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SUMMARY

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A program was designed for the calculation of the performance, weight, and area characteristics of a single-panel central-fin-tube flat-plate sensible-heat radiator for a set of thermodynamic and fluid mechanic conditions. The FORTRAN 7094 main program and its subroutines are reported herein. The program is based on the analysis, equations, and techniques developed and reported in NASA Technical Note D-2839.

A typical computer printout sheet is included and a discussion of the definitions of the FORTRAN symbols and groups of numbers that designate the inputs, the error tests, and the outputs is presented.

Author

INTRODUCTION

A design analysis and general characteristics of flat-plate central-fin-tube sensible-heat space radiators were presented in reference 1. It was shown therein that a combination of equations based on the relations of heat transfer, fluid mechanics, and meteoroid protection resulted in specific relations for calculating radiator geometry, weight, and panel planform area. In order to perform the parametric studies reported in reference 1, these equations and required inputs were programed for an IBM 7094 electronic digital computer.

The purpose of this report is to describe the FORTRAN 7094 main program and its subroutines. Some phases of the computational procedure (e.g., Kalaba's method) will be discussed in more detail. Computer program diagrams are included to illustrate the procedure and to show how the various elements and subroutines are interconnected to generate the required outputs.

In addition, a typical printout sheet will be presented and explained. It contains the inputs and the outputs for two sensible-heat radiator examples: a Brayton cycle case and a secondary cooling radiator case. Various FORTRAN symbols and groups of quantities without symbols will be defined as they are written and appear on the printout sheet. The definitions correspond to the definitions of the symbols used in reference 1.

SYMBOLS

A area, sq ft

D diameter, ft

F angle factor

h heat-transfer coefficient, Btu/(sec)(sq ft)(^{o}R)

L half-fin width, ft

Re Reynolds number

R_o outside tube radius, ft

T absolute temperature, ^{o}R

t fin thickness, ft

U_o overall heat-transfer coefficient, Btu/(hr)(sq ft)(^{o}R)

W weight, lb

Z tube length, ft

γ_j heat-transfer parameter

δ_a armor thickness, ft

η fin-tube effectiveness

θ dimensionless temperature ratio

λ dimensionless conductance parameter

Subscripts:

H header

j at location j

o outside

s sink

t tube

tot total

$\underline{X}$ at location $\underline{X}$

COMPUTATIONAL PROCEDURE AND COMPUTER PROGRAM LISTING

Procedure

As shown in the analysis section of reference 1, a combination of equations based on the relations of the heat transfer, fluid mechanics, and meteoroid protection resulted in certain relations for calculating radiator size, weight, and panel planform area. In order to perform the parametric studies, these equations and required inputs were programed for an IBM 7094 electronic digital computer

The FORTRAN 7094 program consists of two versions of the main program and four subroutines. The only difference in these versions is that the first version finds the fin-tube effectiveness by solving the proper equations using subroutines TOJ, DEQ2, and FXX. The second version using subroutine TABLE finds fin-tube effectiveness by interpolating in a table listing fin-tube effectiveness, which is read into the machine. Hereinafter, the main program refers to either version.

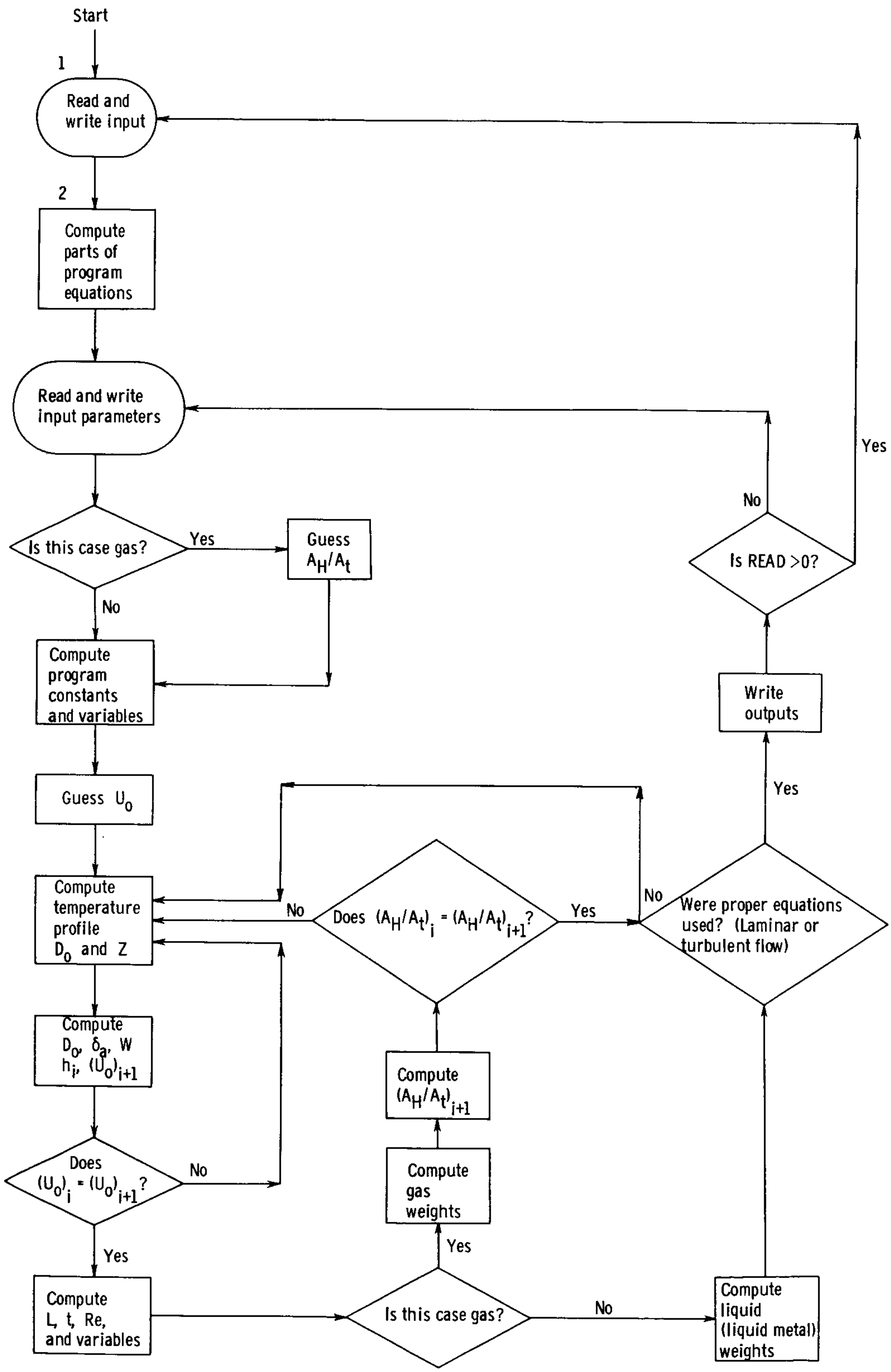
The flow diagram of the main program is shown in figure 1(a). The main program is written for either a gas, a liquid, or a liquid metal as the working fluid. For the radiator using gas as the working fluid, the program involves the ratio of header surface area to tube surface area A_H/A_t. For liquids and liquid metals the ratio A_H/A_t does not appear, since the header area is assumed to be negligible compared with the tube surface area.

Block 1 of figure 1(a) contains the main program inputs. They are the physical and thermal properties of the working fluid and the radiator structural materials (such as, sonic velocity, viscosity, specific heat, density, thermal conductivity, emissivity), as well as meteoroid protection parameters (meteoroid flux, density, operation time, probability of no meteoroid penetration, occlusion and spalling factors). Also included are the flow rate, inlet and outlet temperatures, the pressures and pressure drops, the accuracy percentages of the computations, the branching command numbers, and the number of points in the various meshes.

Parts of some equations can be computed based on the inputs and constants listed in the previous paragraph. This is done in block 2 of figure 1(a). The next step is to read and write the input parameters: inside tube diameter, fin-tube profile ratio, and fin conductance parameter at the radiator inlet. There are branches throughout the program that select either gas, liquid, or liquid metal radiator equations, variables, and constants. The program is written for tubes and headers with inside liners. Both turbulent-flow and laminar-flow equations are contained in the program for all three mediums: gas, liquid, and liquid metal. First, a solution is obtained for given inputs from turbulent-flow equations. After the solution is converged, the Reynolds number is checked. Then the Reynolds number is used as a test either to read the next set of inputs (if the Reynolds number indicates turbulent flow) or to find a second solution from the laminar-flow equations. A single result is printed out when the Reynolds number is less than 2300 or greater than 3000. If the Reynolds number is between 2300 and 3000, both laminar and turbulent flow results are printed.

The noteworthy feature of the main program is the iteration for the overall heat-transfer coefficient. The iteration starts with a guessed value and proceeds by using the method of false position (Regula Falsi) that is based on the principle that a curve over a short interval can be approximated by a straight line between two values, each being on opposite sides of the right value. The same method is used to calculate the ratio A_H/A_t for the gas working fluid. The overall heat-transfer coefficient iteration is accomplished within the A_H/A_t iteration.

During both iteration processes the values for the tube and header wall



(a) Main program.

Figure 1. - Computer program flow diagrams.

thickness, the tube outside diameter, the tube length, number of tubes, tube and liquid content weights, and the panel planform area are also obtained. With this information, the half-fin width, the fin thickness, fin weight, and header dimensions and weights are obtained.

