NBS TECHNICAL NOTE 1048

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids

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Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids

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Contents

Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids

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An interactive FORTRAN IV computer program is given for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. The program is designed for use with a computer terminal accessing a large computer in an interactive mode. The program provides prompting for selection of several options including: 1) choice of fluid, 2) choice of SI or engineering units, 3) choice of the single phase or liquid-vapor phase, and 4) a table of properties or a single value.

Properties are computed for the single phase region from input of two of the variables, temperature, pressure, and density. Values on the liquid-vapor boundary are computed from an entry of temperature or pressure. The program returns values for pressure, temperature, density, internal energy, enthalpy, entropy, specific heats at constant volume and pressure, and sound velocity. Viscosity, thermal conductivity, and dielectric constant are given for some of the fluids. Copies of the programs may be obtained from Office of Standard Reference Data, Attention: Reference Center, National Bureau of Standards, Washington, D.C. 20234.

Key words: argon; computer programs; density; enthalpy; equation of state; ethylene; hydrogen; nitrogen; nitrogen trifluoride; oxygen; specific heat at constant pressure; specific heat at constant volume.

1. Introduction

This report presents an interactive FORTRAN IV program for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. It is a companion publication to reference [1]. The properties found in this reference are computed from a standard set of equations and are presented in tables. References to the original works from which these correlations were abstracted are given in [1].

This is an interactive program which allows selection of several options including: 1) a choice of fluids, 2) SI or engineering units, 3) properties for the single phase or for the liquid-vapor boundary, and 4) a table of values or a single value. Properties of the homogeneous phase are computed at a single point from entry of any two of the three variables, temperature, pressure, and density. Properties on an isobar may be specified as well. Properties on the liquid-vapor boundary are computed from an entry of temperature or pressure.

2. Computer Routines

This program is a modification of program "Fluids Pack" by R. D. McCarty [2]. An early version of this type of program, which represents the thermophysical properties of several fluids, is program "GASP" (gas properties) by R. C. Hendricks, et al. [3]. The improvements in the experimental data used in the correlations, that have occurred since the publication of [3], have been incorporated in this report. Also, by retaining the same form of the equations for all fluids, the computer programming is much simplified and easier to use. Only the numerical constants, which are found in Appendix E, are changed from one fluid to the next.

A complete listing of the computer program is in Appendices D, E and F. The thermophysical properties produced by this system are the values given in reference [1]. The program is designed to be run interactively and provides instructions for its use and detects certain types of errors such as entry of variables outside of the range of validity for the equation of state. The temperature and pressure range allowed for each fluid is automatically displayed when the fluid is first called. Since the basic equation of state for the fluids is semi-empirical in nature, the program should not be used outside the temperature and pressure range displayed for each fluid. Large errors in calculated properties can be expected outside the allowed ranges. An example of the program in use is presented in appendix B. Properties for computer program verification are given for each of the fluids in appendix C.

3. Thermodynamic and Related Properties

3.1 The Equation of State

The relation for computing pressure as a function of temperature and density is a 32-term modified Benedict-Webb-Rubin (MBWR) equation of state. Its versatility and adaptability to efficient computer technique make it appropriate for use with multiproperty fitting techniques, where deviations from the PVT surface and heat capacity or sound velocity data are minimized simultaneously, resulting in a more accurate model than would be the case if the PVT data alone were used. This technique has been described by R. D. McCarty [2,4]. Other advantages of the MBWR are: (1) accurate representation of the thermodynamic surface over wide ranges of temperature and pressure, (2) adaptability to least squares fitting methods using many different kinds of experimental data, and (3) convenience in correlating data from different sources.

The mathematical form of the MBWR is,

$$
\begin{aligned}
P = \; & \rho RT + \rho^2(G(1)T + G(2)T^{1/2} + G(3) + G(4)/T + G(5)/T^2) \\
& + \rho^3(G(6)T + G(7) + G(8)/T + G(9)/T^2) \\
& + \rho^4(G(10)T + G(11) + G(12)/T) + \rho^5(G(13)) \\
& + \rho^6(G(14)/T + G(15)/T^2) + \rho^7(G(16)/T) \\
& + \rho^8(G(17)/T + G(18)T^2) + \rho^9(G(19)/T^2) \\
& + \rho^3(G(20)/T^2 + G(21)/T^3)\exp(\gamma\rho^2) \\
& + \rho^5(G(22)/T^2 + G(23)/T^4)\exp(\gamma\rho^2) \\
& + \rho^7(G(24)/T^2 + G(25)/T^3)\exp(\gamma\rho^2) \\
& + \rho^9(G(26)/T^2 + G(27)/T^4)\exp(\gamma\rho^2) \\
& + \rho^{11}(G(28)/T^2 + G(29)/T^3)\exp(\gamma\rho^2) \\
& + \rho^{13}(G(30)/T^2 + G(31)/T^3 + G(32)/T^4)\exp(\gamma\rho^2)
\end{aligned}
\tag{1}
$$

The nonlinear coefficient, γ, is defined generally as $\gamma = -1/\rho_c^2$, and is held constant during the fitting process to determine the linear coefficients G(i).

Coefficients for each of the fluids are given in appendix E.

3.2 Two Phase Boundaries

3.2.1 Vapor Pressure

The temperature of the liquid-vapor boundary for each isobar in the tables is computed from a vapor pressure equation,

$$\ell n P = \ell n P_t + V_p(1)x + V_p(2)x^2 + V_p(3)x^3 + V_p(4)x^4 + V_p(5)x(1-x)^{V_p(6)} \qquad (2)$$

where

$$x = (1 - T_t/T)/(1 - T_t/T_c) \qquad (3)$$

The coefficients shown here as V_p are given in appendices D, E and F as VP since these appendices are listings of Fortran programs and subroutines. The same applies for other subscripted coefficients.

3.2.2 Vapor Densities at Coexistence

Densities of the vapor in coexistence with liquid, which are used to generate all the saturated densities given in the tables, are given by

$$\rho = \rho_c + (\rho_{tv} - \rho_c) \exp\ f(T) \qquad (4)$$

and

$$f(T) = A(1)\ \ell n\ x + \sum_{i=2}^{4} A(i)(1 - x^{(i-5)/3}) + \sum_{i=5}^{13} A(i)(1 - x)^{(i-4)/3} \qquad (5)$$

where

$$x = (T - T_c)/(T_t - T_c)\ . \qquad (6)$$

3.2.3 Liquid Densities at Coexistence

The liquid density at coexistence is calculated from,

$$\rho = \rho_c + (\rho_{t\ell} - \rho_c) \exp\ f(T) \qquad (7)$$

and

$$f(T) = A(14)\ \ell n\ x + \sum_{i=15}^{17} A(i)(1 - x^{(i-18)/3}) + \sum_{i=18}^{20} A(i)(1 - x^{(i-17)/3}) \qquad (8)$$

where x is defined in eq 6.

3.2.4 The Melting Line

The pressures at melting are given by,

$$P = P_x(1) + P_x(2)T^{P_x(3)} \qquad (9)$$

3.3 Derived Thermodynamic Properties

The properties derived from the equation of state and ideal heat capacity are entropy, enthalpy, internal energy, specific heat at constant volume and at constant pressure, and sound velocity.

3.3.1 Entropy

The entropy is computed from

$$S(T,\rho) = S_o(T_o) + \int_{T_o}^{T} \left\{ C_p^o/T \right\} dT - R\ \ell n(RT\rho/P_o) + \int_o^{\rho} \left\{ R/\rho - (1/\rho^2)\left(\frac{\partial P}{\partial T}\right)_\rho \right\}_T d\rho\ . \qquad (10)$$

3.3.2 Ideal Gas Specific Heat

The ideal gas specific heat, C_p^o is computed from the following,

$$C_p^o/R = G_i(1)/T^3 + G_i(2)/T^2 + G_i(3)/T + G_i(4) + G_i(5)T + G_i(6)T^2 + G_i(7)T^3 + G_i(8)u^2e^u/(e^u - 1)^2 \quad (11)$$

where,

$$u = G_i(9)/T \quad . \quad (12)$$

3.3.3 Reference State

The reference states S_o and H_o at T = 298.15 K (given below in table 1) are from Wagman, et al. [5], except for parahydrogen which is taken from Woolley, Scott, and Brickwedde [6], since reference [5] gives only the normal hydrogen values.

Table 1. Reference Values for Temperature, Entropy and Enthalpy. The reference value for temperature is T = 298.15 K for all fluids. Values of S° and H° are from NBS TN 270-3 [5], except hydrogen [6].

	S° J/mol K	H° J/mol
argon	154.7335	6169.5
ethylene	219.451	10564.6
parahydrogen	130.407	8409.8
nitrogen	191.502	8669.0
nitrogen trifluoride	260.621	11828.0
oxygen	205.029	8680.1

3.3.4 Enthalpy

The enthalpy is computed from

$$H(T,\rho) = H^\circ + (P - \rho RT)/\rho + \int_0^\rho \left\{ \frac{P}{\rho^2} - \frac{T}{\rho^2}\left(\frac{\partial P}{\partial T}\right)_\rho \right\}_T d\rho + \int_{T_o}^{T} C_p^o \, dT \quad . \quad (13)$$

3.3.5 Internal Energy

The internal energy is,

$$E(T,\rho) = H(T,\rho) - P/\rho \quad . \quad (14)$$

3.3.6 Specific Heat at Constant Volume

The specific heat at constant volume is,

$$C_v(T,\rho) = C_p^o - R - \int_0^\rho \left\{ \frac{T}{\rho^2} \left(\frac{\partial^2 P}{\partial T^2}\right)_\rho \right\}_T d\rho \quad . \quad (15)$$

3.3.7 Specific Heat at Constant Pressure

The specific heat as constant pressure is,

$$C_p(T,\rho) = C_v(T,\rho) + \left\{ \frac{T}{\rho^2} \left(\frac{\partial P}{\partial T}\right)_\rho^2 \Big/ \left(\frac{\partial P}{\partial \rho}\right)_T \right\} \quad . \quad (16)$$

3.3.8 Sound Velocity

The sound velocity can be computed as,

$$W(T,\rho) = \left\{ \frac{C_p}{C_v} \left(\frac{\partial P}{\partial \rho}\right)_T \right\}^{1/2} \quad . \tag{17}$$

4. Transport Properties: Viscosity and Thermal Conductivity

Viscosity and thermal conductivity are given for argon, methane, nitrogen, and oxygen. The theory and discussion of the relations used here are from the work of Hanley, McCarty and Haynes [7]. The functional forms for viscosity and thermal conductivity are,

$$\eta = \eta_0(T) + \eta_1(T)\rho + \eta_2(\rho,T) \tag{18}$$

and

$$\lambda = \lambda_0(T) + \lambda_1(T)\rho + \lambda_2(\rho,T) + \lambda_c(\rho,T) \quad . \tag{19}$$

The first terms of eqs (18) and (19) are the contributions of the dilute gas,

$$\eta_0(T) = \sum_{i=1}^{9} G_v(i)T^{(4-i)/3} \quad ,$$

and (20)

$$\lambda_0(T) = \sum_{i=1}^{9} G_t(i)T^{(4-i)/3} \quad .$$

The second terms in eqs (18) and (19) represent the contribution to the transport coefficients of the moderately dense gas.

$$\eta_1(T) = F_v(1) + F_v(2) \quad F_v(3) - \ln\,(T/F_v(4))^{\;2} \quad ,$$

and (21)

$$\lambda_1(T) = F_t(1) + F_t(2) \quad F_t(3) - \ln\,(T/F_t(4))^{\;2} \quad .$$

The third terms in these equations are the contribution of the dense gas,

$$\eta_2(\rho,T) = \exp F(\rho,T) - \exp G(T) \quad . \tag{22}$$

$$F(\rho,T) = E_v(1) + E_v(2)H(\rho) + E_v(3)\rho^{0.1} + E_v(4)H(\rho)/T^2 + E_v(5)\rho^{0.1}/T^{1.5} + E_v(6)/T + E_v(7)H(\rho)/T \tag{23}$$

$$G(T) = E_v(1) + E_v(2)/T \tag{24}$$

where

$$H(\rho) = \rho^{0.5}\,(\rho - E_v(8))/E_v(8) \quad . \tag{25}$$

The functional forms of eqs (22), (23), (24) and (25) are used for the corresponding thermal conductivity equations with the coefficients E_t substituted for the E_v's.

The last term of eq (19) is the critical enhancement term. Critical effects can be very large, especially in the range $(\rho-\rho_c)/\rho < 0.25$ and $(T-T_c)/T < 0.025$ and in fact, as the critical point is approached, this term may be larger than the sum of the other terms by several orders of magnitude. We include λ_c to give the proper behavior in the critical region and to produce a smooth transition from outside the critical region to within it.

5. Dielectric Constant

The dielectric constant defines the well known Clausius Mossotti relation,

$$C_m = \frac{\varepsilon-1}{\varepsilon+2} 1/\rho \quad . \tag{26}$$

The C_m is represented by the empirical relation,

$$C_m = B_x(1) + B_x(2)\rho + B_x(3)\rho^2 + B_x(4)\rho^3 + B_x(5)T + B_x(6)P \quad . \tag{27}$$

Coefficients are given for parahydrogen, nitrogen, and oxygen, but not for argon, ethylene, or nitrogen trifluoride. The coefficients of Stewart [8] for parahydrogen were modified to conform to eq (27). The data of Ely and Straty for nitrogen [9] were used in a fit of eq (27). The oxygen coefficients are from Younglove [10].

