4. 0026D0
I=M
GO TO( 50, 50, 30, 40) K

```

```

500 D2=D*D
    D3=D2*D
    D4=D3*D
    N=1
    R=. 0820558D0
    M=I
    GAMMA=B( 27, M)
    EX=DEXP( D2*GAMMA)
    SINT=T*D*R*( 2. *DBDT( T ) +D2DBDT2( T) *T)
    A( N)=0. 0D0
    N=N+1
    A( N)=( D4*D/5. D0) *T**(- 2. D0) *(- 1. D0) *(- 2. D0)
    N=N+1
    DO 502 I=1, 6
    FI=I
    A( N)=( D4/4. D0) *T**( . 75D0-FI/4. D0-1. D0)
1*( . 75D0-FI/4. D0) *( . 75D0-FI/4. D0-1. D0)
502 N=N+1
    DO 503 I=1, 4
    FI=I
    A( N)=( D3/3. D0) * T**( 1. 5D0-FI-1. D0) *( 1. 5D0-FI) *( 1. 5D0-FI-1. D0)
503 N=N+1
    DO 501 I=1, 8
    FI=I
    A( N)=( D2/2. D0) *T**( 1. 5D0-FI/2. D0-1. D0) *( 1. 5D0-FI/2. D0)
1*( 1. 5D0-FI/2. D0-1. D0)
501 N=N+1
    DO 504 I=1, 3
    FI=I
    A( N)=( EX/( 2. D0*GAMMA) ) *T**( 1. D0-FI-1. D0) *( 1. D0-FI)
1*( 1. D0-FI-1. D0)
504 N=N+1
    DO 505 I=1, 3
    FI=I
    A( N)=( D2*EX/( 2. D0*GAMMA) -EX/( 2. D0*GAMMA**2) ) *
1T**( 1. D0-FI-1. D0) *( 1. D0-FI) *( 1. D0-FI-1. D0)
505 N=N+1
    N=N-1
    DO 506 I=1, N
506 SINT=SINT+B( I, M) *A( I)
    P=SINT
    EX=1. D0
    D2=0
    N=21
    DO 510 I=1, 3
    FI=I
    A( N)=( EX/( 2. D0*GAMMA) ) *T**( 1. D0-FI-1. D0) *( 1. D0-FI)
1*( 1. D0-FI-1. D0)
510 N=N+1
    DO 511 I=1, 3
    FI=I
    A( N)=( D2*EX/( 2. D0*GAMMA) -EX/( 2. D0*GAMMA**2) ) *
1T**( 1. D0-FI-1. D0) *( 1. D0-FI) *( 1. D0-FI-1. D0)
511 N=N+1
    N=N-1
    DO 512 I=21, N
512 P=P-B( I, M) *A( I)
    P=5. 193043D0*( 3. D0/5. D0) *4. 0026D0-P*101. 3278D0
    I=M
    GO TO( 50, 50, 30, 40) K
20 K=2
    I=3
    T=TT
    D=DD
    GO TO 8
30 K=3
    GO TO( 33, 34, 35) KK
33 D=DD

```

```

T=TT
KK=2
IF(DD.GT.17.3987D0)GO TO 40
I=1
GO TO 8
34 PTI=P
I=3
KK=3
T=TT
D=DD
GO TO 8
35 PTIII=P
38 F=(15.D0-T)/5.D0
P=F*PTI+(1.D0-F)*PTIII
IF(KH.LT.1)GO TO 413
PP=P
RETURN
40 IF(K.EQ.3)K1=3
GO TO(41,42,43,44)K4
41 K=4
I=2
K4=2
D=DD
IF(K1.EQ.0)T=TT
GO TO 8
42 PIID=P
D=17.3987D0
IF(T.LT.5.2014D0)D=SATL(T)*1000.D0/4.0026D0
K4=3
GO TO 8
43 PIIDC=P
I=1
K4=4
GO TO 8
44 PIDC=P
P=PIDC+(PIID-PIIDC)
K4=1
IF(K1.EQ.3)GO TO 30
PP=P
RETURN
50 PP=P
RETURN
END
DOUBLE PRECISION FUNCTION CP(D,T)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
CALL PROPS(DPDD,D,T,2)
CALL PROPS(DPDT,D,T,3)
CP=CV(D,T)+(T*(DPDT**2)/((D**2)*DPDD))*101.3278D0
RETURN
END
DOUBLE PRECISIONFUNCTION SOUND(D,T)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
CALL PROPS(DPDD,D,T,2)
SOUND=((CP(D,T)/CV(D,T))*(DPDD*25311.D0))**.5D0
RETURN
END
DOUBLE PRECISION FUNCTION P MELT(TT)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION A(5)
DATA A/33.28D0,-44.156D0,31.799D0,-4.8159D0,.30313D0/
T=TT
IF(T.LE.5.2D0)GO TO 7

```