Within the iteration of overall heat-transfer coefficient, the program solves for the tube surface temperature of each isothermal elemental strip by Newton's method. The first version requires a subroutine TOJ, the flow diagram for which is shown in figure 1(b). The fin-tube effectiveness is also computed by the subroutine TOJ. This involves solving the second-order differential equation

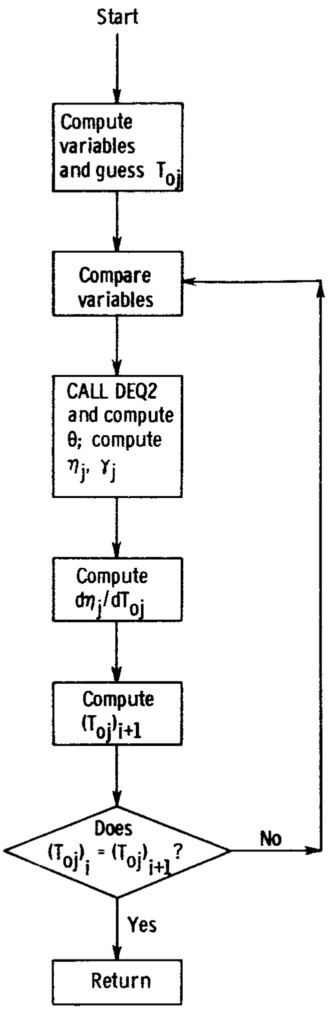
$$\left(\frac{d^2\theta}{d\bar{X}^2}\right) = \lambda\left[\theta^4 - \theta_s^4 - \left(1 - \theta_s^4\right)F_{\bar{X}}\right] \tag{1a}$$

$$F_{\bar{X}} = F_{\bar{X}-1} + F_{\bar{X}-2} \tag{1b}$$

where

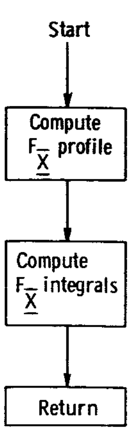
$$\left.\begin{aligned} \theta = 1 \quad &\text{at} \quad \bar{X} = 0 \\ d\theta/d\bar{X} = 0 \quad &\text{at} \quad \bar{X} = 1 \end{aligned}\right\} \tag{2}$$

by using subroutines DEQ2 and FXX. These additional subroutines will be discussed later. As part of Newton's method, the derivative $d\eta$ is computed, and a value of $T_{o,j}$ is obtained, which is checked against the guessed value depicted in the first block (fig. 1(b)). The iteration is repeated until the new value of $T_{o,j}$ agrees with the previous value within the required accuracy.



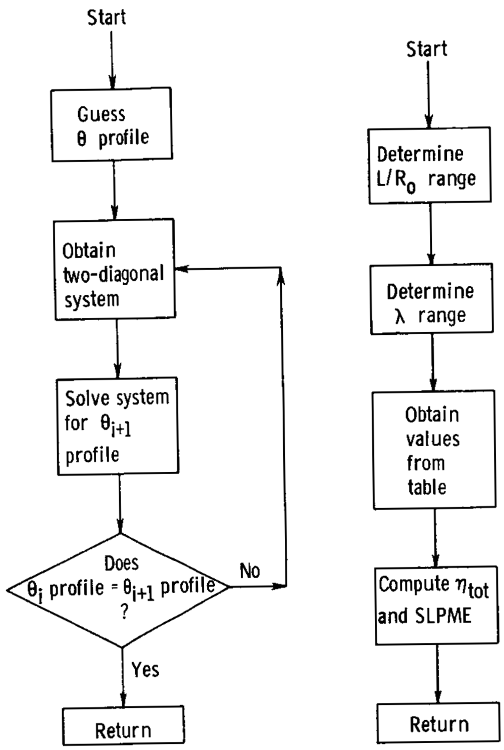
(b) Subroutine TOJ.

The subroutine FXX (fig. 1(c)) computes the angle factors between fin and tube at each mesh point for use in the subroutine DEQ2 (fig. 1(d)). Subroutine FXX also obtains integrals independent of θ to be used in subroutine TOJ (fig. 1(c)) for calculating the integral in the expression for the fin-tube effectiveness (ref. 1). The subroutine DEQ2 is used to solve the second-order differential equation (eqs. 1(a) and (b)) with its boundary conditions (eq. (2)). The method used in this program was devised by Kalaba (ref. 2). With this method, θ^4 is approximated by a linear function θ, namely, by the first two terms of its Taylor series. The central differences are applied to $d^2\theta/d\bar{X}^2$. The linear approximation, the difference approximation to $d^2\theta/d\bar{X}^2$, and the boundary conditions are used to obtain a set of linear equations whose corresponding tri-diagonal matrix



(c) Subroutine FXX.

Figure 1. - Continued. Computer program flow diagrams.



(d) Subroutine DEQ2. (e) Subroutine TABLE.

Figure 1. - Concluded. Computer program flow diagrams.

is reduced to two-diagonal form. The temperature θ profile is then solved by backward substitution. An initial θ profile guess is used and each successive iteration yields approximately one significant figure of accuracy.

By using the second version of the main program, computation time can be significantly reduced with the introduction of a table. The subroutine called TABLE (fig. 1(e)) now is used instead of subroutines TOJ, FXX, and DEQ2.