Although the range of the Clausius-Mossotti function for most liquids is small, the very high precision of the data require the terms of eq (27). The temperature and pressure terms are useful in fitting the compressed liquid states. The pressure term allows the flexibility which is useful in fluids with low compressibilities, usually found at low temperatures and high pressures [9].

6. Sample Calculations

In appendix C we have provided numerical values computed from the program (as given in appendices D, E and F). Values for the various properties are given for the saturated vapor and liquid at a pressure of 0.101325 MPa (1 atmosphere), and for the single phase at 35 MPa and 300 K. Failure to reproduce these numbers usually arises from using too few significant figures. This work was done using a 60 bit word. Use of double precision calculations may be necessary on computers with smaller word length.

7. Acknowledgments

We are indebted to the Office of Standard Reference Data of the National Bureau of Standards for its generous support, and to Robert D. McCarty on whose work this report is based.

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Appendix A. List of Symbols and Units.

Primary Thermophysical Quantities.

P, P_c, P_t	pressure, P at critical point, P at triple point, MPa
ρ, ρ_c	density, ρ at critical point, mol/dm^3
$\rho_{t\ell}, \rho_{tv}$	ρ of liquid at triple point, ρ of gas at triple point
T, T_c, T_t	temperature, T at critical point, T at triple point, K
C_p, C_p	specific heat at constant pressure, C_p of ideal gas, J/mol K
C_v, C_v	specific heat at constant volume, C_v for ideal gas, J/mol K
E	internal energy, J/mol
H, H°	enthalpy, reference value of H, J/mol
S, S°	entropy, reference value of S, J/mol K
W	sound velocity, m/s
η	viscosity, μPa s
λ	thermal conductivity, W/m K
ϵ	dielectric constant

Other Variables and Constants.

R	the gas constant, 8.31434 J/mol K
K_t	isothermal bulk modulus, (MPa)$^{-1}$
M_r	molecular weight, g/mol
N_a	Avagodro's number, per mol
C_m	Clausius-Mossotti function
T_o	reference temperature, 298.15 K

Critical Point Values.

	P_c (MPa)	ρ_c (mol/dm^3)	T_c (K)
Ar	4.9058	13.41	150.86
C_2H_4	5.0404	7.650	282.34
H_2	1.28377	15.556	32.938
N_2	3.39908	11.21	126.26
Nf_3	4.4607	7.92	234.0
O_2	5.043	13.630	154.581

```
 CALL,FLUIDS

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

  WHEN THE PROGRAM ASKS FOR A FLUID SELECTION, ENTER THE APPROPRIATE
  NUMBER.  AN INAPPROPRIATE NUMBER WILL TERMINATE THE PROGRAM.  WHEN
  IT ASKS FOR A PRESSURE, DENSITY, AND TEMPERATURE, ENTER ANY TWO OF
  OF THE THREE AND A ZERO FOR THE THIRD.
  THE ORDER MUST BE P,D,T, AND ONE OF THE THREE MUST BE ZERO.
  IF ALL THREE ARE ZERO THE PROGRAM ASKS FOR A NEW FLUID.

  SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER
 1=ARGON,      2=ETHYLENE,               3=PARA HYDROGEN,
 4=NITROGEN,   5=NITROGEN TRIFLUORIDE,   6=OXYGEN            7=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.
? 10 100 150 10

   P      T      DEN     E      H      S    CV    CP   SOUND  VISC  COND
   MPA    K      MOL/L  === J/MOL/ == ==== J/MOL-K ===  M/S    PA-S MW/M-K
                                                               E+6
 10.000 100.000 33.744 -4271. -3974.  59.6 20.4  44.0  800. 205.0 115.1
 10.000 110.000 32.191 -3839. -3529.  63.8 19.5  45.2  739. 162.7 102.9
 10.000 120.000 30.525 -3396. -3069.  67.8 18.8  46.9  672. 131.2  92.1
 10.000 130.000 28.695 -2936. -2587.  71.7 18.2  49.5  602. 106.4  81.8
 10.000 140.000 26.609 -2447. -2072.  75.5 17.6  54.1  526.  85.9  71.7
 10.000 150.000 24.096 -1909. -1494.  79.5 17.3  62.3  444.  67.9  61.7

 ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE
 AND A TEMPERATURE INCREMENT AND IN THAT ORDER
? 0 0 0 0

  SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER
 1=ARGON,      2=ETHYLENE,               3=PARA HYDROGEN,
 4=NITROGEN,   5=NITROGEN TRIFLUORIDE,   6=OXYGEN            7=STOP
? 8

 EXIT.
```

ARGON PROPERTIES.

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND
K	MOL/L	=== J/MOL ===		==== J/MOL-K ====			M/S	PA-S E+6	MW/M-K
SATURATED VAPOR AT 0.101325 MPA.									
87.2815	.1446	1038.7	1739.4	128.63	13.22	22.76	170.7	7.3	5.9
SATURATED LIQUID AT 0.101325 MPA.									
87.2815	34.8946	-4708.7	-4705.8	54.82	22.27	44.73	814.4	260.3	128.3
SINGLE PHASE AT 35 MPA AND 300 K.									
300.0000	13.6426	1830.3	4395.8	100.94	14.07	32.82	445.8	39.5	36.9

ETHYLENE PROPERTIES

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND
K	MOL/L	=== J/MOL ===		==== J/MOL-K ====			M/S	PA-S E+6	MW/M-K
SATURATED VAPOR AT 0.101325 MPA.									
169.4093	.0744	4180.6	5541.6	197.66	27.13	36.89	252.3		
SATURATED LIQUID AT 0.101325 MPA.									
169.4093	20.2449	-8001.8	-7996.8	117.73	38.22	67.92	1310.1		
SINGLE PHASE AT 35 MPA AND 300 K.									
300.0000	15.8136	-504.6	1708.7	151.74	41.68	70.79	868.6		

HYDROGEN PROPERTIES

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
K	MOL/L	=== J/MOL ===		==== J/MOL-K ====			M/S	PA-S E+6	MW/M-K	==
SATURATED VAPOR AT 0.101325 MPA.										
20.27	.664	229.5	382.0	60.40	13.31	24.68	354.			1.00404
SATURATED LIQUID AT 0.101325 MPA.										
20.27	35.118	-518.9	-516.0	16.11	11.43	19.49	1100.			1.22981
SINGLE PHASE AT 35 MPA AND 300 K.										
300.00	11.517	5837.0	8875.8	81.58	22.23	31.12	1609.			1.07174

NITROGEN PROPERTIES.

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
K	MOL/L	=== J/MOL ===		==== J/MOL-K ====			M/S	PA-S E+6	MW/M-K	==
SATURATED VAPOR AT 0.101325 MPA.										
77.36	.164	1548.0	2163.5	151.54	21.59	31.45	175.	5.3	7.6	1.00217
SATURATED LIQUID AT 0.101325 MPA.										
77.36	28.863	-3404.3	-3400.8	79.54	27.82	57.80	939.	151.6	133.7	1.43356
SINGLE PHASE AT 35 MPA AND 300 K.										
300.00	11.756	4623.9	7601.1	138.73	22.29	38.11	514.	28.7	48.0	1.16337

NITROGEN TRIFLUORIDE PROPERTIES.

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND
K	MOL/L	=== J/MOL	===	==== J/MOL-K		====	M/S	PA-S E+6	MW/M-K
SATURATED VAPOR AT 0.101325 MPA.									
144.1082	.0879	3575.7	4728.5	227.83	29.65	39.49	144.1		
SATURATED LIQUID AT 0.101325 MPA.									
144.1082	21.6563	-6832.5	-6827.8	147.66	40.30	72.20	757.5		
SINGLE PHASE AT 35 MPA AND 300 K.									
300.0000	14.3859	3299.9	5732.9	197.40	50.03	80.58	412.4		

OXYGEN PROPERTIES.