```

PMELT=-17.80D0+17.31457D0*T**1.555414D0
PMELT=PMELT*.98066D0/1.01325D0
RETURN
7 P=0.0D0
DO 9 I=1,5
9 P=P+A(I)*T**(I-1)
PMELT=P*9.80665D0/10.1325D0
RETURN
END
DOUBLE PRECISION FUNCTION VIRB(T)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION A(9)
DATA A/-5.0815710041D-7,-1.1168680862D-4,1.1652480354D-2,
1 7.4474587998D-2,-5.3143174768D-1,-9.5759219306D-1,
2 3.9374414843D0,-5.1370239224D0,2.0804456338D0/
C COEFFICIENTS FROM PROGRAM 5/28/70-1630
C THIS SUB PROGRAM CALCULATES THE SECOND VIRIAL COEFFICIENT FOR
C HELIUM. THE RANGE IS FROM 2 TO 1500 DEG K. INPUT IS TEMPERATURE
C IN DEGREES KELVIN
C UNITS ARE ATM, DEG KELVIN, AND MOLES/LITER, 4/3/69-1253, R. D. MCCARTY
C REVISED 2/12/70-925
1 B=0.0D0
DO 5 I=1,9
FI=I
5 B=B+T**(1.5D0-FI/2.D0)*A(I)
VIRB=B
RETURN
END
DOUBLE PRECISION FUNCTION DBDT (T)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION A(9),V(45)
C THIS SUB PROGRAM CALCULATES THE SECOND VIRIAL COEFFICIENT FOR
C HELIUM. THE RANGE IS FROM 2 TO 1500 DEG K. INPUT IS TEMPERATURE
C IN DEGREES KELVIN
DATA A/-5.0815710041D-7,-1.1168680862D-4,1.1652480354D-2,
1 7.4474587998D-2,-5.3143174768D-1,-9.5759219306D-1,
2 3.9374414843D0,-5.1370239224D0,2.0804456338D0/
C UNITS ARE ATM, DEG KELVIN, AND MOLES/LITER, 5/28/70-1630, R. D. MCCARTY
1 B=0.0D0
DO 5 I=1,9
FI=I
5 B=B+T**(.5D0-FI/2.D0)*A(I)*(1.5D0-FI/2.D0)
DBDT=B
RETURN
END
DOUBLE PRECISION FUNCTION D2DBDT2(T)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DIMENSION A(9)
DATA A/-5.0815710041D-7,-1.1168680862D-4,1.1652480354D-2,
1 7.4474587998D-2,-5.3143174768D-1,-9.5759219306D-1,
2 3.9374414843D0,-5.1370239224D0,2.0804456338D0/
C THIS SUB PROGRAM CALCULATES THE SECOND VIRIAL COEFFICIENT FOR
C HELIUM. THE RANGE IS FROM 2 TO 1500 DEG K. INPUT IS TEMPERATURE
C IN DEGREES KELVIN
1 B=0.0D0
DO 5 I=1,9
FI=I
5 B=B+T**(.5D0-FI/2.D0-1.D0)*(1.5D0-FI/2.D0)*(.5D0-FI/2.D0)*A(I)
D2DBDT2=B
RETURN
END
DOUBLE PRECISION FUNCTION FINDTV(PP)

```