The values of the fin-tube effectiveness were first obtained from subroutines TOJ, FXX, and DEQ2 by using the fin-tube profile ratio, conductance parameter, and sink temperature ratio as independent variables. These values are then tabulated for use in subroutine TABLE. The first version may be used if these parameters are outside the range of TABLE or if it is desired to avoid the slight inaccuracy caused by using linear interpolation of nonlinear functions.

```
$IBFTC GASLMC  DECK
C              SAULE - GAS,LIQUID,LIQUID METAL RADIATOR
      DIMENSION TABL(13,36),          TWR(100),DELZNW(100),DELZW(100),
     1           FLWRIT(100) ,
     2          DIJ(20),FLRJ(20),FLAMRJ(20)
      COMMON TABL,FLR,FNC,ETATOT,SLPME,TUSE
      READ  (5,130)((TABL(I,J),J=1,36),I=1,13)
  130 FORMAT(12F6.3)
  132 FORMAT(9F6.2)
      READ  (5,134)PIE,FNMESH,FTEST,TEST,TESUH,FATST
  134 FORMAT(E13.6,6E10.3)
      WRITE (6,487)
  215 READ  (5,3)STEPH,ALPHA,BETA,EMACH,RHAP,VAVG,PNAN,      FCCLU,TDAY,
     1EPSL,ATICK,GSRLQ,QLMR,TZWR
      NMESH=FNMESH
    3 FORMAT(6E12.5)
    4 FORMAT(8E15.5)
C
C             BRANCH - GAS OR LIQUID,LIQUID METAL RADIATOR
C
C                       IF GAS CASE,THEN GSRLQ = 0, AND QLMR =
C                       IF LIQUID CASE, THEN GSRLQ = 1 AND QLMR = 0
C                   IF LIQUID METAL CASE ,  THEN GSRLQ = 1.AND QLMR = 1
C
C
    2 IF(GSRLQ)160,160,150
  150 READ  (5,9)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,RHAIN,RHAF,
     1  RHAH,RHAT,PDRPT,PDRPH,THERKF,TCGAS,TS,RHAC
      IF (QLMR) 664,664,665
  664 WRITE (6,662)
      GO TO 667
  665 WRITE (6,666)
  667 WRITE (6,4)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,     RHAIN,RHAF,
     1RHAH,RHAT,PDRPT,PDRPH,THERKF,TCGAS,TS,RHAC,STEPH,      ALPHA,BETA,
     2EMACH,RHAP,VAVG,PNAN,FCCLU,TDAY,EPSL,ATICK,FTEST,      TEST,TESUH,
     3FNMESH,GSRLQ,QLMR,TZWR
  419 TCLQ=TCGAS
      RHAL=RHAIN
  155 FF=1.0
      GO TO 165
  160 READ  (5,9)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT, RGAS,PINLT,
     1  RHAF,RHAH,RHAT,PTUBT,PTUBH,THERKF,TCGAS,TS,RHAC
      WRITE (6,663)
      WRITE (6,4)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,     RGAS,PINLT,
     1RHAF,RHAH,RHAT,PTUBT,PTUBH,THERKF,TCGAS,TS,RHAC,STEPH,ALPHA,
     2BETA,EMACH,RHAP,VAVG,PNAN,FCCLU,TDAY,EPSL,ATICK,FTEST,TEST,
     3 TESUH,FNMESH,FATST,GSRLQ,QLMR,TZWR
      PDRPT=PINLT*PTUBT
      PDRPH=PINLT*PTUBH
      PEXIT=PINLT-(PDRPT+2.0*PDRPH)
      RHAIN=PINLT/(RGAS*TINLT)
  163 RHAUT=PEXIT/(RGAS*TEXIT)
      TINTD=1.0/TINLT
      TEXTD=1.0/TEXIT
```

```
      TINTD2=TINTD**2
      TEXTD2=TEXTD**2
      FF2=TEXTD2-TINTD2
      FF3=TEXTD2*TEXTD-TINTD2*TINTD
      FF=1.5*FF2/(FF3*TINLT)
C
  165 FLTN= 2.0
C
      DELT=(TINLT -TEXIT)/FNMESH
      TEMPRD=TINLT-DELT/2.0
      HI1=RHAIN/VISC
      HI3=VISC*CPH/TCGAS
      IF(QLMR)204,204,201
  201 HI4=HI3**0.4
      HI5=0.625*TCGAS*HI4
      GO TO 206
  204 HI4=HI3**0.3
      HI5=0.023*TCGAS*HI4
  206 DELZN1=FMAS*CPH*DELT
      DELZN2=3600.0*DELZN1/PIE
      FMAS2=FMAS*FMAS
      DELT1=(62.45*RHAP/RHAT)**0.5
      DELT2=(VAVG/SCVEL)**(2.0/3.0)
      DELT3=(0.6747E-04/RHAP)**(1.0/3.0)
      BETAD=1.0/(3.0*BETA)
      DELT4=-TDAY*ALPHA/ALOG(PNAN)
      DELT5=2.0/(3.0*EMACH*BETA+2.0)
      DELT6=PIE*DELT4*DELT5
      DELTA1=DELT1*DELT2*DELT3
    5 DELTA2=2.0*ATICK*FCCLU*DELTA1
      FMAS23=20.3/FMAS
      ZBG3=RHAIN*PDRPT/FF
      ZBG4=ZBG3**(5.0/14.0)
      ZBG5=(1.0/VISC)**(1.0/14.0)
    6 ZBG7=ZBG4*ZBG5
      VNE1=4.0*FMAS/(PIE*RHAIN)
      WT1=PIE*RHAT
      TS4=TS**4
    7 WF1=2.0*RHAF
    8 READ(5,524) JDI,(DIJ(J),J=1,JDI)
      READ(5,524) JFLR,(FLRJ(J),J=1,JFLR)
      READ(5,524) JBRU,(FLAMRJ(J),J=1,JBRU),READ
      DO 525 JB1=1,JBRU
      FLAMRD= FLAMRJ(JB1)
      DO 526  JB2=1,JFLR
      FLR= FLRJ(JB2)
      DO 120 JB3=1,JDI
      DI = DIJ(JB3)
      WRITE (6,10)      DI,    FLR,FLAMRD
   10 FORMAT(1HO,                      5H  DI=E13.6,3X,
     15H FLR=E13.6,3X,7HFLAMRD=E13.6)
C
C
      IF(RHAC)460,460,461
  460 DLCC=0.0
      GO TO 464
  461 DI04=.04*DI
      IF(DI04-.00125) 417,415,415
  415 DLCC=DI04
      GO TO 464
  417 DLCC=.00125
```

```
C
C
  464 DLCC2= DLCC+DLCC
      JL23= 0
      LADTR= 2
      DEBUG DLCC,DI
C
C
  605 IF(GSRLQ) 306,306,310
  306 JAT=1
      JAT1=0
      JAT2=0
      JAT3=2
      JAT4=1
      JAT5=0
      JAT6=0
      AHT=0.3
      AHT1=0.3
  308 AHT2=0.3
      GO TO 312
  310 JAT=0
  312 GAM1=STEPH*FLTN*EPSL/PIE
      TLITT1=STEPH*FLTN*EPSL/THERKF
      FNC=FLAMRD
      CALL TABLE
      ETARD=ETATOT
      DI2=DI*DI
      ZBG6=DI**(12.0/7.0)
      GAM2=ETARD*(1.0+FLR)
   11 GAM3=GAM2*GAM1
      UHETP=UHETRD
      KCNT=0
   14 UHET=UHETP
      TEMP1=TEMPRD
      FLAM1=FLAMRD
      ETA1=ETARD
      GAMMA1=GAM3/UHET
      GAMSAV=GAMMA1
      KPP=0
      TDMY=TEMP1
   17 TDMY2=TDMY*TDMY
      TDMY4=TDMY2*TDMY2
      FNWT1=GAMMA1*(TDMY4-TS4)
   18 FNWT=FNWT1+TDMY-TEMP1
      IF(ABS(FNWT)-FTEST) 25,25,20
   20 IF(KPP-20) 23,23,21
   21 WRITE (6,22)
   22 FORMAT(1H0,32H TROUBLE-LOOK AT STATEMENT NO.20)
      GO TO 120
   23 KPP=KPP+1
      TDMY3=TDMY2*TDMY
      DNWT=4.0*GAMMA1*TDMY3+1.
   24 TDMY=TDMY-FNWT/DNWT
      GO TO 17
   25 TSAVE=TDMY
      TZERC=TDMY**3
      DELZN=DELZN2/(TEMP1-TSAVE)/UHET
      DZN=DELZN
      TWR(1)=TDMY
      DELZNW(1)=DELZN
      JEND=NMESH
```

```
      FLWRIT(1)= FLAMRD
   30 DO 55 J=2,JEND
      KNN=0
      TEMP2=TEMP1-DELT
      TSAVE3=TSAVE**3
      DFNTW1=3.0*GAMMA1*FLAM1
      DFNTW2=DFNTW1/(ETA1*TSAVE3)
      TDMY=TEMP2
   35 FLAM2=FLAM1*(TDMY/TSAVE)**3
   36 FNC=FLAM2
      CALL TABLE
   37 ETA2=ETATOT
      GAMMA2=GAMMA1*(ETA2/ETA1)
      TDMY2=TDMY*TDMY
      TDMY4=TDMY2*TDMY2
      FNTW1=GAMMA2*(TDMY4-TS4)
   39 FNTW=TEMP2-TDMY-FNTW1
      IF(ABS(FNTW)-TEST)45,45,40
   40 IF(KNN-20) 43,43,41
   41 WRITE (6,42)
   42 FORMAT(1H0,32H TROUBLE-LOOK AT STATEMENT NO.40)
      GO TO 120
   43 KNN=KNN+1
      TDMY3=TDMY2*TDMY
      DFNTW3=(TDMY4-TS4)*TDMY2
      DFNTWT=DFNTW2*DFNTW3*SLPME
      DFNTW4=4.0*GAMMA2*TDMY3
      DFNTW=-(1.0+DFNTW4+DFNTWT)
   44 TDMY=TDMY-FNTW/DFNTW
      GO TO 35
   45 TSAVE=TDMY
      TEMP1=TEMP2
      GAMMA1=GAMMA2
      FLAM1=FLAM2
   48 ETA1=ETA2
      DELZN=DELZN2/(TEMP1-TSAVE)/UHET
   50 DZN=DZN+DELZN
      TWR(J)=TDMY
      DELZNW(J)=DELZN
      FLWRIT(J)=FLAM2
   55 CONTINUE
      IF(JAT)57,57,320
  320 DLAHT=1.0+AHT
      DELT8=(DZN*DELT6*DLAHT)**BETAD
      GO TO 324
   57 DELT8=(FLTN*DZN*DELT6/2.0)**BETAD
  324 DELTA=DELTA2*DELT8
   60 DIAT=DI+FLTN*(DELTA+DLCC)
   67 ZN=DZN/DIAT
C
C
      IF(LADTR-1) 446,446,448
  446 IF(GSRLQ) 450,450,452
  450 ZBG1= 0.7903*ZN*PINLT*PINLT*PTUBT*DI**4
      ZBIG= SQRT(ZBG1/(FMAS*RGAS*TINLT*VISC*FF))
      GO TO 69
  452 ZBG1= 0.7903*ZN*RHAIN*PDRPT*DI**4
      ZBIG= SQRT(ZBG1/FMAS/VISC)
      GO TO 69
C
C
```

```
  448 ZBG1=FMAS23*ZN
      ZBG2=ZBG1**(9.0/14.0)
   68 ZBIG=ZBG2*ZBG6*ZBG7
   69 FLATN=ZN/ZBIG
      DEBUG LADTR,ZBG1,ZBIG,ZN,PDRPT,DI
      NBIG=FLATN
      BIGN=FLOAT(NBIG)+1.0
      IF(FLATN-BIGN+1.0) 71,71,73
   71 BIGN=BIGN-1.0
   73 VNE=VNE1/(BIGN*DI2)