T	DEN	E	H	S	CV	CP	SOUND	VISC	COND	DIEL
K	MOL/L	=== J/MOL	===	==== J/MOL-K		====	M/S	PA-S E+6	MW/M-K	==
SATURATED VAPOR AT 0.101325 MPA.										
90.19	.140	1811.5	2535.6	169.58	21.72	31.34	178.	6.7	8.5	1.00166
SATURATED LIQUID AT 0.101325 MPA.										
90.19	35.658	-4265.5	-4262.7	94.19	29.54	54.22	905.	194.7	151.8	1.48704
SINGLE PHASE AT 35 MPA AND 300 K.										
300.00	13.742	4233.0	6780.0	150.97	22.62	41.95	442.	34.7	46.4	1.17222

```
      PROGRAM FLUIDS(INPUT,OUTPUT)
      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/DIEL/BX(6),PX(6)
 1000 FORMAT(* FOR INFORMATION ON HOW TO USE THIS PROGRAM, ENTER "0" *
     A * OTHERWISE, ENTER "1"*)
      PRINT 1000
      IP=3
      PRINT 1210
      READ 1010,I
      IF(I.EQ.0)CALL INFO
      PRINT 1210
 1010 FORMAT(I1)
  110 PRINT 1020
      PRINT 1030
 1020 FORMAT(*  SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER*)
 1030 FORMAT(* 1=ARGON,      2=ETHYLENE,              3=PARA HYDROGEN,
     A    *,/,* 4=NITROGEN,   5=NITROGEN TRIFLUORIDE,   6=OXYGEN*
     B ,*             7=STOP*)
      READ *,IF
      PRINT 1210
      GO TO(1,2,3,4,5,6,999),IF
    1 CALL DATA AR
      GO TO 120
    2 CALL DATA C3
      GO TO 120
    3 CALL DATA PH2
      GO TO 120
    4 CALL DATA N2
      GO TO 120
    5 CALL DATA NF3
      GO TO 120
    6 CALL DATA O2
      GO TO 120
  120 PRINT 1040
 1040 FORMAT(* FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"*)
      READ 1010,IU
      PRINT 1210
      PRINT 1050
 1050 FORMAT(* FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER *
     A *"1"*)
      READ 1010,IC
      PRINT 1210
      PRINT 1060
 1060 FORMAT(* FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"*)
      READ 1010,IV
      PRINT 1210
  160 IF(IC.EQ.0)GO TO 240
      IF(IV.EQ.1)GO TO 330
  170 IF(IU.EQ.0)GO TO 180
      PRINT 1080
      READ *,P,D,T
      PRINT 1210
      GO TO 190
  180 PRINT 1070
 1070 FORMAT(* ENTER PRESSURE(PSIA), DENSITY(LB/CU FT), AND TEMPERATURE*
     A *(F)*)
      READ *,P,D,T
      PRINT 1210
      P=(P/14.695949)*.101325
```

```
      D=D*16.01846371/EM
      IF(T.EQ.0.0)GO TO 190
      T=(T-32.)/1.8+273.15
  190 IF(P.LE.0.0)GO TO 220
 1080 FORMAT(* ENTER PRESSURE(MPA), DENSITY(MOL/L), AND TEMPERATURE(K)*)
      IF(D.LE.0.0)GO TO 210
      IF(T.LE.0.0)GO TO 200
      GO TO 170
  200 IF(P.LE.0.OR.D.LE.0.0)GO TO 110
      T=FIND T(P,D)
      CALL LIMITS(P,T,IL)
      IF(IL.LE.0)GO TO 170
      GO TO 230
  210 IF(T.LE.0.OR.P.LE.0)GO TO 110
      CALL LIMITS(P,T,IL)
      IF(IL.LE.0)GO TO 170
      D=FIND D(P,T)
      GO TO 230
  220 IF(D.LE.0.0.OR.T.LE.0)GO TO 110
      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 PRINT 1090
 1090 FORMAT(* FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"*)
      READ 1010,IP
      PRINT 1210
      IF(IV.EQ.1)GO TO 330
      PRINT 1095
 1095 FORMAT(* TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"*)
      READ 1010,II
      PRINT 1210
      IF(II.EQ.1)GO TO 290
  250 IF(IU.EQ.1)GO TO 260
 1100 FORMAT(* ENTER A TEMPERATURE IN DEGREES F*)
      PRINT 1100
      READ *,TI
      PRINT 1210
      T=(TI-32.)/1.8+273.15
      IF(T.LE.0.0)GO TO 110
      GO TO 270
  260 PRINT 1110
 1110 FORMAT(* ENTER A TEMPERATURE(K)*)
      READ *,T
      PRINT 1210
  270 IF(T.LT..000001)GO TO 110
      IF(T.GT.TCC.OR.T.LT.TTP)GO TO 280
      P=VPN(T)
      IF(IP.EQ.0)P=P+.00001
      D=FIND D(P,T)
      CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
      GO TO 250
  280 PRINT 1120,TTP,TCC,(TTP-273.15)*1.8+32.,(TCC-273.15)*1.8+32.
 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
      PRINT 1130
 1130 FORMAT(* ENTER A PRESSURE IN LB/SQ IN*)
      READ *,PI
      PRINT 1210
      IF(PI.LE.0.0)GO TO 110
      P=(PI/14.695949)*.101325
      GO TO 310
```

```
 300 PRINT 1140
1140 FORMAT(* ENTER A PRESSURE(MPA)*)
     READ *,PI
     PRINT 1210
     IF(PI.LE.0.0)GO TO 110
     P=PI
 310 IF(P.GT.PCC.OR.P.LT.PTP)GO TO 320
     T=FIND TV(P)
     P=VPN(T)
     IF(IP.EQ.0)P=P+.00001
     D=FIND D(P,T)
     CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
     GO TO 290
 320 PRINT 1150, PTP,PCC
1150 FORMAT(* YOUR INPUT PRESSURE IS OUTSIDE THE RANGE OF SATURATION*
    A * PRESSURES*/* FOR THIS FLUID.  TRIPLE POINT=*,F6.5,* MPA,*
    B *  CRITICAL POINT=*,F6.3,* MPA*/*  TRY AGAIN*)
     GO TO 290
 330 IF(IC.EQ.1)GO TO 370
     IF(IU.EQ.1)GO TO 340
     PRINT 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
     PRINT 1210
     IF(DELT.LE.0.0)GO TO 110
     TS=(TS-32.)/1.8+273.15
     TF=(TF-32.)/1.8+273.15
     DELT=DELT/1.8
     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 PRINT 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
     PRINT 1210
     IF(DELT.LE.0.0)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.0.0)P=P+.00001
     D=FIND D(P,T)
     CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
     GO TO 330
 360 PRINT 1180,TTP,TCC,(TTP-273.15)*1.8+32.,(TCC-273.15)*1.8+32
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
     PRINT 1190
1190 FORMAT(* ENTER PRESSURE(PSIA), STARTING TEMPERATURE(F), FINAL *
    A *TEMPERATURE(F)*/* AND A TEMPERATURE INCREMENT, IN THAT ORDER*)
     READ *,PI,TS,TF,DELT
     PRINT 1210
     IF(DELT.LE.0.0)GO TO 110
     P=(PI/14.695949)*.101325
     T=(TS-32.)/1.8+273.15
     TF=(TF-32.)/1.8+273.15
     DELT=DELT/1.8
     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 PRINT 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
      PRINT 1210
      IF(DELT.LE.0.0)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=FIND D(P,T)
      CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
      GO TO 370
  999 CONTINUE
 1210 FORMAT(* *)
      END


      SUBROUTINE REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
      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.
      IF(IU.EQ.0)GO TO 100
      PRINT 1000
      PRINT 1010
      PRINT 1020
      GO TO 110
  100 PRINT 1000
      PRINT 1030
      PRINT 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-1000.*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.4.OR.IF.EQ.6) GO TO 150
C     IF=4 FOR N2,  IF=6 FOR O2.
      IF(IF.EQ.1) GO TO 140
C     IF=1 FOR AR
      IF(IF.EQ.3) GO TO 130
C     IF=3 FOR H2
C     IF=2 FOR C2H4, IF=5 FOR NF3
      PRINT 2000, P,T,D,E,H,S,CVV,CPP,W
      GO TO 200
  130 EPS=DIEL(P,D,T)
      PRINT 2010, P,T,D,E,H,S,CVV,CPP,W,EPS
      GO TO 200
  140 TH=THERM(D,T)*1000.
      V=VISC(D,T)
      PRINT 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.
      EPS=DIEL(P,D,T)
      PRINT 2030, P,T,D,E,H,S,CVV,CPP,W,V,TH,EPS
      GO TO 200
  160 H=H/(2.324445*EM)
      E=E/(2.324445*EM)
      S=S/(4.184001*EM)
      CPP=CPP/(4.184001*EM)
      CVV=CVV/(4.184001*EM)
      W=W*3.280840
      PO=(P/.101325)*14.695949
      DO=D*EM/16.01846371
      TO=T*1.8-459.67
      IF(IF.EQ.4.OR.IF.EQ.6) GO TO 190
      IF(IF.EQ.1) GO TO 180
      IF(IF.EQ.3) GO TO 170
      PRINT 3000, PO,TO,DO,E,H,S,CVV,CPP,W
      GO TO 200
  170 EPS=DIEL(P,D,T)
      PRINT 3010, PO,TO,DO,E,H,S,CVV,CPP,W,EPS
      GO TO 200
  180 V=VISC(D,T)*.067196897
      TH=THERM(D,T)*.578176
      PRINT 3020, PO,TO,DO,E,H,S,CVV,CPP,W,V,TH
      GO TO 200
  190 V=VISC(D,T)*.067196897
      TH=THERM(D,T)*.578176
      EPS=DIEL(P,D,T)
      PRINT 3030, PO,TO,DO,E,H,S,CVV,CPP,W,V,TH,EPS
  200 T=T+DELT
      IF(T.GT.TF+.01)GO TO 220
      IF(IC.EQ.0)P=VPN(T)
      IF(IP.EQ.0)P=P+.00001
  210 CONTINUE
  220 CONTINUE
      PRINT 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+7")
 2000 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0)
 2010 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,13X,F8.5)
 2020 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1)
 2030 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1,F8.5)
 3000 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0)
 3010 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,11X,F8.5)
 3020 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4)
 3030 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4,F8.5)
      END
```

```
      SUBROUTINE DATA AR
      DIMENSION G(32),VP(9)
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      DIMENSION A(20)
      COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
      COMMON/SATC/A,DTPV
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      COMMON/CPID/GI(11),GH(11),GL(11)
      COMMON/ISP/N,NW,NWW
      COMMON/FIXPT/TO,SO,HO
      COMMON/DIEL/BX(6),PX(6)
      NWW=0
      PRINT 100
  100 FORMAT(* THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K*
     1/* WITH PRESSURES TO 100 MPA*)
      N=0 $ NW=1
      EM=39.948 $ EOK=152.8 $ RM=3.669E-08 $ TC=150.725
      DC=0.533  $ X=1.7124   $ PC=4.8619    $ SIG=3.297
      XO=0.183  $ BETA=0.355 $ DELTA=4.352 $ E1=2.27 $ E2=0.287
      AGAM=1.190
C
C ****  ARGON COEFFICIENTS FOR MBWR EQN
C
      G( 1)= -.65697312940E-04
      G( 2)=  .18229578010E-01
      G( 3)= -.36494701410E+00
      G( 4)=  .12320121070E+02
      G( 5)= -.86135782740E+03
      G( 6)=  .79785796910E-05
      G( 7)= -.29114891100E-02
      G( 8)=  .75818217580E+00
      G( 9)=  .87804881690E+03
      G(10)=  .14231459890E-07
      G(11)=  .16741461310E-03
      G(12)= -.32004479090E-01
      G(13)=  .25617663720E-05
      G(14)= -.54759349410E-04
      G(15)= -.45050320580E-01
      G(16)=  .20132546530E-05
      G(17)= -.16789412730E-07
      G(18)=  .42073292710E-04
      G(19)= -.54442129960E-06
      G(20)= -.80048550110E+03
      G(21)= -.13193042010E+05
      G(22)= -.49549239300E+01
      G(23)=  .80921321770E+04
      G(24)= -.98701040610E-02
      G(25)=  .20204415620E+00
      G(26)= -.16374172050E-04
      G(27)= -.70389441360E-01
      G(28)= -.11543245390E-07
      G(29)=  .15559901170E-05
      G(30)= -.14921785360E-10
      G(31)= -.10013560710E-08
      G(32)=  .29339632160E-07
      GAMMA=-.0055542372
C
C ****  ARGON COEFFICIENTS FOR VAPOR PRESSURE
C
      VP(1)=   3.4151115519    $  VP(2)=   1.1910812519
```

```
      VP(3)=   -.3407632334    $  VP(5)=    .89555855251
      VP(6)=   1.5             $  VP(9)=    .06890606625
      VP(7)=  83.80            $  VP(8)= 150.86
      VP(4)=   0.0
C
C ****  ARGON COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C
      A( 1)=  -.270262923777E+02
      A( 2)=   .131040241866E+00
      A( 3)=  -.267486438128E+01
      A( 4)=   .300176804406E+02
      A( 5)=  -.875899149326E+02
      A( 6)=  -.408267436456E+02
      A( 7)=   .104268066451E+03
      A( 8)=  -.671278555379E+02
      A( 9)=   .151002935701E+02
      A(10)=  -.331243536637E+02
      A(11)=   .633146212581E+02
      A(12)=  -.427149706899E+02
      A(13)=   .100599900030E+02
      A(14)=   .137682084900E+02
      A(15)=  -.664630363191E-01
      A(16)=   .133368782730E+01
      A(17)=  -.144371463244E+02
      A(18)=   .601938472000E+02
      A(19)=  -.230888463887E+02
      A(20)=   .465318358887E+01
C
C ****  ARGON COEFFICIENTS FOR IDEAL GAS  CP.
C
      GI(1)=GI(2)=GI(3)=0
      GI(4)=GI(9)=2.5
      GI(5)=GI(6)=GI(7)=0
      GI(8)=0
      GI(10)=GI(11)=0.0
C
C ****  ARGON COEFFICIENTS FOR FIRST TERM OF VISCOSITY EQN.
C ****  VISCOSITY IN MICRO-PA*S, DENSITY IN G/CC.
C
      GV(1)=  .61145472787E+04  $  GV(2)= -.10394390312E+05
      GV(3)=  .67594614619E+04  $  GV(4)= -.22536509380E+04
      GV(5)=  .42593950138E+03  $  GV(6)= -.47252671093E+02
      GV(7)=  .31795275425E+01  $  GV(8)= -.11629083780E+00
      GV(9)=  .18043010592E-02
C
C ****  ARGON COEFFICIENTS FOR FIRST TERM OF THERMAL CONDUCTIVITY EQN.
C ****  THERMAL CONDUCTIVITY IN WATT/(M*K), DENSITY IN G/CC.
C
      GT(1)=  .62777703742E+01  $  GT(2)= -.96096376637E+01
      GT(3)=  .58887549191E+01  $  GT(4)= -.18920926320E+01
      GT(5)=  .34886571437E+00  $  GT(6)= -.38016786193E-01
      GT(7)=  .25207283167E-02  $  GT(8)= -.91098744478E-04
      GT(9)=  .13990842942E-05
C
C ****  ARGON COEFFICIENTS FOR SECOND TERM OF VISCOSITY EQN.
C
      FV(1)=  .14653652433E+00  $  FV(2)= -.77487424965E-01
      FV(3)=  .14000000000E+01  $  FV(4)=  .15280000000E+03
C
C ****  ARGON COEFFICIENTS FOR SECOND TERM OF THERMAL CONDUCTIVITY EQN.
C
      FT(1)=  .24142103270E-01  $  FT(2)=  .75696234255E-02
      FT(3)=  .10000000000E+01  $  FT(4)=  .15280000000E+03
C
C ****  ARGON COEFFICIENTS FOR THIRD TERM OF VISCOSITY EQN.
```

```
C
      EV(1)= -.12313579086E+02  $  EV(2)=  .20694685712E+00
      EV(3)=  .16029145122E+02  $  EV(4)=  .11717461351E+04
      EV(5)= -.56995898780E+03  $  EV(6)=  .40136071933E+02
      EV(7)=  .39870122403E+02  $  EV(8)=  .53700000000E+00
C
C ****  ARGON COEFFICIENTS FOR THIRD TERM OF THERMAL CONDUCTIVITY EQN.
C
      ET(1)= -.33327027332E+02  $  ET(2)= 0.0
      ET(3)=  .30694859971E+02  $  ET(4)= 0.0
      ET(5)=  .22956551674E+04  $  ET(6)= -.35559415848E+03
      ET(7)= 0.0                $  ET(8)= 1.0
C
C ****  ARGON COEFFICIENTS FOR MELTING EQUATION.
C
      PX(1)= -.210562165E+03
      PX(2)=  .177760527E+00
      PX(3)=  .159817868E+01

C     THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     ARGON

      R=.08205616*.101325
      TO=298.15  $  SO=154.7335  $  HO=6196.5
      GI(10)=HO-HI(TO)
      GI(11)=SO-SI(TO)
      DTP=.3540027619188E+02
      DTPV=.1029227022329
      TCC=VP(8)
      PCC=VPN(TCC)
      PTP=VP(9)
      TTP=VP(7)
      TUL=400.
      TLL=TTP
      PUL=100.
      DCC=13.41
      RETURN
      END


C
C
      SUBROUTINE DATA C3
C     COEFFICIENTS FOR ETHYLENE
      DIMENSION A(20)
      DIMENSION G(32),VP(9)
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(4)
      COMMON/CPID/GI(11),GH(11),GL(11)
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      COMMON/ISP/N,NW,NWW
      COMMON/SATC/A,DTPV
      COMMON/DIEL/BX(6),PX(6)
      N=0
      PRINT 100
  100 FORMAT(* THE TEMPERATURE RANGE FOR ETHYLENE IS 104 TO 400K*
     1/* WITH PRESSURES TO 40 MPA*)
C
C ****  ETHYLENE COEFFICIENTS FOR MBWR EQN
C
      G( 1)= -.2146684366683E-02