```

IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4 (I-N)
P=PP
IF(P.LT..842105D0)GO TO 12
T=5.D0
PCAL=VPN(T)
GO TO 13
12 PCAL=.049737D0
IF(DABS(P-PCAL)-.0000001D0*PP)11,11,1
1 T=2.1720D0
13 DO 10 I=1,50
DP=DPDTVP(T)
DEL=(PCAL-P)/DP
T=T-DEL
PCAL=VPN(T)
IF(DABS(P-PCAL)-.0000001D0*P)11,11,2
2 IF(DABS(DEL)-.0000001D0*T)11,11,10
10 CONTINUE
WRITE(*,100)
11 FINDTV=T
RETURN
100 FORMAT(' TEMPERATURE ITERATION FAILED AT T=',E14.7)
END
DOUBLE PRECISION FUNCTION DPDTVP(TT)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4 (I-N)
DIMENSION C(12),D(14)
DATA C/-3.9394635287D0,141.27497598D0,-1640.7741565D0
1,11974.557102D0,-55283.309818D0,
1166219.56504D0,-325212.82840D0,398843.22750D0,
2-277718.06992D0,83395.204183D0,0.D0,0.D0/
DATA D/-49.510540356D0,651.9236417D0,-3707.5430856D0
1,12880.673491D0,
1 -30048.545554D0,49532.267436D0,-59337.558548D0,52311.296025D0,
2-33950.233134D0,16028.674003D0,-5354.1038967D0,1199.0301906D0,
3 -161.46362959D0,9.8811553386D0/
P=0.0D0
T=TT-DELT(TT)
IF(T-2.1720D0)10,10,1
1 DO 5 I=1,10
5 P=P+C(I)*T**(1-I)*(2-I)
DPDTVP=P*VPN(T)
RETURN
10 DO 15 I=1,14
15 P=P+D(I)*T**(1-I)*(2-I)
DPDTVP=P*VPN(T)
RETURN
END
DOUBLE PRECISION FUNCTION VPN(TT)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4 (I-N)
DIMENSION C(12),D(14)
DATA C/-3.9394635287,141.27497598,-1640.7741565,11974.557102,
1-55283.309818,166219.56504,-325212.82840,398843.22750,
2-277718.06992,83395.204183,0.D0,0.D0/
DATA D/-49.510540356,651.9236417,-3707.5430856,12880.673491,
1 -30048.545554,49532.267436,-59337.558548,52311.296025,
2-33950.233134,16028.674003,-5354.1038967,1199.0301906,
3 -161.46362959,9.8811553386/
T=TT
T=T-DELT(T)
P=0.0D0
IF(T-2.1720D0)10,10,1
1 DO 5 I=1,10
5 P=P+C(I)*T**(2-I)

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      VPN=DEXP(P) /. 76D+6
      RETURN
10 DO 15 I=1, 14
15 P=P+D(I)*T**(2-I)
      VPN=DEXP(P) /. 76D+6
      RETURN
      END
      DOUBLE PRECISION FUNCTION DELT(TT)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      T=TT
      DELT=. 001D0+. 002D0*T
      RETURN
      END
      DOUBLE PRECISION FUNCTION SATV(TT)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      DIMENSION GV(6)
      DATA GV/-. 069267495322D0, -. 1292532553D0, . 29347470712D0
1, -. 40806658212D0, . 35809505624D0, -. 11315580397D0/
      DATA DC/. 06964D0/
      DATA TC/5. 2014D0/
      T=TT
      DCAL=DC
      R=(1. D0/TC)
      DO 1 I=1, 6
      FI=I
1 DCAL=DCAL+GV(I)*R**(FI/3. D0)
      SATV=DCAL
      RETURN
      END
      DOUBLE PRECISION FUNCTION SATL(TT)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      DIMENSION GL(9)
      DATA GL/. 12874326484D0, -. 43128217346D0, 1. 7851911824D0
1, -3. 3509624489D0, 3. 0344215824D0, -1. 0981289602D0, 0. D0, 0. D0, 0. D0/
      DATA DC/. 06964D0/
      DATA TC/5. 2014D0/
      T=TT
      DCAL=DC
      R=(1. D0-T/TC)
      DO 2 I=1, 6
      FI=I
2 DCAL=DCAL+GL(I)*R**(FI/3. D0)
      SATL=DCAL
      RETURN
      END
      DOUBLE PRECISION FUNCTION SURFTEN(T)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      SURFTEN=. 5308D0*(1. -T/5. 2014D0)
      RETURN
      END
      DOUBLE PRECISION FUNCTION R INDEX(D, W)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      DD=D*4. 0026D0/1000. D0
      ALG=0. 123396D0-0. 0014*DD+33701. 617944/D0W**2-12325284955. D0/W**4
      FAC=ALG*DD/0. 95555D0
      R=((2. D0*FAC+1. D0)/(FAC-1. D0))
      IF(R.LT. 0. 0D0) R=R*(-1.)
      R=R**(. 5D0)