C
      IF(LADTR-1) 456,456,454
  456 HI= 4.36*TCGAS/DI
      GO TO 458
C
  454 IF(QLMR)212,212,210
  210 HI2=(HI1*VNE*DI)**0.4
      GO TO 75
  212 HI2=(HI1*VNE*DI)**0.8
   75 HI=HI5*HI2/DI
  458 DIAT36=3600.0/DIAT
      DEBUG HI,HI2,VNE,BIGN
C                                 BRANCH AND COMPUTE UO
C
      IF(QLMR) 520,520,503
  503 DAODI= DIAT/DI
      UOO1 = DAODI/(3600.0*HI)
      UOLN= ALOG(DAODI)
      UOO2= DIAT*UOLN/(THERKF+THERKF)
      UHETP= 1.0/(UOO1+UOO2)
      GO TO 522
C
  520 UHETP=DIAT36*HI*DI
  522 DIFFU=UHETP-UHET
      TESH=(UHETP+UHET)*TESUH/2.0
   77 ADIFFU=ABS(DIFFU)-ABS(TESH)
      IF(ADIFFU)85,85,78
   78 KCNT=KCNT+1
      IF(KCNT-20) 14,14,82
   82 WRITE (6,83)
   83 FORMAT(1H0,32H TROUBLE-LOOK AT STATEMENT NO.78)
      GO TO 120
   85 FLEN=FLR*DIAT/2.0
      FLEN2=FLEN*FLEN
      FLDI=DIAT+2.0*FLEN
      TLITT2=TLITT1*FLEN2/FLAMRD
      TLITT=TLITT2*TZERC
      TLITTW=12.0*TLITT
      WF2=WF1*FLEN
      WT2=ZN*WT1
      IF(GSRLQ)445,445,435
  435 DCC=DI+DLCC+DLCC
      DCC2=DCC*DCC
      WCT1=PIE*ZN/4.0
      WCT2=RHAT*(DIAT*DIAT-DCC2)
      WCT3=RHAC*(DCC2-DI*DI)
      WT=WCT1*(WCT2+WCT3)
      GO TO 87
  445 WT= PIE*ZN*(RHAT*DELTA*(DI+DLCC2 +DELTA) +RHAC*DLCC*(DI+DLCC))
      DEBUG WT,DLCC,DELTA,ZN
   87 WF=WF2*ZN*TLITT
```

```
      PANEL=ZN*DIAT*(1.0+FLR)
      REYN=VNE*DI*RHAIN/VISC
  169 IF(GSRLQ)180,180,170
  170 P124=1.0/24.0
      P524=5.0/24.0
      P924=9.0/24.0
      DH1= PDRPH*RHAIN
      DH2= BIGN*FLDI/DH1
      DH4= DH2**P524
      DH5=0.174*VISC**P124
      DH6=FMAS**P924
      DH=DH4*DH5*DH6
      WLQH2=BIGN*FLDI*RHAH
  455 WCH1=2.0*PIE*BIGN*FLDI
      WCH2=RHAH*DELTA*(DH+DELTA+DLCC+DLCC)
      WCH3=RHAC*DLCC*(DH+DLCC)
      WLQH=WCH1*(WCH2+WCH3)
  173 WLQI2=2.0*BIGN*FLDI
      WLQI3=WLQI2*DH*DH
      WLQI4=WLQI3+DI2*ZN
      WLQI=PIE*RHAIN*WLQI4/4.0
      WLQ2=WT+WF
  174 WLQ=WLQ2+WLQH+WLQI
C
C
      DEBUG LAOTR,REYN,VNE,DI,RHAIN,VISC,BIGN,JL23
      IF(JL23-1) 607,609,601
  609 IF(REYN-2300.0) 648,610,610
  648 WRITE (6,646)
      GO TO 601
  610 WRITE(6,612) REYN
      GO TO 120
  607 IF(REYN-2300.0) 602,614,614
  602 JL23= 1
      LAOTR= 1
      WRITE (6,624) REYN
      GO TO 605
  614 JL23= 2
C
C
  601 IF(TZWR) 477,477,485
  477 DIAFLT=1.0/(DIAT*FLATN)
      DO 479 J=1,JEND
      DELZW(J)=DELZNW(J)*DIAFLT
  479 CONTINUE
      WRITE (6,467)(TWR(J),J=1,JEND)
      WRITE (6,469)(DELZW(J),J=1,JEND)
  485 WRITE (6,175)WLQ,WLQH,WLQI,WT,WF,DH,DIAT,PANEL,UHETP,  DELTA,BIGN,
     1ZBIG,ZN,HI,VNE,TLITTW,REYN
  175 FORMAT(1H ,5H WLQ=E13.6,3X,5HWLQH=E13.6,3X,5HWLQI=E13.6,3X,
     15H  WT=E13.6,3X,5H  WF=E13.6,3X,5H  DH=E13.6/1X,5HDIAT=E13.6,3X,
     26HPANEL=E13.6,2X,6HUHETP=E13.6,4X,6HDFLTA=E13.6,2X,5HBIGN=E13.6,
     33X,5HZBIG=E13.6/1X,5H  ZN=E13.6,3X,5H  HI=E13.6,3X,5H VNE=E13.6,
     43X,6HTLITT=E13.6,3X,6H REYN=E13.6)
C
C
      IF(JL23-2) 120,613,120
  613 JL23= 3
      IF(REYN-3000.0) 616,120,120
  616 LAOTR= 1
      WRITE (6,646)
```

```
      GO TO 605
  180 FC1=PDRPH*RHAIN
      FC4=VISC/FMAS**0.6
      FC2=FLDI/FC1
      WH1=FMAS2/PDRPH
      WH5=(1.0/RHAIN)**0.2
      WH8=PIE*RHAH
      WH2=WH1*FLDI
      AH3=1.405*FLDI
      AT1=PIE*DIAT
      FC3=FC2*BIGN
      FC5=FC3**0.2
      FC6=FC5*FC4
      FSM=0.0382*FC6**0.208
      WH3=WH2*FSM*BIGN
      WH4=WH3**0.2
      DNE3=WH3/RHAIN
      DNE=0.596*DNE3**0.2
      DTW1=RHAIN/RHAUT
      DTW2=DTW1**0.2
      DTW=DTW2*DNE
      WHH= BIGN*FLDI
      WIH= PIE*WHH*((0.75*DNE +DLCC2 +DELTA)*DELTA*RHAH +(0.75*DNE+
     1          DLCC)*RHAC*DLCC)
      WOH=PIE*WHH*((0.75*DTW +DLCC2 +DELTA)*DELTA*RHAH
     1          (0.75*DTW+DLCC)*RHAC*DLCC)
      WH= WIH+WOH
      W= WH+WF+WT
      DEBUG WH,W,WOH,WHH,WIH,DELTA,BIGN
C
C
      AH1=WH4*WH5
      AH2=1.0+DTW2
      AH4=AH1*AH2*AH3
   95 AH=AH4*BIGN
      AT=AT1*ZN
      IF(JAT) 97,97,328
  328 KCNT=0
      IF(JAT6)330,330,395
  330 AHTC=AH/AT
      FAHT=AHT-AHTC
      IF(ABS(FAHT)/FAHT) 334,334,336
  334 NSG=-1
      GO TO 338
  336 NSG=1
  338 IF(JAT1) 340,340,341
  340 NSV1=NSG
      FAHTS1=FAHT
      AHTS1=AHT
      JAT1=1
      AHT1=0.25*AHT1
      AHT=AHT1
      GO TO 14
  341 IF(JAT2)342,342,360
  342 IF(NSG+NSV1)344,343,344
  343 JAT2=1
      FAHTS2=FAHT
      AHTS2=AHT
      GO TO 370
  344 IF(JAT4-6) 348,385,385
  348 JAT4=JAT4+1
```

```
      GO TO (350,352),JAT3
  350 AHT1=0.25*AHT1
      AHT=AHT1
      JAT3=2
      GO TO 354
  352 AHT2=AHT2+0.4
      AHT=AHT2
      JAT3=1
  354 UHETP=UHETRD
      GO TO 380
  360 IF(NSV1+NSG)362,365,362
  362 NSV1=NSG
      FAHTS1=FAHT
      AHTS1=AHT
      GO TO 370
  365 FAHTS2=FAHT
      AHTS2=AHT
  370 AHTSV=AHT
      AHTDS=(AHTS1-AHTS2)/(FAHTS1-FAHTS2)
  372 AHT=AHTS1-FAHTS1*AHTDS
      ATST=0.5*(AHT+AHTSV)*FATST
      IF(ABS(AHT-AHTSV)-ATST)390,390,38
  380 JAT5=JAT5+1
      IF(JAT5-30)14,14,382
  382 WRITE (6,383)JAT5,AHTC
      GO TO 395
  385 WRITE (6,387)JAT4,AHTC,NSV1
      GO TO 395
  390 JAT6=1
      GO TO 14
   97 AHT=AH/AT
C
C
      DEBUG REYN,VNE,DI,RHAIN,VISC,BIGN,JL23,LAOTR
  395 IF(JL23-1) 632,634,630
  634 IF(REYN-2300.0) 650,636,636
  650 WRITE (6,646)
      GO TO 630
  636 WRITE(6,612) REYN
      GO TO 120
  632 IF(REYN-2300.0) 638,640,640
  638 JL23= 1
      LAOTR=1
      WRITE(6,624) REYN
      GO TO 605
  640 JL23= 2
C
C
  630 IF(TZWR)462,462,475
  462 DIAFLT=1.0/(DIAT*FLATN)
      DO 465 J=1,JEND
      DELZW(J)=DELZNW(J)*DIAFLT
  465 CONTINUE
      WRITE (6,467)(TWR(J),J=1,JEND)
      WRITE(6,469) (FLWRIT(J),J=1,JEND)
      WRITE (6,469)(DELZW(J),J=1,JEND)
  475 WRITE (6,100)AH,DNE,DTW,BIGN,WT,WF,WH,W,ZBIG,HI,AT,AHT,ZN,DELTA,
     1DIAT,PANEL,UHETP,VNE,TLITTW,REYN
C
C
      IF(JL23-2) 120,642,120
```

```
  642 JL23=3
      IF(REYN-3000.0) 644,120,120
  644 LAOTR=1
      WRITE (6,646)
      GO TO 605
  120 CONTINUE
  526 CONTINUE
  525 CONTINUE
  530 IF(READ-1.0) 8,2,215
C
C
  100 FORMAT(1H ,5H  AH=E13.6,3X,5H DNE=E13.6,3X,5H DTW=E13.6,3X,
     15HBIGN=E13.6,3X,5H  WT=E13.6,3X,5H  WF=E13.6/1X,5H  WH=E13.6,3X,
     25H   W=E13.6,3X,5HZBIG=E13.6,3X,5H  HI=E13.6,3X,5H  AT=E13.6,3X,
     35H AHT=E13.6/1X,5H  ZN=E13.6,2X,6HDELTA=E13.6,3X,5HDIAT=E13.6,
     42X,6HPANEL=E13.6,2X,6HUHETP=E13.6,3X,5H VNE=E13.6/1X,
     5 5HTLIT=E13.6,3X,5HREYN=E13.6)
  383 FORMAT(1H ,28HTROUBLE - SEE STATE. NO. 382,4X,5HJAT5=I3,4X,
     15HAHTC=E12.5)
  387 FORMAT(1H ,28HTROUBLE - SEE STATE. NO. 344,4X,5HJAT4=I3,4X,
     15HAHTC=E12.5,I7)
    9 FORMAT(11E7.5)
  467 FORMAT(12F10.2)
  469 FORMAT(12F10.4)
  487 FORMAT (//,1H0,35H GAS, LIQUID, LIQUID METAL RADIATOR/
     1         ,1H0,73H NOTE - THE COMPUTED TEMP.,LAMDA AND DEL Z PROFIL
     1ES ARE PRINTED OUT BELOW/
     2 1H0,65H THE OUTPUT IS FOR TURBULENT FLOW EQUAS., UNLESS OTHERWISE
     3 STATED)
C
C
  612 FORMAT(1H ,8HINSTABLE,4X,6HREYN =E12.5)
  622 FORMAT(1H ,18HFOR LAMINAR EQUAS.,2X,6HREYN =E12.5)
  624 FORMAT( 1H ,20HFOR TURBULENT EQUAS.,2X,6HREYN =E12.5)
  646 FORMAT (1H0,31H OUTPUT FOR LAMINAR FLOW EQUAS.)
  524 FORMAT (I4,(10E7.5))
  662 FORMAT (1H0,/,20H INPUT DATA - LIQUID)
  663 FORMAT (1H0,/,17H INPUT DATA - GAS)