      G( 2)=  .1791433722534E+00
      G( 3)= -.3675315603930E+01
      G( 4)=  .3707178934669E+03
      G( 5)= -.3198282566709E+05
      G( 6)=  .5809379774732E-04
      G( 7)= -.7895570824899E-01
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      G( 8)=  .1148620375835E+02
      G( 9)=  .2713774629193E+05
      G(10)= -.8647124319107E-05
      G(11)=  .1617727266385E-01
      G(12)= -.2731527496271E+01
      G(13)= -.2672283641459E-03
      G(14)= -.4752381331990E-02
      G(15)= -.6255637346217E+01
      G(16)=  .4576234964434E-03
      G(17)= -.7534839269320E-05
      G(18)=  .1638171982209E-01
      G(19)= -.3563090740740E-03
      G(20)= -.1833000783170E+05
      G(21)= -.1805074209985E+07
      G(22)= -.4794587918874E+03
      G(23)=  .3531948274957E+07
      G(24)= -.2562571039155E+01
      G(25)=  .1044308253292E+03
      G(26)= -.1695303363659E-01
      G(27)= -.1710334224958E+03
      G(28)= -.2054114462372E-04
      G(29)=  .6727558766661E-02
      G(30)= -.1557168403328E-06
      G(31)= -.1229814736077E-04
      G(32)=  .4234325938573E-04
      GAMMA=-.0172
C
C ****  ETHYLENE COEFFICIENTS FOR VAPOR PRESSURE
C
      VP(1)=   8.2095798       $  VP(2)=   4.315424145
      VP(3)=  -1.692585975     $  VP(5)=   3.446501098
      VP(6)=   1.5             $  VP(9)=    .00012129514
      VP(7)= 103.986           $  VP(8)= 282.3428
      VP(4)=   -.1976495575
C
C ****  ETHYLENE COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C
      A( 1)=  -.609621515594E+02
      A( 2)=   .203185312702E-01
      A( 3)=  -.925441265813E+00
      A( 4)=   .243630795888E+02
      A( 5)=  -.854745622888E+03
      A( 6)=   .123927868183E+04
      A( 7)=  -.142710711789E+04
      A( 8)=   .837358670405E+03
      A( 9)=   .432203696552E+03
      A(10)=  -.137917541161E+04
      A(11)=   .126858600124E+04
      A(12)=  -.571552321713E+03
      A(13)=   .106012234360E+03
      A(14)=  -.479047060183E+01
      A(15)=   .151381345283E-01
      A(16)=  -.403456079445E+00
      A(17)=   .508683920225E+01
      A(18)=  -.246711997987E+02
      A(19)=   .980030915247E+01
      A(20)=  -.216846516122E+01
C
C ****  ETHYLENE COEFFICIENTS FOR IDEAL GAS HEAT CP.
C
      GI(1)=.5603615762E+6
      GI(2)=-.2141069802E+5
      GI(3)=.2532008897E+3
      GI(4)=.3554495281E+1
      GI(5)=-.9951927478E-2
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      GI(6)=.5108931070E-4
      GI(7)=-.1928667482E-7
      GI(8)=-.2061703241E+2
      GI(9)=.3E+4
      GI(10)=GI(11)=0
      TO=298.15  $  SO=219.451   $  HO=10564.6
      GI(10)=HO-HI(TO)
      GI(11)=SO-SI(TO)
C
C ****  ETHYLENE COEFFICIENTS FOR MELTING EQUATION.
C
      PX(1)= -.357923875E+03
      PX(2)=  .245332143E-01
      PX(3)=  .206450000E+01

C     THE FOLLOWING CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     ETHYLENE

      GAMMA=-.0172
      R=.08205616*.101325
      DTP=23.34296694034
      DTPV=.1425455127094E-03
      EM=28.054
      TCC=VP(8)
      PCC=VPN(TCC)
      PTP=VP(9)
      TTP=VP(7)
      TUL=400.
      TLL=TTP
      PUL=40.
      DCC=7.650
      RETURN
      END


C
      SUBROUTINE DATA P H2
      DIMENSION G(32),VP(9),GI(11),GH(11),GL(11)
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      DIMENSION A(20)
      COMMON/SATC/A,DTPV
      COMMON/CPID/GI,GH,GL
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      COMMON/DIEL/BX(6),PX(6)
      COMMON/ISP/N,NW,NWW
      N=1
      PRINT 100
  100 FORMAT(* THE TEMPERATURE RANGE FOR HYDROGEN IS 13.8 TO 400 K*
     1/* WITH PRESSURES TO 120 MPA*)
C
C ****  PARAHYDROGEN COEFFICIENTS FOR MBWR EQUATION.
C
      G( 1)=  .4675528393416E-04
      G( 2)=  .4289274251454E-02
      G( 3)= -.5164085596504E-01
      G( 4)=  .2961790279801E+00
      G( 5)= -.3027194968412E+01
      G( 6)=  .1908100320379E-05
      G( 7)= -.1339776859288E-03
      G( 8)=  .3056473115421E-01
      G( 9)=  .5161197159532E+01
      G(10)=  .1999981550224E-07
      G(11)=  .2896367059356E-04
      G(12)= -.2257803939041E-02
      G(13)= -.2287392761826E-06
      G(14)=  .2446261478645E-05
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      G(15)= -.1718181601119E-03
      G(16)= -.5465142603459E-07
      G(17)=  .4051941401315E-09
      G(18)=  .1157595123961E-06
      G(19)= -.1269162728389E-08
      G(20)= -.4983023605519E+01
      G(21)= -.1606676092098E+02
      G(22)= -.1926799185310E-01
      G(23)=  .9319894638928E+00
      G(24)= -.3222596554434E-04
      G(25)=  .1206839307669E-03
      G(26)= -.3841588197470E-07
      G(27)= -.4036157453608E-05
      G(28)= -.1250868123513E-10
      G(29)=  .1976107321888E-09
      G(30)= -.2411883474011E-13
      G(31)= -.4127551498251E-13
      G(32)=  .8917972883610E-12
      GAMMA=-.0041
C
C ****  PARAHYDROGEN COEFFICIENTS FOR VAPOR PRESSURE
C
      VP(1)=   3.05300134164    $  VP(2)=   2.80810925813
      VP(3)=  -0.655461216567   $  VP(5)=   1.59514439374
      VP(6)=   1.5814454428     $  VP(9)=   0.0070420875
      VP(7)=  13.8              $  VP(8)=  32.938
      VP(4)=   0.0
C
C ****  PARAHYDROGEN COEFFICIENTS.  SATURATED LIQUID AND VAPOR DENSITIES.
C
      A( 1)=   .916617720187E+02
      A( 2)=  -.179492524446E+00
      A( 3)=   .454671158395E+01
      A( 4)=  -.658499589788E+02
      A( 5)=   .734466804535E+03
      A(.6)=  -.682501045175E+03
      A( 7)=   .631783674710E+03
      A( 8)=  -.539408873282E+03
      A( 9)=   .430923811783E+03
      A(10)=  -.300295738811E+03
      A(11)=   .156567165346E+03
      A(12)=  -.504103608225E+02
      A(13)=   .720706926514E+01
      A(14)=  -.123944440318E+03
      A(15)=   .140334800142E+01
      A(16)=  -.211023804313E+02
      A(17)=   .173254622817E+03
      A(18)=  -.444294580871E+03
      A(19)=   .138699365355E+03
      A(20)=  -.235774161015E+02
C
C ****  PARAHYDROGEN COEFFICIENTS FOR IDEAL GAS CP.
C       FOR TEMPERATURES  > 140 K.
C
      GH( 1)=  .5262185164597E+08
      GH( 2)= -.1487906248823E+07
      GH( 3)=  .1601391392264E+05
      GH( 4)= -.8031235938946E+02
      GH( 5)=  .2307407941873E+00
      GH( 6)= -.3176386248370E-03
      GH( 7)=  .1643857271214E-06
      GH( 8)=  .9230816464058E+01
      GH( 9)=  .3E+4
      GH(10)= 0.0
      GH(11)= 0.0
```

```
C
C ****  PARAHYDROGEN COEFFICIENTS FOR IDEAL GAS CP.
C       FOR TEMPERATURES  40 < T < 140 K.
C
      GL( 1)=  .2905965792270E+06
      GL( 2)= -.2831103639248E+05
      GL( 3)=  .1050424877391E+04
      GL( 4)= -.1535751501769E+02
      GL( 5)=  .1218941696566E+00
      GL( 6)= -.2599406479908E-04
      GL( 7)= -.1288757333406E-05
      GL( 8)=  .1717441975231E+06
      GL( 9)=  .3E+4
      GL(10)= 0.0
      GL(11)= 0.0
      TO=298.15  $  SO=130.407   $  HO=8409.8
C         HO AND SO TAKEN FROM WOOLLEY, SCOTT, AND BRICKWEDDE
C         NBS RP 1932, PAGE 387. VALUES FOR PARAHYDROGEN.
      GH(10)=HO-HI(TO)
      GL(10)=GH(10)
      GH(11)=SO-SI(TO)
      GL(11)=GH(11)
C
C
C ****  PARAHYDROGEN COEFFICIENTS FOR MELTING PRESSURE.
C       FOR TEMPERATURES  < 22 K :
C
      PX(1)= -21.281484395
      PX(2)=     .125746643
      PX(3)=   1.955
C
C ****  PARAHYDROGEN COEFFICIENTS FOR MELTING PRESSURE.
C       FOR TEMPERATURES > 22 K :
C
      PX(4)= -26.5289115
      PX(5)=     .248578596
      PX(6)=   1.764739
C
C ****  PARAHYDROGEN COEFFICIENTS FOR DIELECTRIC CONSTANT.
C
      BX(1)=  .20245443E-02
      BX(2)=  .37171832E-06
      BX(3)= -.92085013E-08
      BX(4)= -.34065328E-11
      BX(5)=  .0
      BX(6)=  .0

C     THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     PARAHYDROGEN

      R=.08205616*.101325
      DTP=.3821428945438E+02
      DTPV=.6322296353698E-01
      EM=2.01594
      TCC=VP(8)
      PCC=VPN(TCC)
      PTP=VP(9)
      TTP=VP(7)
      TUL=400.
      TLL=TTP
      PUL=120.
      DCC=15.556
      RETURN
      END
```

```
C
      SUBROUTINE DATA N2
      DIMENSION G(32),VP(9)
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      DIMENSION A(20)
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/SATC/A,DTPV
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/CPID/GI(11),GH(11),GL(11)
      COMMON/ISP/N,NW,NWW
      COMMON/DIEL/BX(6),PX(6)
      NWW=0
      PRINT 100
  100 FORMAT(* THE RANGE OF TEMPERATURE FOR NITROGEN IS 63.15 TO 1900K*
     1/* WITH PRESSURES TO 1000 MPA*)
      N=0 $ NW=1
      EM=28.016 $ EOK=118. $ RM=3.933E-08 $ TC=126.24
      DC=0.3139 $ X=1.67108  $ PC=3.443    $ SIG=3.54
      XO=0.164  $ BETA=0.355 $ DELTA=4.352 $ E1=2.17 $ E2=0.287
      AGAM=1.190
C
C ****  NITROGEN COEFF FOR MBWR EQUATION
C
      G( 1)=  .138029747465691E-03
      G( 2)=  .108450650134880E-01
      G( 3)= -.247132406436209E+00
      G( 4)=  .345525798080709E+01
      G( 5)= -.427970769066595E+03
      G( 6)=  .106491156699760E-04
      G( 7)= -.114086707973499E-02
      G( 8)=  .144490249728747E-04
      G( 9)=  .187145756755327E+04
      G(10)=  .821887688683079E-08
      G(11)=  .236099049334759E-03
      G(12)= -.514480308120135E-01
      G(13)=  .491454501366803E-05
      G(14)= -.115162716239893E-03
      G(15)= -.716803724664983E-01
      G(16)=  .761666761949981E-05
      G(17)= -.113093006621295E-06
      G(18)=  .373683116683089E-04
      G(19)= -.203985150758086E-06
      G(20)= -.171966200898966E+04
      G(21)= -.121305519974777E+05
      G(22)= -.988139914142789E+01
      G(23)=  .561988689351085E+04
      G(24)= -.182304396411845E-01
      G(25)= -.259982649847705E+00
      G(26)= -.419189342315742E-04
      G(27)= -.259640667053023E-01
      G(28)= -.125868320192119E-07
      G(29)=  .104928659940046E-05
      G(30)= -.545836930515201E-10
      G(31)= -.767451167059717E-09
      G(32)=  .593123287099439E-08
      GAMMA=-.0056
C
C ****  NITROGEN COEFF FOR VAPOR PRESS.
C
      VP(1)=   5.1113192094    $  VP(2)=.6482667539
      VP(3)=   -.15108730916   $  VP(5)=.74028493342
      VP(6)=   1.5             $  VP(9)=.012462975
      VP(7)=  63.15            $  VP(8)= 126.26
```

```
      VP(4)=   0.0
C
C ****  N2 COEF FOR SAT LIQUID AND VAPOR DENS.
C
      A( 1)=  -.158453465507E+02
      A( 2)=   .419136911423E-01
      A( 3)=  -.101965371660E+01
      A( 4)=   .134763743799E+02
      A( 5)=  -.109930399087E+03
      A( 6)=   .925518835497E+02
      A( 7)=  -.956233831320E+02
      A( 8)=   .100104366710E+03
      A( 9)=  -.701857937398E+02
      A(10)=   .900076998647E+01
      A(11)=   .286981120347E+02
      A(12)=  -.216767601780E+02
      A(13)=   .496558226471E+01
      A(14)=   .218307928477E+02
      A(15)=  -.126493309807E+00
      A(16)=   .241544188633E+01
      A(17)=  -.245256871794E+02
      A(18)=   .935925207124E+02
      A(19)=  -.360938251632E+02
      A(20)=   .757453271989E+01
C
C ****  N2 COEF FOR IDEAL GAS CP.
C
      GI(1)=   -0.735210401157252E 03
      GI(2)=    0.342239980411978E 02
      GI(3)=   -0.557648284567620E 00
      GI(4)=    0.350404228308756E 01
      GI(5)=   -0.173390185081005E-04
      GI(6)=    0.174650849766463E-07
      GI(7)=   -0.356892033544348E-11
      GI(8)=    0.100538722808834E 01
      GI(9)=    0.335340610000000E 04
      GI(10)=GI(11)=0.0
C
C ~***  N2 COEF FOR 1ST TERM OF VISC
C       VISC IN MICRO PA*S, DENSITY IN G/CC
C
      GV(1)= -.18224240000E+05  $  GV(2)=  .19915327374E+05
      GV(3)= -.91542324494E+04  $  GV(4)=  .23255484059E+04
      GV(5)= -.36307214228E+03  $  GV(6)=  .36457506811E+02
      GV(7)= -.22261880817E+01  $  GV(8)=  .78053904895E-01
      GV(9)= -.11894029104E-02
C
C ****  N2 COEF FOR 1ST TERM THERM. COND.
C       THERM. COND. IN WATT/(M*K), DENS. IN G/CC.
C
      GT(1)= -.20029573972E+02  $  GT(2)=  .49765746684E+01
      GT(3)=  .80188959378E+01  $  GT(4)= -.55022716888E+01
      GT(5)=  .15363738965E+01  $  GT(6)= -.22974737257E+00
      GT(7)=  .19360547346E-01  $  GT(8)= -.85677385768E-03
      GT(9)=  .15564670935E-04
C
C ****  N2 COEF FOR 2ND TERM VISC.
C
      FV(1)= -.11217739623E+00  $  FV(2)=  .32912317244E-01
      FV(3)=  .14000000000E+01  $  FV(4)=  .11800000000E+03
C
C ****  N2 COEF FOR 2ND TERM THERM. COND.
C
      FT(1)=  .53875666637E-01  $  FT(2)=  .61027911104E-02
      FT(3)=  .12000000000E+01  $  FT(4)=  .11800000000E+03
```

```
C
C ****  N2 COEF FOR 3RD. TERM VISC.
C
      EV(1)= -.12128154129E+02  $  EV(2)=  .57156092139E+00
      EV(3)=  .16094611148E+02  $  EV(4)=  .36954086158E+04
      EV(5)= -.80889801180E+03  $  EV(6)=  .68464435640E+02
      EV(7)= -.21241135912E+01  $  EV(8)=  .31500000000E+00
C
C ****  N2 COEF FOR 3RD TERM OF THERM. COND.
C
      ET(1)= -.38613291627E+02  $  ET(2)=  .0
      ET(3)=  .37201743333E+02  $  ET(4)=  .0
      ET(5)= -.39013509079E+02  $  ET(6)= -.31826109485E+02
      ET(7)=  .0                $  ET(8)= 1.0
C
C ****  N2 COEF FOR MELTING.
C
      PX(1)= -.160000281E+03
      PX(2)=  .938575502E-01
      PX(3)=  .179500000E+01
C
C ****  N2 COEF FOR DIEL. CONST.
C
      BX(1)=  .43993836E-02
      BX(2)=  .18932096E-05
      BX(3)= 0.
      BX(4)= -.31450178E-08
      BX(5)= -.28592703E-06
      BX(6)= -.44666034E-07

C     THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     NITROGEN

      R=(8.20539E-2)*.101325
      TO=298.15  $  SO=191.502   $  HO=8669.0
      GI(10)=HO-HI(TO)
      GI(11)=SO-SI(TO)
      DTP=.3097717741477E+2
      DTPV=.242822085710E-1
      TCC=VP(8)
      PCC=VPN(TCC)
      PTP=VP(9)
      TTP=VP(7)
      TUL=1900.
      TLL=TTP
      PUL=1000.
      DCC=11.21
      RETURN
      END


      SUBROUTINE DATA NF3
      DIMENSION G(32),VP(9),A(20)
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/SATC/A,DTPV
      COMMON/CPID/GI(11),GH(11),GL(11)
      COMMON/DIEL/BX(6),PX(6)
      PRINT 100
  100 FORMAT(* THE RANGE OF TEMPERATURE FOR NITROGEN TRIFLUORIDE IS*
     A ,/,* 66.36 K  TO  500 K, WITH PRESSURES TO 50 MPA.*)
C
C ****  NITROGEN TRIFLUORIDE COEFFICIENTS FOR MBWR EQUATION.
C
      G( 1)=  .1774353868E-02
      G( 2)= -.5409379418E-01
      G( 3)=  .3976634466E+00
      G( 4)= -.5209476694E+02
      G( 5)= -.3286322888E+04
```