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```

RINDEX=R
RETURN
END
DOUBLE PRECISION FUNCTION TMELT(PP)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
P=PP*1.01325D0/.98066D0
IF(P-17.80D0.LT.0.0D0)GO TO 1
TMELT=((P-17.80D0)/17.3145D0)**(1./1.555414D0)
RETURN
1 TMELT=2. D0
RETURN
END
DOUBLE PRECISION FUNCTION FDIEL(D)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
DD=D*4.0026D0/1000. D0
ALPHA=.123396D0-.0014D0*DD
ALPHA=ALPHA*DD *1.04652D0
EPS=(1. D0+2. D0*ALPHA)/(1. D0-ALPHA)
FDIEL=EPS
RETURN
END
DOUBLE PRECISION FUNCTION THERM(DD, TT)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
HELIUM
C THIS ROUTINE CALCULATES THERMAL CONDUCTIVITY AND VISCOSITY
C FOR AN INPUT OF DEGREES KELVIN AND DENSITY IN MOLES PER LITER
C THE RANGE OF TEMPERATURE IS FROM 2 TO 2000 K
C FOR TEMPERATURES BELOW 300 K FORMULAS OFD VINCE ARP AND GE STEWARD
C ARE USED, FOR TEMPERATURES ABOVE 300 THE DILUTE GAS OF A CRITICAL
C COMPILATION FROM ENGLAND IS USED FOR BOTH VISCOSITY AND
C THERMAL CONDUCTIVITY AND THE EXCESS FUNCTIONS FROM THE ROUTINES BY
C ARP AND STEWART) THE EXCESS FUNCTIONS ARE CALCULATED FOR TEMPS
C ABOVE 300 K WITH THE TEMPERATURE DEPENDENCE HELD AT 300 K
C FOR TEMPS BELOW 300 K TO 100 K THE VISCOSITY EXCESS IS CALC
C FROM STEWARTS ROUTINE BUT THE DILUTE GAS VALUES ARE TAKEN FROM
C THE ENGLISH CORRELATION FOR TEMPS BETWEEN 100 AND 110 T
C DILUTE GAS CALCULATION IS AVARAGED
1 D=DD
T=TT
RHO=D*4.0026D-3
IF(T.LT.300. D0)GO TO 5
THO30=VISCX(300. D0)*.00781736D0
THO300=CONZ(300. D0)
DEL300=DELC(300. D0, RHO)
THO=VISCX(T)*.00781736D0+THO300-THO30
THE=THO300*DEL300-THO300
THERM=THO+THE
RETURN
5 THERM=CONZ(T)*DELC(T, RHO)+CRITIC(T, RHO)
C OUTPUT IN MW/CM. K
RETURN
END
DOUBLE PRECISION FUNCTION VISC(DD, TT)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
D=DD
T=TT
IF(T.LT.100. D0)GO TO 10
IF(T.LT.300. D0)GO TO 8
ETA0=VISCX(T)
ETO30=VISCX(300. D0)