  666 FORMAT (1H0,/,26H INPUT DATA - LIQUID METAL)
      END


$IBFTC TABLE   DECK
      SUBROUTINE TABLE
C
C
      DIMENSION TABL(13,36)
      COMMON  TABL,FLR,FNC,ETATOT,SLPME,TUSE
C
C
C
      TUSE= 0.0
    6 FLSAVE=FLR
   13 IF(FNC)79,18,18
   18 IF(FLR-10.0)20,100,100
   20 IF(FLR-8.0)310,301,301
  310 IF(FLR-6.0)21,101,101
   21 IF(FLR-4.0)22,102,102
   22 IF(FLR-3.0)311,302,302
```

```
311 IF(FLR-2.0)23,103,103
 23 IF(FLR-1.5)312,303,303
312 IF(FLR-1.0)71,104,104
104 I=1
    DELL=0.5
    FLRT=1.0
    GO TO 60
103 I=3
    DELL=1.0
    FLRT=2.0
    GO TO 60
102 I=5
    DELL=2.0
    FLRT=4.0
    GO TO 60
101 I=6
    DELL=2.0
    FLRT=6.0
    GO TO 60
303 I=2
    FLRT=1.5
    DELL=0.5
    GO TO 60
302 I=4
    FLRT=3.0
    DELL=1.0
    GO TO 60
301 I=7
    FLRT=8.0
    DELL=2.0
    GO TO 60
100 IF(FLR-15.)299,299,300
300 IF(FLR-20.0)99,99,30
 30 IF(FLR-30.0)98,98,31
 31 IF(FLR-50.0)97,97,32
299 I=8
    FLRT=10.0
    DELL=5.0
    GO TO 60
 99 I=9
    DELL=5.0
    FLRT=15.0
    GO TO 60
 98 I=10
    DELL=10.0
    FLRT=20.0
    GO TO 60
 97 I=11
    DELL=20.0
    FLRT=30.0
    GO TO 60
 32 I=12
    IF(FLR-1050.0)40,41,41
 41 FLR=1050
    GO TO 40
 40 DELL=1000.0
    FLRT=50.0
    GO TO 60
 60 IF(FNC-5.0)67,70,200
200 IF(FNC-20.0)209,211,206
206 IF(FLR-50.0)370,370,371
```

```
371 ETA=.145
    GO TO 372
370 ETA=.86567785+FLR*(-.1701984+FLR*(.012712537-FLR*.000191947))
372 WRITE    (6,110)FNC
110 FORMAT(1H0,42HFNC OUT OF RANGE-SEE SUBROUTINE TABLE-FNC=E12.5)
    GO TO 71
209 FJ=21.+(FNC-5.0)
    J=FJ
    FAJ=J
    FRAC=FJ-FAJ
    K=2
    GO TO 61
 67 FJ=FNC/0.25+1.0
    J=FJ
    FAJ=J
    FRAC=FJ-FAJ
    K=0
 61 DEL1=TABL(I,J)-TABL(I+1,J)
    DEL2=TABL(I,J+1)-TABL(I+1,J+1)
    FRAC1=(FLR-FLRT)/DELL
    ETA1=TABL(I,J)-DEL1*FRAC1
    ETA2=TABL(I,J+1)-DEL2*FRAC1
    ETA=ETA1-ETA2
    IF(K-1)62,72,210
210 IF(K-2)213,213,214
 62 ETATOT=ETA1-FRAC*ETA
    SLPME=-4.0*ETA
    FLR=FLSAVE
    GO TO 71
 70 J=20
    K=1
    GO TO 61
 72 ETATOT=ETA2
    SLPME=-4.0*ETA
    FLR=FLSAVE
    GO TO 71
213 ETATOT=ETA1-FRAC*ETA
    SLPME=-ETA
    FLR=FLSAVE
    GO TO 71
214 ETATOT=ETA2
    SLPME=-ETA
    FLR=FLSAVE
    GO TO 71
211 J=35
    K=3
    GO TO 61
C
C
C        TO SEE IF THE POINT (FLR,FNC) IS TABULATED IN THE TABLE
C        TUSE = 1, THEN POINT IS TABULATED
C        TUSE = 0,THEN POINT IS NOT TABULATED
C
C
C
 71 IF (FLR-1.0) 424,401,401
401 IF (FLR-50.0) 402,402,424
402 IF (FRAC1) 424,410,403
403 IF (FRAC1-1.0) 424,410,424
410 IF (FNC)424,411,411
411 IF (FNC-20.0) 412,412,424
```

```
  412 IF (FRAC) 413,423,413
  413 IF (FNC-5.0) 424,423,414
  414 IF(FNC-20.0) 424,423,424
C
C
  423 TUSE= 1.0
      GO TO 425
  424 TUSE= 0.0
  425 RETURN
C
C
C
   79 ETA=1.0
      RETURN
      END
```

```
$IBFTC GASLM    LIST,REF,DECK
C               SAULE - GAS,LIQUID,LIQUID METAL RADIATOR
      DIMENSION TWR(100),DELZNW(100),DELZW(100),BCDMY(12),FXEQ(1000),
     1          FXAB(100)
      COMMON FXEQ,FXAB,FLR,FXGAB,JINTG,MESH,TST,DTST,TS,TEMP2,FLAMTY,
     1       FLAMC,ETAA1,GAMA1,ETAA2,GAMA2,FLAM,FWRITE,FWRTSV
      READ (5,490) (BCDMY(J),J=1,12)
      READ (5,134) FNMESH,FMESH,TESUH,FATST,FJINTG,TST,DTST,FWRITE
      WRITE(6,490) (BCDMY(J),J=1,12)
      WRITE (6,487)
  215 READ  (5,3)STEPH,ALPHA,BETA,EMACH,RHAP,VAVG,PNAN,      FCCLU,TDAY,
     1EPSL,ATICK,GSRLQ,QLMR,TZWR
      NMESH=FNMESH
    2 PIE= 3.1415926
      FWRTSV= FWRITE
      JINTG= FJINTG
      MESH= FMESH
C
C               BRANCH - GAS OR LIQUID,LIQUID METAL RADIATOR
C
      IF(GSRLQ)160,160,150
  150 READ  (5,9)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,RHAIN,RHAF,
     1  RHAH,RHAT,PDRPT,PDRPH,THERKF,TCGAS,TS,RHAC
      IF (QLMR) 664,664,665
  664 WRITE (6,662)
      GO TO 667
  665 WRITE (6,666)
  667 WRITE (6,4)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,      RHAIN,RHAF,
     1RHAH,RHAT,PDRPT,PDRPH,THERKF,TCGAS,TS,RHAC,STEPH,       ALPHA,BETA,
     2EMACH,RHAP,VAVG,PNAN,FCCLU,TDAY,EPSL,ATICK,FNMESH,FMESH,
     3       TESUH,FATST,FJINTG,TST,DTST,FWRITE,GSRLQ,QLMR,TZWR
  419 TCLG=TCGAS
      RHAL=RHAIN
  155 FF=1.0
      GO TO 165
  160 READ  (5,9)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT, RGAS,PINLT,
     1  RHAF,RHAH,RHAT,PTUBT,PTUBH,THERKF,TCGAS,TS,RHAC
      WRITE (6,663)
      WRITE (6,4)SCVEL,FMAS,VISC,UHETRD,CPH,TINLT,TEXIT,      RGAS,PINLT,
     1RHAF,RHAH,RHAT,PTUBT,PTUBH,THERKF,TCGAS,TS,RHAC,STEPH,ALPHA,BETA,
     1EMACH,RHAP,VAVG,PNAN,FCCLU,TDAY,EPSL,ATICK,FNMESH,FMESH,TESUH,
     3       FATST,FJINTG,TST,DTST,FWRITE,GSRLQ,QLMR,TZWR
      PDRPT=PINLT*PTUBT
      PDRPH=PINLT*PTUBH
      PEXIT=PINLT-(PDRPT+2.0*PDRPH)
      RHAIN=PINLT/(RGAS*TINLT)
  163 RHAUT=PEXIT/(RGAS*TEXIT)
      TINTD=1.0/TINLT
      TEXTD=1.0/TEXIT
      TINTD2=TINTD**2
      TEXTD2=TEXTD**2
      FF2=TEXTD2-TINTD2
      FF3=TEXTD2*TEXTD-TINTD2*TINTD
```

```
      FF=1.5*FF2/(FF3*TINLT)
C
  165 FLTN= 2.0
C
      DELT=(TINLT -TEXIT)/FNMESH
      TEMPRD=TINLT-DELT/2.0
      HI1=RHAIN/VISC
      HI3=VISC*CPH/TCGAS
      IF(QLMR)204,204,201
  201 HI4=HI3**0.4
      HI5=0.625*TCGAS*HI4
      GO TO 206
  204 HI4=HI3**0.3
      HI5=0.023*TCGAS*HI4
  206 DELZN1=FMAS*CPH*DELT
      DELZN2=3600.0*DELZN1/PIE
      FMAS2=FMAS*FMAS
      DELT1=(62.45*RHAP/RHAT)**0.5
      DELT2=(VAVG/SCVEL)**(2.0/3.0)
      DELT3=(0.6747E-04/RHAP)**(1.0/3.0)
      BETAD=1.0/(3.0*BETA)
      DELT4=-TDAY*ALPHA/ALOG(PNAN)
      DELT5=2.0/(3.0*EMACH*BETA+2.0)
      DELT6=PIE*DELT4*DELT5
      DELTA1=DELT1*DELT2*DELT3
    5 DELTA2=2.0*ATICK*FCCLU*DELTA1
      FMAS23=20.3/FMAS
      ZBG3=RHAIN*PDRPT/FF
      ZBG4=ZBG3**(5.0/14.0)
      ZBG5=(1.0/VISC)**(1.0/14.0)
    6 ZBG7=ZBG4*ZBG5
      VNE1=4.0*FMAS/(PIE*RHAIN)
      WT1=PIE*RHAT
      TS4=TS**4
    7 WF1=2.0*RHAF
    8 READ (5,9) DI,FLR,FLAMRD,READ
      WRITE (6,10)DI,FLR,FLAMRD
   10 FORMAT(1H0,5H  DI=E13.6,3X,
     15H FLR=E13.6,3X,7HFLAMRD=E13.6)
C
C
      IF(RHAC)460,460,461
  460 DLCC=0.0
      GO TO 464
  461 DI04=.04*DI
      IF(DI04-.00125) 417,415,415
  415 DLCC=DI04
      GO TO 464
  417 DLCC=.00125
C
C
  464 DLCC2= DLCC+DLCC
      JL23= 0
      LAOTR= 2
  605 IF(GSRLQ) 306,306,310
  306 JAT=1
      JAT1=0
      JAT2=0
      JAT3=2
      JAT4=1
      JAT5=0
```

```
      JAT6=0
      AHT=0.3
      AHT1=0.3
  308 AHT2=0.3
      GO TO 312
  310 JAT=0
  312 SEP= 2.0*STEPH*EPSL/PIE
      CALL FXX(FXEQ,FXAB,FXGAB,FLR,MESH,JINTG,FWRITE)
      TLITT1= 2.0*STEPH*EPSL/THERKF
      DI2=DI*DI
   11 ZBG6=DI**(12.0/7.0)
      UHETP=UHETRD
      KCNT=0
   14 UHET=UHETP
      SEPLR= SEP*(1.0+FLR)/UHET
      DZN= 0.0
      FLAMC= FLAMRD
      GAMA1= SEPLR
      ETAA1= 1.
      FLAMTY= 0.0
      TEMP2= TEMPRD
      CALL TOJ(TDMY)
   25 TSAVE=TDMY
      TZERC=TDMY**3
      DELZN=DELZN2/(TEMPRD-TSAVE)/UHET
      DZN=DELZN
      TWR(1)=TDMY
      DELZNW(1)=DELZN
      JEND=NMESH
      FLAMC= 0.
   30 DO 55 J=2,JEND
      GAMA1= GAMA2
      ETAA1= ETAA2
      TEMP2= TEMP2-DELT
      FLAMTY= FLAM/TDMY**3
      CALL TOJ(TDMY)
      DELZN=DELZN2/(TEMP2-TDMY) /UHET
   50 DZN=DZN+DELZN
      TWR(J)=TDMY
      DELZNW(J)=DELZN
   55 CONTINUE
      IF(JAT)57,57,320