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      G( 6)= -.5990517411E-04
      G( 7)=  .9217525601E-01
      G( 8)= -.4848977075E+02
      G( 9)= -.4235892691E+06
      G(10)= -.9824248063E-06
      G(11)=  .5432235989E-02
      G(12)= -.1462388500E+01
      G(13)= -.3366180440E-03
      G(14)=  .2801374599E-01
      G(15)=  .8435288597E+00
      G(16)= -.1324421452E-02
      G(17)=  .1875604377E-04
      G(18)=  .2959643991E-01
      G(19)= -.7009976870E-03
      G(20)=  .4365820912E+06
      G(21)= -.1111397536E+07
      G(22)=  .2411866612E+04
      G(23)=  .3179136276E+06
      G(24)=  .6166849090E+01
      G(25)=  .4260854720E+01
      G(26)=  .1090598789E-01
      G(27)= -.3340951059E+01
      G(28)=  .8597429644E-05
      G(29)=  .1240544214E-03
      G(30)=  .1286224248E-07
      G(31)= -.8941104276E-07
      G(32)=  .3353054595E-05
      GAMMA=-.0056
C
C ****  NITROGEN TRIFLUORIDE COEFFICIENTS FOR VAPOR PRESSURE.
C
      VP(1)=  11.593879492      $  VP(2)=   9.6548502312
      VP(3)=  -2.8727732815     $  VP(5)=   7.3112441673
      VP(6)=   1.5              $  VP(9)=    .18537827E-6
      VP(7)=  66.36             $  VP(8)= 234.0
      VP(4)=  -1.37977007
C
C ****  NITROGEN TRIFLUORIDE COEFF.  FOR SATURATED LIQUID AND VAPOR DENSITIES
C
      A( 1) =   .131285181636E+03
      A( 2) =  -.226998555536E+01
      A( 3) =   .384708389498E+02
      A( 4) =  -.309827268239E+03
      A( 5) =  -.635348526635E+03
      A( 6) =   .926979028357E+03
      A( 7) =   .371498011259E+03
      A( 8) =  -.182291654470E+04
      A( 9) =   .105592403853E+04
      A(10) =   .121673895344E+04
      A(11) =  -.207208928323E+04
      A(12) =   .113463394710E+04
      A(13) =  -.226642137140E+03
      A(14) =   .105087295173E+01
      A(15) =  -.131686474246E-02
      A(16) =   .390141331900E-01
      A(17) =  -.587796597975E+00
      A(18) =   .400900521017E+01
      A(19) =  -.203385386977E+01
      A(20) =   .400434364424E+00
C
C ****  NITROGEN TRIFLUORIDE COEFF CIENTS FOR IDEAL GAS CP.
C
      GI(1)=   .7427518245951E+06
      GI(2)=  -.4389825372134E+05
      GI(3)=   .1012629224351E+04
```