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      ETO300=VISC DT(0.0D0,300.D0)
      ETE300=VISC DT(D,300.D0)-ETO300
      VISC=ETAO+ETE300
C   OUTPUT UNITS ARE MICROPOISE
      RETURN
      8 IF(T.LT.110.D0)GO TO 9
      ETAO=VISCX(T)
      ETEB=VISC DT(D,T)-VISC DT(0.0D0,T)
      VISC=ETAO+ETEB
      RETURN
      9 ETA1=VISC DT(0.0D0,100.D0)
      ETA2=VISCX(110.D0)
      ETAO=ETA1+(ETA2-ETA1)*(T-100.D0)/10.D0
      VISC=ETAO+VISC DT(D,T)-VISC DT(0.0D0,T)
      RETURN
      10 VISC=VISC DT(D,T)
      RETURN
      END
      DOUBLE PRECISION FUNCTION VISCX( T )
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
      VISCX=196.D0*T**.71938D0*DEXP( 12.451D0/T-295.67D0/T/T-4.1249D0)
      RETURN
      END
      DOUBLE PRECISION FUNCTION DELC(TEMP, RHO)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
C   K=KZERO*EXPF(B(T)*RHO + C(T)*RHO**2)
C   THIS PROGRAM RETURNS EXPF(B(T)*RHO + C(T)*RHO**2)
      1 BB=DLOG(TEMP)
      CC=1.D0/TEMP
      BETTY=4.7470660612D0-5.3641468153D0*BB+3.4639703698D0*BB**2
      2-1.0702455443D0*BB**3+0.1571349306D0*BB**4-.00892140047D0*BB**5
      B=DEXP(BETTY)
      C=2.2109006708D0+187.74174808D0*CC-1281.0947055D0*CC*CC
      3+3645.2393216D0*CC**3-3986.6937948D0*CC**4
      DELC=DEXP(B*RHO+C*RHO*RHO)
      RETURN
      END
      DOUBLE PRECISION FUNCTION CONZ(TEMP)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
C   KZERO IN MILLIWATTS/CM-K, T IN KELVIN9 22 JUNE 71.
      1 ANNE=DLOG(TEMP)
      PAT=-4.3611622157D0+1.9250159286D0*ANNE-0.52544120165D0*ANNE**2
      1+.090045763885D0*ANNE**3-.0054773874708D0*ANNE**4
      CONZ=DEXP(PAT)
      RETURN
      END
      DOUBLE PRECISION FUNCTION VISC DT(DGC,T)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
      IMPLICIT INTEGER*4(I-N)
C   W. G. STEWARD, S DATA 23 JUNE 71
C   INPUT UNITS ARE KELVIN AND MOL/LITER
C   OUTPUT UNITS ARE MICROPOISE
      TL=DLOG(T)
      R=DGC*4.0026D0/1000.D0
      ANNE=-0.135311743D0/TL+1.00347841D0+1.20654649D0*TL
      1-0.149564551D0*TL*TL+0.0125208416D0*TL**3
      BETTY=R*(-47.5295259D0/TL+87.6799309D0-42.0741589D0*TL
      1+8.33128289D0*TL*TL-0.589252385D0*TL**3)
      CAROL=R*R*(547.309267D0/TL-904.870586D0+431.404928D0*TL
      1-81.4504854D0*TL*TL+5.37008433D0*TL**3)
      DAGMAR=R**3*(-1684.39324D0/TL+3331.08630D0-1632.19172D0*TL

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1+308.804413D0*TL*TL-20.2936367D0*TL**3)
VISCDT=DEXP(ANNE+ BETTY+ CAROL+ DAGMAR)
RETURN
END
DOUBLE PRECISION FUNCTION CRITIC(TEMP, RHO)
IMPLICIT REAL*8 (A-H)
IMPLICIT REAL*8 (O-Z)
IMPLICIT INTEGER*4(I-N)
C CRITICAL ANOMALY FOR HE THERM. CON., SCALED FROM H-2
C T IN KELVIN, REQUIRES DENSITY IN GRAMS/CC AND CP IN JOULES/MOLE
C THIS DECK OF 18 SEPT 70, I HAVE USED MCCARTY'S HE DECKS OF 7/18/70
4 T=TEMP
5 DML=RHO/0.0040026D0
6 IF(T .GE. 11.83D0) GO TO 11
IF(RHO.GT.0.12D0) GO TO 11
7 CP1=CP(DML, T)
8 CP2=CP(DML, 11.83D0)
9 CRITIC=0.0026D0*(CP1-CP2)/4.0026D0
10 IF(CRITIC) 11, 12, 12
11 CRITIC=0.0D0
12 RETURN
END