  320 DLAHT=1.0+AHT
      DELT8=(DZN*DELT6*DLAHT)**BETAD
      GO TO 324
   57 DELT8=(DZN*DELT6)**BETAD
  324 DELTA=DELTA2*DELT8
   60 DIAT=DI+2.0*(DELTA+DLCC)
   67 ZN=DZN/DIAT
      DEBUG DLCC,DI
C
C
C
      IF(LADTR-1) 446,446,448
  446 IF(GSRLQ) 450,450,452
  450 ZBG1= 0.7903*ZN*PINLT*PINLT*PTUBT*DI**4
      ZBIG= SQRT(ZBG1/(FMAS*RGAS*TINLT*VISC*FF))
      GO TO 69
  452 ZBG1= 0.7903*ZN*RHAIN*PDRPT*DI**4
      ZBIG= SQRT(ZBG1/FMAS/VISC)
      GO TO 69
```

```
  448 ZBG1=FMAS23*ZN
      ZBG2=ZBG1**(9.0/14.0)
   68 ZBIG=ZBG2*ZBG6*ZBG7
   69 FLATN=ZN/ZBIG
      NBIG=FLATN
      BIGN=FLOAT(NBIG)+1.0
      IF(FLATN-BIGN+1.0) 71,71,73
   71 BIGN=BIGN-1.0
   73 VNE=VNE1/(BIGN*DI2)
C
C
C
      IF(LADTR-1) 456,456,454
  456 HI= 4.36*TCGAS/DI
      GO TO 458
C
  454 IF(QLMR)212,212,210
  210 HI2=(HI1*VNE*DI)**0.4
      GO TO 75
  212 HI2=(HI1*VNE*DI)**0.8
   75 HI=HI5*HI2/DI
  458 DIAT36=3600.0/DIAT
C                                BRANCH AND COMPUTE UO
C
      IF(QLMR) 520,520,503
  503 DAODI= DIAT/DI
      UOO1 = DAODI/(3600.0*HI)
      UOLN= ALOG(DAODI)
      UOO2= DIAT*UOLN/(THERKF+THERKF)
      UHETP= 1.0/(UOO1+UOO2)
      GO TO 522
C
  520 UHETP=DIAT36*HI*DI
  522 DIFFU=UHETP-UHET
      TESH=(UHETP+UHET)*TESUH/2.0
   77 ADIFFU=ABS(DIFFU)-ABS(TESH)
      IF(ADIFFU)85,85,78
   78 KCNT=KCNT+1
      IF(KCNT-20) 14,14,82
   82 WRITE (6,83)
   83 FORMAT(1H0,32H TROUBLE-LOOK AT STATEMENT NO.78)
      GO TO 120
   85 FLEN=FLR*DIAT/2.0
      FLEN2=FLEN*FLEN
      FLDI=DIAT+2.0*FLEN
      TLITT2=TLITT1*FLEN2/FLAMRD
      TLITT=TLITT2*TZERC
      TLITTW=12.0*TLITT
      WF2=WF1*FLEN
      WT2=ZN*WT1
      IF(GSRLQ) 445,445,435
  435 DCC=DI+DLCC+DLCC
      DCC2=DCC*DCC
      WCT1=PIE*ZN/4.0
      WCT2=RHAT*(DIAT*DIAT-DCC2)
      WCT3=RHAC*(DCC2-DI*DI)
      WT=WCT1*(WCT2+WCT3)
      GO TO 87
  445 WT= PIE*ZN*(RHAT*DELTA*(DI+DLCC2 +DELTA) +RHAC*DLCC*(DI+DLCC))
   87 WF=WF2*ZN*TLITT
      PANEL=ZN*DIAT*(1.0+FLR)
```

```
      REYN=VNE*DI*RHAIN/VISC
  169 IF(GSRLQ)180,180,170
  170 P124=1.0/24.0
      P524=5.0/24.0
      P924=9.0/24.0
      DH1= PDRPH*RHAIN
      DH2= BIGN*FLDI/DH1
      DH4= DH2**P524
      DH5=0.174*VISC**P124
      DH6=FMAS**P924
      DH=DH4*DH5*DH6
      WLQH2=BIGN*FLDI*RHAH
  455 WCH1=2.0*PIE*BIGN*FLDI
      WCH2=RHAH*DELTA*(DH+DELTA+DLCC+DLCC)
      WCH3=RHAC*DLCC*(DH+DLCC)
      WLQH=WCH1*(WCH2+WCH3)
  173 WLQI2=2.0*BIGN*FLDI
      WLQI3=WLQI2*DH*DH
      WLQI4=WLQI3+DI2*ZN
      WLQI=PIE*RHAIN*WLQI4/4.0
      WLQ2=WT+WF
  174 WLQ=WLQ2+WLQH+WLQI
      DEBUG WT,DLCC,DFLTA,ZN
C
C
      DEBUG LAOTR,REYN,VNE,DI,RHAIN,VISC,BIGN,JL23
      IF(JL23-1) 607,609,601
  609 IF(REYN-2300.0) 648,610,610
  648 WRITE (6,646)
      GO TO 601
  610 WRITE(6,612) REYN
      GO TO 120
  607 IF(REYN-2300.0) 602,614,614
  602 JL23= 1
      LAOTR= 1
      WRITE (6,624) REYN
      GO TO 605
  614 JL23= 2
C
C
  601 IF(TZWR) 477,477,485
  477 DIAFLT=1.0/(DIAT*FLATN)
      DO 479 J=1,JEND
      DELZW(J)=DELZNW(J)*DIAFLT
  479 CONTINUE
      WRITE (6,467)(TWR(J),J=1,JEND)
      WRITE (6,469)(DELZW(J),J=1,JEND)
  485 WRITE (6,175)WLQ,WLQH,WLQI,WT,WF,DH,DIAT,PANEL,UHETP,  DELTA,BIGN,
     1ZBIG,ZN,HI,VNE,TLITTW,REYN
  175 FORMAT(1H ,5H WLQ=E13.6,3X,5HWLQH=E13.6,3X,5HWLQI=E13.6,3X,
     15H  WT=E13.6,3X,5H  WF=E13.6,3X,5H  DH=E13.6/1X,5HDIAT=E13.6,3X,
     26HPANEL=E13.6,2X,6HUHETP=E13.6,4X,6HDELTA=E13.6,2X,5HBIGN=E13.6,
     33X,5HZBIG=E13.6/1X,5H  ZN=E13.6,3X,5H  HI=E13.6,3X,5H VNE=E13.6,
     4  3X,6HTLITT=E13.6,3X,6H REYN=E13.6)
C
C
      IF(JL23-2) 120,613,12
  613 JL23= 3
      IF(REYN-3000.0) 616,120,120
  616 LAOTR= 1
      WRITE (6,646)
```

```
      GO TO 605
  180 FC1=PDRPH*RHAIN
      FC4=VISC/FMAS**0.6
      FC2=FLDI/FC1
      WH1=FMAS2/PDRPH
      WH5=(1.0/RHAIN)**0.2
      WH8=PIE*RHAH
      WH2=WH1*FLDI
      AH3=1.405*FLDI
      AT1=PIE*DIAT
      FC3=FC2*BIGN
      FC5=FC3**0.2
      FC6=FC5*FC4
      FSM=0.0382*FC6**0.208
      WH3=WH2*FSM*BIGN
      WH4=WH3**0.2
      DNE3=WH3/RHAIN
      DNE=0.596*DNE3**0.2
      DTW1=RHAIN/RHAUT
      DTW2=DTW1**0.2
      DTW=DTW2*DNE
      WHH= BIGN*FLDI
      WIH= PIE*WHH*((0.75*DNE +DLCC2 +DELTA)*DELTA*RHAH +(0.75*DNE+
     1          DLCC)*RHAC*DLCC)
      WOH=PIE*WHH*((0.75*DTW +DLCC2 +DELTA)*DELTA*RHAH
     1          (0.75*DTW+DLCC)*RHAC*DLCC)
      WH= WIH+WOH
      W= WH+WF+WT
      AH1=WH4*WH5
      AH2=1.0+DTW2
      AH4=AH1*AH2*AH3
   95 AH=AH4*BIGN
      AT=AT1*ZN
      IF(JAT) 97,97,328
  328 KCNT=0
      IF(JAT6)330,330,395
  330 AHTC=AH/AT
      FAHT=AHT-AHTC
      IF(ABS(FAHT)/FAHT) 334,334,336
  334 NSG=-1
      GO TO 338
  336 NSG=1
  338 IF(JAT1) 340,340,341
  340 NSV1=NSG
      FAHTS1=FAHT
      AHTS1=AHT
      JAT1=1
      AHT1=0.25*AHT1
      AHT=AHT1
      GO TO 14
  341 IF(JAT2)342,342,360
  342 IF(NSG+NSV1)344,343,344
  343 JAT2=1
      FAHTS2=FAHT
      AHTS2=AHT
      GO TO 370
  344 IF(JAT4-6) 348,385,385
  348 JAT4=JAT4+1
      GO TO (350,352),JAT3
  350 AHT1=0.25*AHT1
      AHT=AHT1
```

```
      JAT3=2
      GO TO 354
  352 AHT2=AHT2+0.4
      AHT=AHT2
      JAT3=1
  354 UHETP=UHETRD
      GO TO 380
  360 IF(NSV1+NSG)362,365,362
  362 NSV1=NSG
      FAHTS1=FAHT
      AHTS1=AHT
      GO TO 370
  365 FAHTS2=FAHT
      AHTS2=AHT
  370 AHTSV=AHT
      AHTDS=(AHTS1-AHTS2)/(FAHTS1-FAHTS2)
  372 AHT=AHTS1-FAHTS1*AHTDS
      ATST=0.5*(AHT+AHTSV)*FATST
      IF(ABS(AHT-AHTSV)-ATST)390,390,38
  380 JAT5=JAT5+1
      IF(JAT5-30)14,14,382
  382 WRITE (6,383)JAT5,AHTC
      GO TO 395
  385 WRITE (6,387)JAT4,AHTC,NSV1
      GO TO 395
  390 JAT6=1
      GO TO 14
   97 AHT=AH/AT
      DEBUG WH,W,WOH,WHH,WIH,DELTA,BIGN
C
C
C
      DEBUG REYN,VNE,DI,RHAIN,VISC,BIGN,JL23,LAOTR
  395 IF(JL23-1) 632,634,630
  634 IF(REYN-2300.0) 650,636,636
  650 WRITE (6,646)
      GO TO 630
  636 WRITE(6,612) REYN
      GO TO 120
  632 IF(REYN-2300.0) 638,640,640
  638 JL23= 1
      LAOTR=1
      WRITE(6,624) REYN
      GO TO 605
  640 JL23= 2
C
C
C
  630 IF(TZWR)462,462,475
  462 DIAFLT=1.0/(DIAT*FLATN)
      DO 465 J=1,JEND
      DELZW(J)=DELZNW(J)*DIAFLT
  465 CONTINUE
      WRITE (6,467)(TWR(J),J=1,JEND)
      WRITE (6,469)(DELZW(J),J=1,JEND)
  475 WRITE (6,100)AH,DNE,DTW,BIGN,WT,WF,WH,W,ZBIG,HI,AT,AHT,ZN,DELTA,
     1DIAT,PANEL,UHETP,VNE,TLITTW,REYN
C
C
      IF(JL23-2) 120,642,120
  642 JL23=3
```

```
      IF(REYN-3000.0) 644,120,120
  644 LAOTR=1
      WRITE (6,646)
      GO TO 605
C
C
  120 IF(READ-1.0)8,2,215
  134 FORMAT(7E10.3)
    3 FORMAT(6E12.5)
    4 FORMAT(8E15.5)
  490 FORMAT(12A6)
  487 FORMAT (//,1H0,35H GAS, LIQUID, LIQUID METAL RADIATOR/
     1          ,1H0,73H NOTE - THE COMPUTED TEMP.,LAMDA AND DEL Z PROFIL
     1ES ARE PRINTED OUT BELOW/
     2 1H0,65H THE OUTPUT IS FOR TURBULENT FLOW EQUAS., UNLESS OTHERWISE
     3 STATED)
  383 FORMAT(1H ,28HTROUBLE - SEE STATE. NO. 382,4X,5HJAT5=I3,4X,
     15HAHTC=E12.5)
  387 FORMAT(1H ,28HTROUBLE - SEE STATE. NO. 344,4X,5HJAT4=I3,4X,
     15HAHTC=E12.5,I7)
    9 FORMAT(11E7.5)
  467 FORMAT(12F10.2)
  469 FORMAT(12F10.4)
  100 FORMAT(1H ,5H  AH=E13.6,3X,5H DNE=E13.6,3X,5H DTW=E13.6,3X,