```
      GI(4)=  -.7140693612211E+01
      GI(5)=   .5481339146452E-01
      GI(6)=  -.7677196006769E-04
      GI(7)=   .4203630864340E-07
      GI(8)=  -.6328752997967E+00
      GI(9)=   .3E+4
      GI(10)=GI(11)=0.0
C
C ****  NITROGEN TRIFLUORIDE COEFFICIENTS FOR MELTING.
C
      PX(1)= -.190939971E+03
      PX(2)=  .813750194E-01
      PX(3)=  .185000000E+01

C     THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     NITROGEN TRIFLUORIDE

C**-  THE TO,HO,SO IDEAL GAS REFERENCE VALUES ARE FROM
C  TO,HO,SO ARE FROM NBS TN 270-3('68), "SELECTED VALUES OF CHEMICAL
C  THERMODYNAMIC PROPERTIES"  WAGMAN ET AL., PP 70
      TO=298.15  $  SO=260.621   $  HO=11828.
      GI(10)=HO-HI(TO)
      GI(11)=SO-SI(TO)
      EM=71.019
      R=.0820568*.101325
      PTP=.185425E-06
      DTP=26.32
      DTPV=.33612E-08
      TTP=66.36
      PCC=4.4607
      DCC=7.92
      TCC=234.0
      TC=234.0
      VP(8)=TC
      DC=7.92
      PUL= 50.
      TUL=500.
      TLL=TTP
      RETURN
      END


      SUBROUTINE DATA 02
      DIMENSION G(32),VP(9),GI(11),GH(11),GL(11)
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      DIMENSION A(20)
      COMMON/SATC/A,DTPV
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/ISP/N,NW,NWW
      COMMON/CPID/GI,GH,GL
      COMMON/DIEL/BX(6),PX(6)
      N=0 $ NW=1 $ NWW=0
      PRINT 100
  100 FORMAT(* THE TEMPERATURE RANGE FOR OXYGEN IS 54.359 TO 400 K*
     1/* WITH PRESSURES TO 120 MPA*)
      XO=0.183  $ BETA=0.355 $ DELTA=4.352 $ E1=2.21 $ E2=0.287
       EM=31.9988 $ EOK=113.0 $ RM=3.8896E-08$ TC=154.575
      DC=0.4362 $ X=2.210636 $ PC=5.0429   $ SIG=3.437
      AGAM = 1.190
C
C ****  OXYGEN COEFFICIENTS FOR MBWR EQUATION.
C
      G( 1)=  -.4365859650E-04
      G( 2)=   .2005820677E-01
      G( 3)=  -.4197909916E+00
      G( 4)=   .1878215317E+02
```

```
      G( 5)=  -.1287473398E+04
      G( 6)=   .1556745888E-05
      G( 7)=   .1343639359E-03
      G( 8)=  -.2228415518E+00
      G( 9)=   .4767792275E+03
      G(10)=   .4790846641E-07
      G(11)=   .2462611107E-03
      G(12)=  -.1921891680E-01
      G(13)=  -.6978320847E-06
      G(14)=  -.6214145909E-04
      G(15)=  -.1860852567E-01
      G(16)=   .2609791417E-05
      G(17)=  -.2447611408E-07
      G(18)=   .1457743352E-04
      G(19)=  -.1726492873E-06
      G(20)=  -.2384892520E+03
      G(21)=  -.2301807796E+05
      G(22)=  -.2790303526E+01
      G(23)=   .9400577575E+04
      G(24)=  -.4169449637E-02
      G(25)=   .2008497853E+00
      G(26)=  -.1256076520E-04
      G(27)=  -.6406362964E-01
      G(28)=  -.2475580168E-08
      G(29)=   .1346309703E-05
      G(30)=  -.1161502470E-10
      G(31)=  -.1034699798E-08
      G(32)=   .2365936964E-07
      GAMMA=-.0056
C
C ****  OXYGEN COEFFICIENTS FOR VAPOR PRESSURE.
C
      VP(1)=   7.568956      $  VP(2)=   5.004836
      VP(3)=  -2.13746       $  VP(5)=   3.454481
      VP(6)=   1.514         $  VP(9)=    .0001479953
      VP(7)=  54.359         $  VP(8)= 154.581
      VP(4)=   0.0
C
C ****  OXYGEN COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C
      A( 1)=   .581394753076E+02
      A( 2)=  -.490241196133E-01
      A( 3)=   .168328893252E+01
      A( 4)=  -.325161223398E+02
      A( 5)=   .550300989872E+03
      A( 6)=  -.510968506115E+03
      A( 7)=   .315091559049E+03
      A( 8)=  -.232566659258E+02
      A( 9)=  -.488425479359E+02
      A(10)=  -.150624217523E+03
      A(11)=   .280441603851E+03
      A(12)=  -.176693896861E+03
      A(13)=   .403247747449E+02
      A(14)=   .252198688365E+01
      A(15)=  -.136098316472E-01
      A(16)=   .282316159403E+00
      A(17)=  -.286645905341E+01
      A(18)=   .617024212284E+01
      A(19)=  -.810220795462E+00
      A(20)=  -.279601068969E+00
C
C ****  OXYGEN COEFFICIENTS FOR IDEAL GAS CP.
C
      GI(1)=   -0.498199853711943E 04
      GI(2)=    0.230247779995218E 03
```