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-.1509686261900E-06
.6464089890400E-06
.4136235736700E-04
-.3791019035300E-03
.1380645404900E-02
-.2508541205800E-02
.2369756039800E-02
-.9572646106600E-03
.3740593182800E-04
-.6410322033300E-03
.1857936617700E-02
.7400798660600E-03
.1479256814800E-03
-.3253135547700E-02
.1951873928600E-01
-.1057181713500E+00
.3316494444900E+00
-.5113002253500E+00
.3994000490600E+00
-.1555524447100E+00
.4906264031000E-02
-.2614800437700E-01
.3422168554500E-01
.5415966262200E-05
-.1068780677700E-04
-.8948465186900E-05
-.2500000000000E-02
-.4228745462600E-07
.4452935441300E-06
-.1024615095400E-04
.8525460895600E-04
-.2516306925500E-03
.3287770928500E-03
-.1060195758000E-03
-.1068773807400E-03

```

-. 3212095063200E-04
. 1415901897000E-03
. 1472563070100E-02
-. 2618354941000E-02
. 2046150111700E-04
. 1274699628800E-02
-. 2027292958300E-01
. 7464803661500E-01
-. 1721796652100E+00
. 5105343973800E+00
-. 4017820269700E+00
. 2682986463200E+00
. 7906601204000E-02
-. 8939348565600E-01
-. 1507658005300E+00
. 2688249432700E-05
-. 3379431683500E-04
-. 2449595119500E-04
-. 5000000000000E-03
-. 1480219534800E-07
. 4172179111900E-06
-. 2332655327100E-06
. 4085511088000E-06
. 1090056796400E-04
-. 5006095277500E-04
. 1131276504300E-03
-. 1253984328700E-03
. 1966138068800E-05
. 1712293266600E-03
. 2305100056300E-03
-. 9656473910000E-03
-. 3602773529200E-04
. 1607994655500E-02
-. 2744176361500E-01
. 1473950695700E+00
-. 4355934483800E+00
. 1344795607800E+01
-. 1704037512500E+01
. 9026267404000E+00
. 5687564411100E-02
-. 1443814662500E+00
. 3376887485100E-02
. 1075420121800E-05
-. 4526462230800E-04
. 3859738886400E-04
-. 5000000000000E-03

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11. ABSTRACT <i>(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</i> The thermophysical and transport properties of selected fluids have been programmed in FORTRAN 77 which is available for micro computers. The input variables are any two of P, p, T (pressure, density, and temperature) in the single phase regions, and either P or T for the saturated liquid or vapor states. The output is pressure, density, temperature, internal energy, enthalpy, entropy, specific heat capacities (C_p and C_v), speed of sound and, in most cases, viscosity, thermal conductivity, and dielectric constant. The fluids included are: helium, hydrogen, nitrogen, oxygen, argon, nitrogen trifluoride, methane, ethylene, ethane, propane, iso- and normal butane. The programs give properties in both the liquid and vapor states over a wide range of temperature and pressure. Copies of the program may be obtained from the Office of Standard Reference Data, Room A320, Physics Building, National Bureau of Standards, Gaithersburg, MD 20899.			
12. KEY WORDS <i>(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)</i> argon; computer programs; density; dielectric constant; enthalpy; entropy; equation of state; ethane; ethylene; heat capacity; helium; hydrogen; internal energy; isobutane; methane; nitrogen; nitrogen trifluoride; normal butane; oxygen; pressure; speed of sound; temperature; thermal conductivity; viscosity.			
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