     15HBIGN=E13.6,3X,5H  WT=E13.6,3X,5H  WF=E13.6/1X,5H  WH=E13.6,3X,
     25H   W=E13.6,3X,5HZBIG=E13.6,3X,5H  HI=E13.6,3X,5H  AT=E13.6,3X,
     35H AHT=E13.6/1X,5H  ZN=E13.6,2X,6HDELTA=E13.6,3X,5HDIAT=E13.6,
     42X,6HPANEL=E13.6,2X,6HUHETP=E13.6,3X,5H VNE=E13.6/1X,
     5 5HTLIT=E13.6,3X,5HREYN=E13.6)
  612 FORMAT(1H ,8HINSTABLE,4X,6HREYN =E12.5)
  622 FORMAT(1H ,18HFOR LAMINAR EQUAS.,2X,6HREYN =E12.5)
  624 FORMAT( 1H ,20HFOR TURBULENT EQUAS.,2X,6HREYN =E12.5)
  646 FORMAT (1H0,31H OUTPUT FOR LAMINAR FLOW EQUAS.)
  662 FORMAT (1H0,/,20H INPUT DATA - LIQUID)
  663 FORMAT (1H0,/,17H INPUT DATA - GAS)
  666 FORMAT (1H0,/,26H INPUT DATA - LIQUID METAL)
      END
```

```
$IBFTC TOJ     LIST,REF,DECK
      SUBROUTINE TOJ(TDMY)
C
C        FOR SAULE   -     GAS-L-LM
      DIMENSION FXEQ(1000),FXAB(100),FXA(1000),THA(1000),
     1          FXTHA(1000),FTGA(1000)
      COMMON  FXEQ,FXAB,FLR,FXGAB,JINTG,MESH,TST,DTST,TSA,TEMP2,
     1          FLAMTY,FLAMC,ETAA1,GAMA1,ETAA2,GAMA2,
     2         FLAM,FWRITE,FWRTSV
      FWRTSV=FWRTSV-1.0
    5 FJINTG=JINTG
      MESH1= MESH+1
    7 FMESH=MESH
      DX= 1.0/FMESH
      FLR1= FLR+1.0
      KTDMY=0
    8 TDMY=TEMP2
C
C
C                         BEGIN TDMY INTERATION
```

```
C
C
C                         TO SOLVE THE DIFFERENTIAL EQUA. USING SUB. DEQ2
C                            AND SUB. FXX
C
   10 TDMY2=TDMY*TDMY
      THSA=TSA/TDMY
      FLAM=FLAMTY*TDMY**3+FLAMC
   12 THSA3=THSA**3
      THSA4=THSA3*THSA
   14 THSA5=1.0-THSA4
      FLAMA5=FLAM*THSA5
   16 FLAMA4=FLAM*THSA4
      DO 30 J=1,MESH1
   18 FXA(J)=-FLAMA5*FXEQ(J)-FLAMA4
   30 CONTINUE
      IF(FLAM) 26,22,26
   22 DO 25 J=1,MESH1
      THA(J)=1.
   25 CONTINUE
      GO TO 28
   26 CALL DEQ2(THA,FXA,FLAM,4.0,MESH,TST,FWRTSV)
   28 SLPA=(THA(2)-1.0)/DX
C
C                         TO COMPUTE ETA AND GAMMA
C
      IF(FWRTSV)33,33,130
  130 WRITE(6,132) DX,FLR1,TDMY,TDMY2,THSA,FLAM,THSA3,THSA4,
     1   THSA5,FLAMA5,FLAMA4,SLPA
  132 FORMAT(1H , 8H TOJ-133,(/8E15.5))
   33 DO 35 J=1,MESH1
   34 FXTHA(J)= FXEQ(J)*THA(J)**4
   35 CONTINUE
      CALL FNTGRL(MESH1,DX,FXTHA,FTGA)
      ET1A=2.0-THSA4
   37 ET2A=         ET1A*FXGAB        -FTGA(MESH1)
      IF(FLAM)38,39,38
   39 SLPMA=0.0
      ETAA2= 1.
      GAMAD= 0.
      GO TO 40
   38 SLPMA=SLPA/FLAM
   43 ET3A= THSA5 +FLR*(ET2A-SLPMA)
      ETAA2= ET3A/THSA5/FLR1
   40 GAMA2= GAMA1*ETAA2/ETAA1
C
C                         END ETA AND GAMA COMP.
C
C
C                         TO COMPUTE DERIVATIVE OF ETA WRT TDMY
C
      IF(FLAM)44,62,44
   44 DRTHA1=4.0*THSA3*TSA/TDMY2
      TAFLR= THSA5*FLR1
      DXX=1.0/FJINTG
      DXX4= 4.0*DXX
      JDEL=MESH/JINTG
      JMESH=-JDEL/2+1
      IF(FWRTSV)46,46,140
  140 WRITE(6,142) ET1A,ET2A,ET3A,ETAA2,GAMA2,
     1   DRTHA1,TAFLR,DXX,DXX4,SLPMA,
```

```
     1    (FXEQ(I),FXA(I),THA(I),FXTHA(I),
     1      THA(I),FXTHA(I),I=98,101)
  142 FORMAT(1H , 8H TOJ-142,(/8E15.5))
   46 ETAAD3=0.
C
C                     TO COMPUTE AN APPROXIMATION TO THE DERIVATIVE
C                             OF THETA WRT. TDMY
C
         DO 55 J=1,JINTG
      JMESH=JMESH+JDEL
      TBARA    = THA(JMESH)
   48 TBARA3      = TBARA**3
      DRTHA2    = DRTHA1*(DXX-FXAB(J))
   50 DRTHA= -DRTHA2/(DXX4*TBARA3)
      ETAAD1=4.0*TBARA3*(DXX-FXAB(J))
   52 ETAAD2= DRTHA*ETAAD1
   54 ETAAD3= ETAAD3+ETAAD2
      IF(FWRTSV)55,55,150
  150 WRITE(6,152) JMESH,TBARA,TBARA3,DRTHA2,
     1    DRTHA,ETAAD1,ETAAD2,ETAAD3
  152 FORMAT(1H , 8H TOJ-152,I5,(/8E15.5))
   55 CONTINUE
      ETAAD4= DRTHA1*FLR1*(1.0-ETAA2)
   58 ETAAD = (ETAAD4+FLR*ETAAD3)/TAFLR
   60 GAMAD= GAMA1*ETAAD/ETAA1
C
C
C                      END COMP. OF DERIVATIVE OF ETA WRT TDMY
C
C                       TO SOLVE FOR TDMY BY NEWTONS METHOD
C
   62 TDMY3= TDMY2*TDMY
      TDMY4= TDMY3*TDMY
      TDMY34=4.0*TDMY3
      FNWTA= TDMY4-TSA**4
   64 FNWT = TDMY-TEMP2+GAMA2*FNWTA
      DFNWTA= GAMA2*TDMY34 + GAMAD*FNWTA
   66 DFNWT= 1.0+DFNWTA
      TSAVE= TDMY
      TDMY= TDMY-FNWT/DFNWT
   68 TDTST= 0.5*ABS(TSAVE+TDMY)*DTST
      IF(FWRTSV)70,70,160
  160 WRITE(6,162) KTDMY,ETAAD4,ETAAD,GAMAD,
     1    TDMY3,TDMY4,TDMY34,FNWTA,FNWT,DFNWTA,DFNWT,
     2    TSAVE,TDMY,TDTST
  162 FORMAT(1H , 8H TOJ-160,I5,(/8E15.5))
   70 IF(ABS(TSAVE-TDMY)-TDTST)90,90,85
   85 KTDMY= KTDMY+1
      IF(KTDMY-30)10,10,87
   87 WRITE(6,88)TDMY,TDTST,KTDMY
   88 FORMAT(1H ,16H TROUBLE SUB TOJ,4X,5HTDMY=E12.5,4X,E12.5,4X,I3)
   90 RETURN
      END


$IBFTC FXX     DECK
      SUBROUTINE FXX(FXEQ,FXAB,FXGAB,FLR,MESH,JINTG)
C
C         FOR SAULE  -  GAS-L-LM   AND   SOLAR PROGRAMS
      DIMENSION FXEQ(1000),FXAB(100)
```

```
    3 FMESH=MESH
      FJINTG=JINTG
    5 DX=1.0/FMESH
      MESH1=MESH+1
      X=-DX
    7 FLRD=1.0/FLR
      FLRDS= FLRD*FLRD
      FLRD2= FLRD+2.0
    9 FLRD5=0.5*FLRD
C
C
C                         TO OBTAIN FUNCTION(X) AT EACH MESH POINT
C                            FOR USE IN SUB DEQ2
C
      DO 30 J=1,MESH1
      X=X+DX
   16 FXA1=FLRD+X
      FXA2= FXA1*FXA1-FLRDS
      FXA= 1.0-SQRT(FXA2)/FXA1
      FXB1= FLRD2-X
   18 FXB2= SQRT(FXB1*FXB1-FLRDS)
      FXB= 1.0-FXB2/FXB1
   20 FXEQ(J)= 0.5*(FXA+FXB)
   30 CONTINUE
C
C
C                         TO OBTAIN JINT INTEGRALS OF FUNCTION (X)
C
C                         INTEGRALS TO BE USED IN SUB TOJ
C
      X=0.0
      FXAB1=0.0
   34 DX=1.0/FJINTG
      FXGB1=FLRD2/FLRD
      FXGB2=SQRT(FXGB1*FXGB1-1.0)
   36 FXGB3=FXGB2-ATAN(FXGB2)
      DO 50 J=1,JINTG
      X=X+DX
      FXGA1=(FLRD+X)/FLRD
      FXGA2=SQRT(FXGA1*FXGA1-1.0)
   38 FXGA3= FXGA2-ATAN(FXGA2)
      FXGB4=(FLRD2-X)/FLRD
      FXGB5=SQRT(FXGB4*FXGB4-1.0)
   40 FXGB6=FXGB5-ATAN(FXGB5)
      FXGB7=FXGB6-FXGB3
      FXAB2=-FLRD5*(FXGA3-FXGB7)
      FXAB(J)=DX+FXAB2-FXAB1
   42 FXAB1=FXAB2
   50 CONTINUE
C
   52 FXGAB=1.0+FXAB2
   55 RETURN
      END


$IBFTC DEQ2    DECK
      SUBROUTINE DEQ2(TH,FX,C,POW,MESH,TST)
C
C        FOR SAULE  -   GAS-L-LM   AND   SOLAR PROGRAMS
      DIMENSION TH(1000),FX(1000),FD(1000),DG(1000),DGD(1000)
```

```
      FMESH=MESH
   14 DX=1.0/FMESH
      DX2=DX*DX
      DGC=C*POW*DX2
   16 PM1=POW-1.0
      FDC=(-PM1)*C*DX2
   18 KCNT=0
      DO 20 J=1,MESH
      TH(J)=1.0
   20 CONTINUE
   22 DGD(1)=0.
      DG(1)=1.0
   23 FD(1)=1.0
C
C                            TO REDUCE MATRIX FROM TRI-DIAGONAL TO TWO DIAG.
C
      DO 27 J=2,MESH
      THPOW=TH(J)**POW
   25 DG(J)= -DGD(J-1)-2.0-DGC*THPOW/TH(J)
      DGD(J)=1.0/DG(J)
      FD1=FDC*THPOW+DX2*FX(J)
   26 FD(J)=FD1-FD(J-1)/DG(J-1)
   27 CONTINUE
      DGD(MESH)=1.0/(DG(MESH)+1.0)
   28 TH(MESH+1)=0.0
      MESH2=MESH+2
   30 KTST=0
C
C                            TO SOLVE FOR TH BY BACK SUBSTITUTION
C
      DO 35 JJ=2,MESH
      J=MESH2-JJ
      THSV=TH(J)
   31 TH(J)=DGD(J)*(FD(J)-TH(J+1))
      IF(ABS(THSV-TH(J))-TST)35,35,32
   32 KTST=KTST+1
   35 CONTINUE
C
   36 IF(KTST)43,43,37
   37 KCNT=KCNT+1
      IF(KCNT-25)22,22,40
   40 WRITE(6,41) KCNT,KTST
   43 TH(MESH+1)=TH(MESH)
   41 FORMAT(1H ,23H TROUBLE SEE SUBR. DEQ2,[illegible]X,5HKCNT=I3,4X,5HKTST=I3)
   45 RETURN
      END
```