```
      GI(3)=   -0.345565323510732E 01
      GI(4)=    0.352187677367116E 01
      GI(5)=   -0.435420216024420E-04
      GI(6)=    0.134635345013162E-07
      GI(7)=    0.162059825959105E-10
      GI(8)=    0.103146851572565E 01
      GI(9)=    0.223918105000000E 04
      GI(10)=GI(11)=0.0
C
C ****  OXYGEN COEFFICIENTS FOR FIRST TERM OF VISCOSITY EQN.
C       VISCOSITY IN MICRO-PA*S, DENSITY IN G/CC.
C
      GV(1)= -.97076378593E+04  $  GV(2)=  .82801254201E+04
      GV(3)= -.24668758803E+04  $  GV(4)=  .21324360243E+03
      GV(5)=  .37851049522E+02  $  GV(6)= -.10487216090E+02
      GV(7)=  .11134441304E+01  $  GV(8)= -.53676093757E-01
      GV(9)=  .10279379641E-02
C
C ****  OXYGEN COEFFICIENTS FOR FIRST TERM OF THERMAL CONDUCTIVITY EQN.
C       THERMAL CONDUCTIVITY IN WATTS/(M*K), DENSITY IN G/CC.
C
      GT(1)= -.20395052193E+03  $  GT(2)=  .24088141709E+03
      GT(3)= -.12014175183E+03  $  GT(4)=  .32954949190E+02
      GT(5)= -.54244239598E+01  $  GT(6)=  .54734865540E+00
      GT(7)= -.32854821539E-01  $  GT(8)=  .10753572103E-02
      GT(9)= -.14610986820E-04
C
C ****  OXYGEN COEFFICIENTS FOR SECOND TERM OF VISCOSITY EQN.
C
      FV(1)=  .43526515153E+00  $  FV(2)= -.20361263878E+00
      FV(3)=  .14000000000E+01  $  FV(4)=  .10000000000E+03
C
C ****  OXYGEN COEFFICIENTS FOR SECOND TERM OF THERMAL CONDUCITIVY EQN.
C
      FT(1)=  .30600000000E-01  $  FT(2)=  .27850000000E-01
      FT(3)=  .11200000000E+01  $  FT(4)=  .10000000000E+03
C
C ****  OXYGEN COEFFICIENTS FOR THIRD TERM OF VISCOSITY EQN.
C
      EV(1)= -.14454972110E+02  $  EV(2)= -.31421728994E+00
      EV(3)=  .18201161468E+02  $  EV(4)=  .27390429525E+03
      EV(5)= -.27498956948E+04  $  EV(6)=  .24340689667E+03
      EV(7)=  .11911504104E+03  $  EV(8)=  .43500000000E+00
C
C ****  OXYGEN COEFFICIENTS FOR THIRD TERM OF THERMAL CONDUCTIVITY EQN.
C
      ET(1)= -.21520741137E+02  $  ET(2)=  .0
      ET(3)=  .16799504261E+02  $  ET(4)=  .0
      ET(5)= -.29944878721E+04  $  ET(6)=  .47350508788E+03
      ET(7)=  .0              $  ET(8)= 1.0
C
C ****  OXYGEN COEFFICIENTS FOR MELTING
C
         PX(1)= -.267226854E+03
         PX(2)=  .227606348E+00
         PX(3)=  .176900000E+01
C
C ****  OXYGEN COEFFICIENTS FOR DIELECTRIC CONSTANT.
C
         BX(1)=  .39608100E-02
         BX(2)=  .29700000E-06
         BX(3)= -.41300000E-07
         BX(4)= 0.0
         BX(5)= 0.0
         BX(6)= -.21400000E-07
```

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C     THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C     OXYGEN

C  TO,HO,SO ARE FROM NBS TN270 (SELECTED VALUES OF CHEM THERMO PROPS)
C  PAGE 11.  COMPUTED IDEAL GAS PROPS CONFORM TO JANAF(NSRDS-NBS37(71))
      TO=298.15  $  SO=205.029   $  HO=8680.1
      GI(10)= HO-HI(TO)
      GI(11)= SO-SI(TO)
      R=8.20539E-2*.101325
      DTP=.4081997364372E+02
      DTPV=.3318894767078E-03
      TCC=VP(8)
      PCC=VPN(TCC)
      PTP=VP(9)
      TTP=VP(7)
      TUL=400.
      TLL=TTP
      PUL=120.
      DCC=13.63
      RETURN
      END
```

```
      SUBROUTINE PROPS(PP,DD,TT)
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
      COMMON/1/B
      DATA(ID=1)
      DATA(IZ=1)
    1 CONTINUE
      IF(IZ.LE.0)GO TO 2
      IZ=0
    2 CONTINUE
      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=SQRT (T)
      T2=T*T
      T3=T2*T
      T4=T3*T
      T5=T4*T
      F=EXP (GM*D2)
      GO TO (100,200,300,400,500,600,700),K
      ENTRY PRESS
C     ENTRY FOR PRESSURE, INPUT IS DENSITY
C     AND TEMP. IN MOL/L AND K, OUTPUT IS IN MPA.
      K=1
      GO TO 1
  100 CONTINUE
      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
      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
      IF(ID.GT.0)GO TO 102
      B(33)=P-R*D*T
      RETURN
  102 P=0
      M=32
      DO 101 I=1,M
  101 P=P+B(I)*G(I)
      P=P+R*D*T
      PP=P
      RETURN
      ENTRY DPDD
C     PARTIAL OF PRESSURE WITH RESPECT TO
C     DENSITY - SEE PRESSURE
C     ENTRY FOR UNITS
      K=2
      GO TO 1
  200 CONTINUE
      F1=2.00*F*GM*D
      F21=3.000*F*D2 +F1*D3
      F22=5.000*F*D4 +F1*D5
      F23=7.000*F*D6 +F1*D7
      F24=9.000*F*D8 +F1*D9
      F25=11.00*F*D10+F1*D11
      F26=13.00*F*D12+F1*D13
      B( 1)=2.00*D*T
      B( 2)=2.00*D*TS
      B( 3)=2.00*D
      B( 4)=2.00*D/T
      B( 5)=2.00*D/T2
      B( 6)=3.00*D2*T
      B( 7)=3.00*D2
      B( 8)=3.00*D2/T
      B( 9)=3.00*D2/T2
      B(10)=4.00*D3*T
      B(11)=4.00*D3
      B(12)=4.00*D3/T
      B(13)=5.00*D4
      B(14)=6.00*D5/T
      B(15)=6.00*D5/T2
      B(16)=7.00*D6/T
      B(17)=8.00*D7/T
      B(18)=8.00*D7/T2
      B(19)=9.00*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
      M=32
      IF(ID.GT.0)GO TO 202
      B(33)=P-R*T
      RETURN
  202 P=0
      DO 201 I=1,M
  201 P=P+B(I)*G(I)
      P=P+R*T
      PP=P
      RETURN
      ENTRY DPDT
C     PARTIAL OF PRESSURE WITH RESPECT
C     TO TEMPERATURE - SEE PRESSURE
C     ENTRY FOR UNITS
      K=3
      GO TO 1
  300 CONTINUE
      X( 1)=D2
      X( 2)=D2/(2.00*TS)
      X( 3)=0
      X( 4)=-D2/T2
      X( 5)=-2.00*D2/T3
      X( 6)=D3
      X( 7)=0
      X( 8)=-D3/T2
      X( 9)=-2.00*D3/T3
      X(10)=D4
      X(11)=0
      X(12)=-D4/T2
      X(13)=0
      X(14)=-D6/T2
      X(15)=-2.00*D6/T3
      X(16)=-D7/T2
      X(17)=-D8/T2
      X(18)=-2.00*D8/T3
      X(19)=-2.00*D9/T3
      X(20)=-2.00*D3*F/T3
      X(21)=-3.00*D3*F/T4
      X(22)=-2.00*D5*F/T3
      X(23)=-4.00*D5*F/T5
      X(24)=-2.00*D7*F/T3
      X(25)=-3.00*D7*F/T4
      X(26)=-2.00*D9*F/T3
      X(27)=-4.00*D9*F/T5
      X(28)=-2.00*D11*F/T3
      X(29)=-3.00*D11*F/T4
      X(30)=-2.00*D13*F/T3
      X(31)=-3.00*D13*F/T4
      X(32)=-4.00*D13*F/T5
      IF(ID.GT.0)GO TO 302
      X(33)=PP-R*D
      RETURN
  302 P=0
      DO 301 I=1,32
  301 P=P+G(I)*X(I)
      PP=P+R*D
      RETURN
      ENTRY DSDN
C     PARTIAL OF ENTROPY WITH
```

```
C     RESPECT TO THE G COEFFICIENTS
      K=4
      GO TO 1
  400 CONTINUE
C     S=SO-R*LOGF(D*R*T/PO)+(DSDN(D)-DSDN(0))*1000. +CPOS(T)
      G1=F/(2.00*GM)
      G2=(F*D2-2.00*G1)/(2.00*GM)
      G3=(F*D4-4.00*G2)/(2.00*GM)
      G4=(F*D6-6.00*G3)/(2.00*GM)
      G5=(F*D8-8.00*G4)/(2.00*GM)
      G6=(F*D10-10.00*G5)/(2.00*GM)
      X( 1)=-D
      X( 2)=-D/(2.00*TS)
      X( 3)=0.D0
      X( 4)=+D/T2
      X( 5)=2.00*D/T3
      X( 6)=-D2/2.00
      X( 7)=0.D0
      X( 8)=D2/(2.00*T2)
      X( 9)=D2/T3
      X(10)=-D3/3.00
      X(11)=0.D0
      X(12)=D3/(3.00*T2)
      X(13)=0.D0
      X(14)=D5/(5.00*T2)
      X(15)= 2.00*D5/(5.00*T3)
      X(16)=D6/(6.00*T2)
      X(17)=D7/(7.00*T2)
      X(18)=2.00*D7/(7.00*T3)
      X(19)=D8/(4.00*T3)
      X(20)=2.00*G1/T3
      X(21)=3.00*G1/T4
      X(22)=2.00*G2/T3
      X(23)=4.00*G2/T5
      X(24)=2.00*G3/T3
      X(25)=3.00*G3/T4
      X(26)=2.00*G4/T3
      X(27)=4.00*G4/T5
      X(28)=2.00*G5/T3
      X(29)=3.00*G5/T4
      X(30)=2.00*G6/T3
      X(31)=3.00*G6/T4
      X(32)=4.00*G6/T5
      IF(ID.GT.0)GO TO 402
      RETURN
  402 P=0
      DO 401 I=1,32
  401 P=P+G(I)*X(I)
      PP=P
      RETURN
      ENTRY DUDN
C     TERMS NEEDED FOR ENTHALPY CALCULATION
      K=5
      GO TO 1
  500 CONTINUE
C     H=HO+(T*DSDN(D)-DSDN(0))*1000.+(DUDN(D-DUDN(0))*1000.+CPOH(T)
C     +(P/D-R*T)*1000.
      G1=F/(2.00*GM)
      G2=(F*D2-2.00*G1)/(2.00*GM)
      G3=(F*D4-4.00*G2)/(2.00*GM)
      G4=(F*D6-6.00*G3)/(2.00*GM)
      G5=(F*D8-8.00*G4)/(2.00*GM)
      G6=(F*D10-10.00*G5)/(2.00*GM)
      X( 1)=D*T
      X( 2)=D*TS
```

```
      X( 3)=D
      X( 4)=D/T
      X( 5)=D/T2
      X( 6)=D2*T/2.00
      X( 7)=D2/2.00
      X( 8)=D2/(2.00*T)
      X( 9)=D2/(2.00*T2)
      X(10)=D3*T/3.00
      X(11)=D3/3.00
      X(12)=D3/(3.00*T)
      X(13)=D4/4.00
      X(14)=D5/(5.00*T)
      X(15)=D5/(5.00*T2)
      X(16)=D6/(6.00*T)
      X(17)=D7/(7.00*T)
      X(18)=D7/(7.00*T2)
      X(19)=D8/(8.00*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
      IF(ID.GT.0)GO TO 502
      RETURN
  502 P=0
      DO 501 I=1,32
  501 P=P+G(I)*X(I)
      PP=P
      RETURN
      ENTRY TDSDT
C     TEMP. TIMES THE PARTIAL OF
C     ENTROPY WITH RESPECT TO TEMP.
      K=6
      GO TO 1
  600 CONTINUE
C     CV=CVO+(TDSDN(/)-TDSDN(D))*1000.
      G1=F/(2.00*GM)
      G2=(F*D2-2.00*G1)/(2.00*GM)
      G3=(F*D4-4.00*G2)/(2.00*GM)
      G4=(F*D6-6.00*G3)/(2.00*GM)
      G5=(F*D8-8.00*G4)/(2.00*GM)
      G6=(F*D10-10.00*G5)/(2.00*GM)
      X(1)=0
      X( 2)=-D/(4.00*TS)
      X(3)=0
      X( 4)=2.00*D/T2
      X( 5)=6.00*D/T3
      X(6)=0
      X(7)=0
      X( 8)=D2/T2
      X( 9)=3.00*D2/T3
      X(10)=0
      X(11)=0
      X(12)=(2.00*D3)/(3.00*T2)
      X(13)=0
      X(14)=(2.00*D5)/(5.00*T2)
      X(15)=(6.00*D5)/(5.00*T3)
```

```
      X(16)=D6/(3.00*T2)
      X(17)=(2.00*D7)/(7.00*T2)
      X(18)=(6.00*D7)/(7.00*T3)
      X(19)=(3.00*D8)/(4.00*T3)
      X(20)=6.000*G1/T3
      X(21)=12.00*G1/T4
      X(22)=6.000*G2/T3
      X(23)=20.00*G2/T5
      X(24)=6.000*G3/T3
      X(25)=12.00*G3/T4
      X(26)=6.000*G4/T3
      X(27)=20.00*G4/T5
      X(28)=6.000*G5/T3
      X(29)=12.00*G5/T4
      X(30)=6.000*G6/T3
      X(31)=12.00*G6/T4
      X(32)=20.00*G6/T5
      IF(ID.GT.0)GO TO 602
      RETURN
  602 P=0
      DO 601 I=1,32
  601 P=P+G(I)*X(I)
      PP=P
      RETURN
      ENTRY DP2D2
C     SECOND PARTIAL OF PRESSURE WITH
C     RESPECT TO DENSITY SQUARED
      K=7
      GO TO 1
  700 CONTINUE
      F1=2.*F*GM*D
      F12=2.*F1*GM*D+2.*F*GM
      F212=3.*F1*D2+3.*2.*D*F+F12*D3+F1*3.*D2
      F222=5.*F1*D4 +5.*4.*D3*F+5.*D4*F1+F12*D5
      F232=7.*F1*D6+7.*6.*D5*F+7.*D6*F1+F12*D7
      F242=9.*F1*D8+9.*8.*D7*F+9.*D8*F1+F12*D9
      F252=11.*F1*D10+10.*11.*D9*F+11.*D10*F1+F12*D11
      F262=13.*F1*D12+13.*12.*D11*F+13.*D12*F1+F12*D13
      B(1)=2.*T  $B(2)=2.*TS  $  B(3)=2.
      B(4)=2./T  $  B(5)=2./T2  $  B(6)=6.*D*T
      B(7)=6.*D  $  B(8)=6.*D/T  $  B(9)=6.*D/T2
      B(10)=12.*D2*T  $  B(11)=12.*D2  $  B(12)=12.*D2/T
      B(13)=20.*D3  $  B(14)=30.*D4/T  $  B(15)=30.*D4/T2
      B(16)=42.*D5/T  $  B(17)=56.*D6/T  $  B(18)=56.*D6/T2
      B(19)=72.*D7/T2  $  B(20)=F212/T2  $  B(21)=F212/T3
      B(22)=F222/T2
      B(23)=F222/T4  $  B(24)=F232/T2  $  B(25)=F232/T3
      B(26)=F242/T2  $  B(27)=F242/T4  $  B(28)=F252/T2
      B(29)=F252/T3  $  B(30)=F262/T2  $  B(31)=F262/T3
      B(32)=F262/T4
      M=32
      IF(ID.GT.0)GO TO 702
      B(33)=PP
      RETURN
  702 P=0
      DO 701 I=1,M
  701 P=P+B(I)*G(I)
      PP=P
      RETURN
      END


C
      FUNCTION VPN(TT)
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.-VP(7)/T)/(1.-VP(7)/VP(8))
      VPN=VP(9)*EXP (VP(1)*X+VP(2)*X*X+VP(3)*X**3+VP(4)*X**4+VP(5)*X*
     1(1.-X)**VP(6))
      RETURN
      END


C
      FUNCTION FINDTV(POBS)
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(ABS (P-POBS)-.000001*POBS)8,8,6
    6 CONTINUE
      CORR=(POBS-P)/DPDTVP(T)
    7 T=T+CORR
    8 CONTINUE
      FINDTV=T
      RETURN
      END


C
      FUNCTION CV(D,T)
C  CALCULATES CV(J/(MOL*K)).  INPUT DENS(MOL/L) AND TEMP(K).
      DATA(R=8.31434)
      DD=D
      TT=T
      CALL TDSDT(CD,DD,TT)
      DD=0
      CALL TDSDT(CO,DD,TT)
      CV=CPI(TT)+(CO-CD)*1000.
      CV=CV-R
      RETURN
      END


C
      FUNCTION FIND D(P,T)
C  ITERATES EQUATION OF STATE FOR DENSITY(MOL/L), FOR GIVEN PRESSURE(MPA) AND
C  TEMPERATURE(K).  IF ITERATION FAILS TRY USING  FUNCTION FIND M.
      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)*.99999)GO TO 100
      IF( P.GT.VPN(TT))GO TO 101
      DD=SATV(TT)
      GO TO 102
  100 PC=PCC
      X=(1.1/(9.*PC))*P+.7/9.
      DD=P/(R*T*X)
      IF(P/PC.GT.20..AND.T/VP(8).LT.2.5)DD=DTP
      GO TO 102
  101 DD=SATL(TT)
  102 CONTINUE
      DO 10 I=1,50
      IF(DD.LE.0.0.OR.DD.GT.50.)GO TO 11
      CALL PRESS(PP,DD,TT)
```

```
      IF(PP.LE.0.0)GO TO 11
      P2=PP
      IF(ABS (P-P2)-1.E-7*P)20,20,1
    1 CALL DPDD(PP,DD,TT)
      DP=PP
      CORR=(P2-P)/DP
      IF(ABS (CORR)-1.E-7*DD)20,20,10
   10 DD=DD-CORR
   11 CALL REGULA(P,DD,T)
   20 FIND D=DD
      RETURN
      END


C
      SUBROUTINE REGULA(PI,DD,TT)
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
      IF(T.LT.TCC)GO TO 10
      D0=DCC*TCC/T
      GO TO 20
   10 PP=VPN(T)
      IF(P.GT.PP)GO TO 15
      D0=SATV(T)
      DO 11  I=1,150
      CALL PRESS(P0,D0,T)
      IF(P0.GE.P)GO TO 12
   11 D0=D0+.0001*D0
      GO TO 42
   12 D1=D0
   13 CALL PRESS(P1,D1,T)
      IF(P1.LT.P)GO TO 14
      IF(D1.LE..1*PTP)GO TO 42
      D0=D1
      Z=(P1-P)/P
      IF(Z.LT..1)Z=.1
      IF(Z.GT..9)Z=.9
      D1=D1-Z*D1
      GO TO 13
   14 CALL PRESS(P0,D0,T)
      DO 140 I=1,50
      D=D1
      P3=P1
      IF(ABS(P-P1).LT..00001*P)GO TO 40
      P2=P-P1
      D1=D1+(D1-D0)*P2/(P1-P0)
      IF(ABS(D-D1).LE..00001*D)GO TO 40
      IF(ABS(P-P1).LT..005*P)D2=FIND M(P,T,D1)
      IF(D2.GT.0.0.AND.D2.LT.50.)D1=D2
      D2=0
      CALL PRESS(P1,D1,T)
      IF(P0.GT.P.AND.P1.GT.P)GO TO 120
      IF(P0.LT.P.AND.P1.LT.P)GO TO 120
      GO TO 140
  120 P0=P3
      D0=D
  140 CONTINUE
      GO TO 41
   15 D0=SATL(T)
      DO 16 I=1,10
      CALL PRESS(P0,D0,T)
```

```
      IF(PO.LE.P)GO TO 17
   16 DO=DO-.0001*DO
      GO TO 42
   17 D1=DO
   18 CALL PRESS(P1,D1,T)
      IF(D1.GE.50.)GO TO 42
      IF(P1.GT.P)GO TO 14
      DO=D1
      Z=(P-P1)/P
      Z=Z*10
      IF(T/TCC.LT..6)Z=1.
      IF(Z.LT.1.)Z=1.
      IF(Z.GT.9.)Z=9.
      D1=D1+.01*D1*Z
      GO TO 18
   20 CALL PRESS(PO,DO,T)
      IF(P.LE.PO)GO TO 30
      D1=DO
   21 CALL PRESS(P1,D1,T)
      IF(P1.GE.P)GO TO 14
      IF(D1.GE.50.)GO TO 42
      DO=D1
      Z=(P-P1)/P
      Z=Z*10
      IF(Z.LT.1)Z=1
      IF(Z.GT.9)Z=9
      D1=D1+.1*D1*Z
      GO TO 21
   30 D1=DO
   31 CALL PRESS(P1,D1,T)
      IF(P1.LE.P)GO TO 14
      IF(D1.LE..1*PTP)GO TO 42
      DO=D1
      Z=(P1-P)/P
      Z=Z*10
      IF(Z.LT.1)Z=1
      IF(Z.GT.9)Z=9
      D1=D1-.1*D1*Z
      GO TO 31
   40 DD=D1


      RETURN
   41 PRINT 101,P,T,D
  102 FORMAT(* REGULA FAILED AT P=*,F7.2,* AND T=*,F7.2)
  101 FORMAT(* DENSITY ITTERATION FAILED AT P=*,F7.2,* AND T=*,F7.2,
     1/* DENSITY RETURNED IS*,E17.8)
      RETURN
   42 PRINT 102,P,T
      RETURN
      END


C
      FUNCTION CP(D,T)
C  CALCULATES CP(J/(MOL*K)).  INPUT DENS(MOL/L), TEMP(K).
      CVEE=CV(D,T)
      CALL DPDT(DPT,D,T)
      CALL DPDD(DPD,D,T)
      CP=CVEE+(T/(D**2)*(DPT**2)/DPD)*1000.
      RETURN
      END


C
```

```
      FUNCTION DPDTVP(TT)
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.-VP(7)/T)/(1.-VP(7)/VP(8))
      DXDT=(VP(7)/T**2)/(1.-VP(7)/VP(8))
      DPDT=VP(1)*DXDT+2.*VP(2)*X*DXDT+VP(3)*3.*X**2*DXDT+VP(5)*
     1((1.-X)**VP(6))*DXDT+VP(5)*X*((1.-X)**(VP(6)-1.))*VP(6)*(-DXDT)
      DPDT=DPDT*VPN(T)
      DPDTVP=DPDT
      RETURN
    1 DPDTVP=0
      RETURN
      END


C
      FUNCTION FIND M(P,T,DD)
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 FIND D.
      TT=T
      DO 10 I=1,50
      CALL PRESS(PP,DD,TT)
      P2=PP
      IF(ABS (P-P2)-1.E-7*P)20,20,1
    1 CALL DPDD(PP,DD,TT)
      DP=PP
      CORR=(P2-P)/DP
      D=DD
      IF(ABS (CORR)-1.E-7*D)20,20,10
   10 DD=DD-CORR
      FIND M=0
      RETURN
   20 FIND M=DD
      RETURN
      END


C
      FUNCTION ENTHAL(P,D,T)
C  RETURNS ENTHALPY(J/MOL)  FOR AN INPUT OF PRESSURE(MPA) AND DENSITY(MOL/L),
C  AND TEMPERATURE(K).
      R= .00831434
      DD=D
      TT=T
      CALL DSDN(SD,DD,TT)
      CALL DUDN(UD,DD,TT)
      DD=0
      CALL DSDN(SO,DD,TT)
      CALL DUDN(UO,DD,TT)
      ENTHAL=T*(SD-SO)*1000.+(UD-UO)*1000.+HI(T)+(P/D-R*T)*1000.
      RETURN
      END


C
      FUNCTION ENTROP(D,T)
C  CALCULATES ENTROPY(J/(MOL-K), FROM INPUT OF DENSITY(MOL/L) AND TEMP(K).
      R=  .00831434
      PO=  .101325
      DD=D
```

```
      TT=T
      CALL DSDN(SD,DD,TT)
      DD=0
      CALL DSDN(SO,DD,TT)
      ENTROP=(SD-SO)*1000.-R*ALOG(D*R*T/PO)*1000.+SI(T)
      RETURN
      END


C
      FUNCTION SATL(TT)
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
      T=TT
      K=14
      KK=7
      GO TO 10
      ENTRY SATV
      K=1
      KK=13
      T=TT
   10 IF(T.GE.TCC*.99990)GO TO 20
      ITT=TCC
      IF(ITT+1-T.LT.1.)T=ITT
      X=(T-TCC)/(TTP-TCC)
      D=A(K)*ALOG(X)
      DO 11 I=2,KK
      K=K+1
      MM=I
      IF(MM.GE.5)MM=MM+1
   11 D=D+A(K)*(1.-X**((MM-5)/3.))
      IF(K.LT.14)GO TO 12
      D=DCC+EXP(D)*(DTP-DCC)
      GO TO 13
   12 D=DCC+EXP(D)*(DTPV-DCC)
   13 SATL=D
      IF(ITT+1-TT.LT.1.)SATL=D-(D-DCC)*(TT-T)
      RETURN
   20 DSATL=DCC
      RETURN
      END


C
      FUNCTION SOUND(D,T)
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 DPDD(DP,D,T)
      SOUND=((CP(D,T)/CV(D,T))*DP*1000000./W)**.5
      RETURN
      END


C
      FUNCTION VISC(DD,T)
C  CALCULATES VISCOSITY(MICRO PA*S).  INPUT IS DENSITY(MOL/L) AND TEMP(K).
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      D=DD*EM/1000.
      VISC=DILV(T)+FDCV(D,T)+EXCESV(D,T)
      RETURN
      END
```

```
C
      FUNCTION THERM(DD,T)
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/ EM, EOK, RM, TC, DC, X , PC, SIG
      D=DD*EM/1000.
      CR=CRITC(D,T)
      THER=DILT(T)+FDCT(D,T)+EXCEST(D,T)+CR
      TCI=THER-CR
      THERM=THER
      RETURN
      END


C
      FUNCTION EXCESV(D,T)
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**(.5)*((D-EV(8))/EV(8))
      R=D**(.1)
      X=EV(1)+EV(2)*R2+EV(3)*R+EV(4)*R2/(T*T)+EV(5)*R/T**(1.5)+EV(6)/T
     1+EV(7)*R2/T
      X1=EV(1)+EV(6)/T
      EXCESV= EXP(X)- EXP(X1)
      RETURN
      ENTRY EXCEST
C     CALCULATES EXCESS THERMAL CONDUCTIVITY
      R2=D**(.5)*((D-ET(8))/ET(8))
      R=D**(.1)
      X=ET(1)+ET(2)*R2+ET(3)*R+ET(4)*R2/(T*T)+ET(5)*R/T**(1.5)+ET(6)/T
     1+ET(7)*R2/T
      X1=ET(1)+ET(6)/T
      EXCESV= EXP(X)- EXP(X1)
      RETURN
      END


C
      FUNCTION FDCV(D,T)
C  FIRST DENSITY CORRECTION FOR VISC AND THERMAL COND.
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      FDCV=(FV(1)+FV(2)*(FV(3)-ALOG(T/FV(4)))**2)*D
      RETURN
      ENTRY FDCT
      FDCV=(FT(1)+FT(2)*(FT(3)-ALOG(T/FT(4)))**2)*D
      RETURN
      END


C
      FUNCTION CRITC(D,T)
C  CALCULATES CRITICAL ENHANCEMENT FOR THERM. COND.
C  INPUT UNITS ARE G/CC, K,  OUTPUT IS W/(M*K).
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/CHECK/DELD,DELT,DSTAR,TSTAR
      COMMON/HJM/EPSI,CPCV,RRR,AKT
      COMMON/ISP/N,NW,MWW
      AV=6.0225E+23 $ BK=1.38054E-16
      DELD=ABS (D-DC)/DC $ DELT=ABS (T-TC)/TC
C  CALCULATE DISTANCE PARAMETER
      R=(RM**2.5)*(D**0.5)*(AV/EM)**0.5
      R=R*(EOK**0.5)*X/(T**0.5)
```

```
      RRR=R
C   GENERAL  EQUATION
      DX=D*1000.0/EM
C  DX IN MOL/L,  D IN G/CM3.
      CALL DPDT(DPT,DX,T)
C  DPDT IN MPA/K.
      DPT=DPT*1.0E+7
C  DPDT NOW IN DYNES/(CM2*K)
      CALL DPDD(DPD,DX,T)
C  DPDD IN L*MPA/MOL.
      DPD=DPD*1.0E+7*1000./EM
C  DPDD NOW IN DYNE*CM/G.
      IF( DPD.LT.0.0) DPD=1.0
   94 VIS=VISC(DX,T)*(1.0E-05)
C  VISCOSITY NOW IS G/(CM*S).
      IF(DELD.EQ.0.25. OR. DELD.LT. 0.25) 8,10
    8 IF(DELT.EQ.0.025. OR. DELT.LT.0.025 ) 9, 10
    9 COMPRES=SENG(D,T)
      GO TO 12
   10 COMPRES=1.0/(D*DPD)**0.5
   12 EX=BK*T**2*(DPT**2)*COMPRES
      EXB=R*((BK*T)**0.5)*(D**0.5)*((AV/EM)**0.5)
      CRIT=EX/(EXB*6.0*3.14159*VIS)
C   THERMAL COND, CRIT, IS IN ERG/(CM*SEC*K)
C   PUT IN DAMPING FACTOR
      BDD=((D-DC)/DC)**4
      BTT=((T-TC)/TC)**2
      BXX= -18.66*BTT - 4.25*BDD
      IF(BXX.LT.-1.E+2) BXX= -1.E+2
      FACT= EXP( BXX )
C     FACT=EXP (-18.66*BTT - 4.25*BDD)
      DELC=CRIT*FACT
      CRITC=DELC/100000.
C   THERMAL COND, CRITC, IS NOW IN W/(M*K)
      AKT=COMPRES*COMPRES
      EPSI=R*R*BK*T*(AV*D/EM)*AKT
      EPSI=EPSI**0.5
C   CALC  CP-CV
      CPCV=T*(DPT**2)*AKT/D
      RETURN
      END


C
      FUNCTION SENG(D,T)
C  SCALED EQUATION OF STATE FOR CRITICAL REGION
      COMMON/CRIT/ EM, 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./BETA
      XX=DELT/DELD**BETO
      AG=AGAM-1.0
       BET2= 2.0*BETA
      AGB=AG/BET2
      DEL1=DELTA-1.0
       AGBB=(AG-BET2)/BET2
      XXO=(XX+ XO)/XO
      XXB=XXO**BET2
      BRAK=1.0 + 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=1.0/(RCOM*DSTAR**2)
```

```
      RCM=RCOMP/(PC*1.0E+7)
C  RCM IN CM2/DYNE, PC IN MPA
      RCM=RCM**0.5
C
       SENG=RCM
       RETURN
      END


C
      FUNCTION DILV(T)
C  DILUTE GAS VISCOSITY AND THERMAL CONDUCTIVITY.
      COMMON/DATA1/GV,GT,FV,FT,EV,ET
      DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
      SUM=0
      TF=T**(1./3.)
      TFF=T**(-4./3.)
      DO 10 I=1,9
      TFF=TFF*TF
   10 SUM=SUM+GV(I)*TFF
      DILV=SUM
      RETURN
      ENTRY DILT
      TF=T**(1./3.)
      TFF=T**(-4./3.)
      SUM=0
      DO 20 I=1,9
      TFF=TFF*TF
   20 SUM=SUM+GT(I)*TFF
      DILV=SUM
      RETURN
      END


C
      FUNCTION FIND P(D,T)
      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 PRESS(PP,DD,TT)
      FIND P=PP
      RETURN
   10 P=VPN(TT)
      DV=FIND D(P-.0001,TT)
      DL=FIND D(P+.0001,TT)
      IF(DD.LE.DV.OR.DD.GE.DL)GO TO 1
      PRINT 100,DV,DL,DD
      CALL PRESS(PP,DV,TT)
      FIND P=PP
      D=DV
      RETURN
  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


C
      FUNCTION FINDT(P,D)
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=FIND D(PP-.00001,TSAT)
      DL=FIND D(PP+.0001,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 PRESS(P2,DD,TT)
      IF(ABS(PP-P2)-1.E-7*PP)20,20,11
   11 CALL DPDT(DP,DD,TT)
      CORR=(P2-PP)/DP
      IF(ABS(CORR)-1.E-5)20,20,10
   10 TT=TT-CORR
   20 FINDT=TT
      RETURN
   30 FINDT=TSAT
      D=DV
      PRINT 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*)
      RETURN
      END


C
      SUBROUTINE INFO
      PRINT 100
  100 FORMAT(/*  WHEN THE PROGRAM ASKS FOR A FLUID SELECTION, ENTER THE*
     1*APPROPRIATE NUMBER.*/*  AN INAPPROPRIATE NUMBER WILL TERMINATE*
     2* THE PROGRAM.  WHEN THE PROGRAM ASKS*/*  FOR A PRESSURE, DENSITY*
     3*, AND TEMPERATURE, ENTER ANY TWO OF THE THREE*/*  AND A ZERO FOR*
     4* THE THIRD.*/*  THE ORDER MUST BE P,D,T, AND ONE OF THE THREE*
     5* MUST BE ZERO.*/*  IF ALL THREE ARE ZERO THE PROGRAM ASKS FOR A*
     6* NEW FLUID.*)
      RETURN
      END


C
      FUNCTION DIEL(P,D,T)
C  DIELECTRIC CONSTANT.  INPUT P(MPA), D(MOL/L) AND T(K).
      COMMON/DIEL/BX(6),PX(6)
      CM= BX(1)+ BX(2)*D+ BX(3)*D**2+ BX(4)*D**3+ BX(5)*P+ BX(6)*T
      DIEL=(1.+2.*D*CM)/(1.-D*CM)
      RETURN
      END


      FUNCTION CPI(T)
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
      K=1
      IF(N.EQ.1) 10,15
   10 C=CPO(T)
   15 U=G(9)/T
      EU=EXP (U)
      TS=1./T**4
      GO TO (20,40,55),K
   20 CPI=G(8)*U*U*EU/(EU-1.)**2
      DO 25 I=1,7
      TS=TS*T
   25 CPI=CPI+G(I)*TS
      CPI=CPI*8.31434
      RETURN
C
      ENTRY SI
      K=2
      IF(N.EQ.1) 30,35
   30 C=CPO(T)
   35 GO TO 15
   40 CPI=G(8)*(U/(EU-1.)-ALOG(1.-1./EU))
     1-G(1)*TS*T/3.-G(2)*TS*T*T/2.-G(3)/T+G(4)*ALOG(T)+G(5)*T+G(6)*T*T/2
     2.+G(7)*T**3/3.
      CPI=CPI*8.31434+G(11)
      RETURN
C
      ENTRY HI
      K=3
      IF(N.EQ.1) 45,50
   45 C=CPO(T)
   50 GO TO 15
   55 CPI=G(8)*U*T/(EU-1.)-G(1)/(2.*T*T)-G(2)/T+G(3)*ALOG(T)+G(4)*T
     1+G(5)*T*T/2.+G(6)*T**3/3.+G(7)*T**4/4.
      CPI=CPI*8.31434+G(10)
      RETURN
      END


      FUNCTION CPO(T)
C   SELECTS PROPER COEFF FOR G(I), AND COMPUTES G(10) AND G(11).
C   FOR HYDROGEN ONLY.
      COMMON/CPID/G(11),GH(11),GL(11)
      TX1=140.
      TX2=40.
      DO 10 J=1,11
   10 G(J)=GH(J)
      IF(T.LT.140.) 30,20
   20 CPO=1.0
      RETURN
   30 G(10)=G(10)+GHI(TX1)
      G(11)=G(11)+GSI(TX1)
      DO 40 J=1,8
   40 G(J)=GL(J)
      G(10)=G(10)-GHI(TX1)
      G(11)=G(11)-GSI(TX1)
      IF(T.LT.40.) 60,50
   50 CPO=1.0
      RETURN
   60 G(10)=G(10)+GHI(TX2)
      G(11)=G(11)+GSI(TX2)
      DO 70 J=1,8
   70 G(J)=0.0
      G(4)=2.5000315
      G(10)=G(10)-GHI(TX2)
```

```
      G(11)=G(11)-GSI(TX2)
      CPO=1.0
      RETURN
      END


      FUNCTION GHI(T)
      COMMON/CPID/G(11),GH(11),GL(11)
    1 U=G(9)/T
      EU=EXP(U)
      GHI=G(8)*U*T/(EU-1.)-G(1)/(2.*T*T)-G(2)/T+G(3)*ALOG(T)+G(4)*T
     A +G(5)*T*T/2.+G(6)*T**3/3.+G(7)*T**4/4.
      GHI=GHI*8.31434
      RETURN
C
      ENTRY GSI
      U=G(9)/T
      EU=EXP(U)
      TS=1./T**4
      GHI= G(8)*(U/(EU-1.)-ALOG(1.-1./EU))-
     A G(1)*TS*T/3.-G(2)*TS*T*T/2.-G(3)/T+G(4)*ALOG(T)+G(5)*T+
     B G(6)*T*T/2.+G(7)*T**3/3.
      GHI=GHI*8.31434
      RETURN
      END


      SUBROUTINE LIMITS(P,T,IL)
      DIMENSION G(32),VP(9)
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
      COMMON/DIEL/BX(6),PX(6)
      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 PRINT 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,* BAR*)
      IL=0  $  RETURN
   12 TLLF= (TLL-273.15)*1.8+32.
      TULF= (TUL-273.15)*1.8+32.
      PRINT 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-273.15)*1.8+32.
      PRINT 22, TM,TF
   22 FORMAT(* SOLID PHASE DETECTED.*,/,* FOR THIS PRESSURE,  TEMP*
     A * SHOULD EXCEED *,F8.3,* K, OR*,F9.3,* F*)
      IL=0  $  RETURN
      END


      FUNCTION PMELT(T)
C  COMPUTES MELTING PRESSURE(MPA) FOR INPUT TEMPERATURE(K).
      COMMON/DIEL/BX(6),PX(6)
      COMMON/ISP/N,NW,NWW
      IF(N.EQ.1) 20,10
   10 PMELT= PX(1)+ PX(2)*T**PX(3)
      RETURN
   20 IF(T.GT.22.) 30,10
   30 PMELT= PX(4)+ PX(5)*T**PX(6)
```

```
      RETURN
      END


      FUNCTION TMELT(P)
C   COMPUTES MELTING TEMPERATURE(K) FOR INPUT PRESSURE(MPA)
      COMMON/DIEL/BX(6),PX(6)
      COMMON/ISP/N,NW,NWW
      IF(N.EQ.1) 20,10
   10 TMELT=((P-PX(1))/PX(2))**(1./PX(3))
      RETURN
   20 IF(P.GT.31.64) 30,10
   30 TMELT=((P-PX(4))/PX(5))**(1./PX(6))
      RETURN
      END
```

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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An interactive FORTRAN IV computer program is given for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. The program is designed for use with a computer terminal accessing a large computer in an interactive mode. The program provides prompting for selection of several options including: 1) choice of fluid, 2) choice of SI or engineering units, 3) choice of the single phase or liquid-vapor phase, and 4) a table of properties or a single value.

Properties are computed for the single phase region from input of two of the variables, temperature, pressure, and density. Values on the liquid-vapor boundary are computed from an entry of temperature or pressure. The program returns values for pressure, temperature, density, internal energy, enthalpy, entropy, specific heats at constant volume and pressure, and sound velocity. Viscosity, thermal conductivity, and dielectric constant are given for some of the fluids. Copies of the programs may be obtained from Office of Standard Reference Data, Attention: Reference Center, National Bureau of Standards, Washington, D.C. 20234.

12 KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

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