COMPUTER PRINTOUT SHEET

Description and Symbols

This section contains a printout sheet from the electronic digital computer for an argon gas and an ether (ET-378) example. The sheet is typical for the inputs and outputs discussed in the analysis section of reference 1.

The first group of numbers under the title Input Data represents the physical and thermal properties of the working fluid, radiator material, and meteoroid protection parameters. A brief explanation of these inputs follows for a gas case as they are read from left to right. The symbols preceding these terms represent these inputs in the computational procedure of the computer program listing.

First line:

SCVEL	sonic velocity, ft/sec
FMAS	total mass flow rate, lb/sec
VISC	viscosity of gas, lb/(ft)(sec)
UHETRD	first guess of overall heat-transfer coefficient, Btu/(hr)(sq ft)(^{O}R)
CPH	specific heat of gas, Btu/(lb)(^{O}R)
TINLT	inlet gas temperature, ^{O}R
TEXIT	exit gas temperature, ^{O}R
RGAS	gas constant, ft-lb/(lb)(^{O}R)

Second line:

PINLT	inlet gas pressure, lb/sq ft
RHAF	fin density, lb/cu ft
RHAH	header density, lb/cu ft
RHAT	tube density, lb/cu ft
PTUBT	pressure drop fraction in tubes
PTUBH	pressure drop fraction in each header
THERKF	thermal conductivity of fin, Btu/(hr)(ft)(^{O}R)
TCGAS	thermal conductivity of gas, Btu/(sec)(ft)(^{O}R)

Third line:

TS	equivalent sink temperature of space, $^{\circ}R$
RHAC	liner density, lb/cu ft
STEPH	Stefan-Boltzmann constant
ALPHA	constant in meteoroid mass distribution
BETA	constant in meteoroid mass distribution
EMACH	velocity ratio exponent in meteoroid protection equation
RHAP	meteoroid density, lb/cu ft
VAVG	average meteoroid velocity, ft/sec

Fourth line:

PNAN	probability of no meteoroid penetration
FCCLU	orientation or occlusion factor
TDAY	radiator mission time, days
EPSL	emissivity of surface coating
ATICK	finite plate thickness and spalling correction factor
FTEST	error test in computation of surface temperature
TEST	error test in computation of surface temperature
TESUH	percent error in overall heat-transfer coefficient

Fifth line:

FNMESH	number of elemental isothermal strips
FATST	percent error in header-area to tube-area ratio
GSRLQ	branch number (gas or liquid)
QLMR	branch number (liquid or liquid metal)
TZWR	control for printing of surface temperatures, conductance parameter, and length of elemental strip profiles

The second group of input data is for a radiator that uses liquid ether (ET-378) as a working fluid. It is similar to the inputs of the gas example except that instead of RGAS (gas constant), RHAIN (liquid density, lb/cu ft) is printed. The inlet gas pressure PINLT is not printed for the liquid example. Instead of PTUBT (pressure drop fraction in tubes) and PTUBH (pressure drop fraction in each header) PDRPT (pressure drop in tubes, lb/sq ft) and PDRPH (pressure drop in each header, lb/sq ft) are printed. The difference in inputs of branch numbers GSRLQ and QLMR should also be noted. For the gas example these inputs are 0. and 0.; for the liquid example, 0.10000E 01 and 0.; and for the liquid metal example (not printed), 0.10000E 01 and 0.10000E 01, respectively.

These sets of inputs are for a simplified computational procedure when tabulated relations among effectiveness, conductance parameter, fin-tube profile ratio, and sink temperature are used. When a functional relation is used, additional inputs are included between inputs FATST and GSRLQ.

FJINTG used in approximation of integral in effectiveness computations

TST absolute error for temperature ratio, θ_J

DTST percent error in surface temperature $T_{o,J}$

FWRITE control for debug printing

The group of numbers after the input data starts with parametric inputs.

DI inside tube diameter, ft

FLR fin-tube profile ratio

FLAMRD initial conductance parameter

The next line represents the surface or base temperatures at the middle of each elemental strip (TWR(J)), followed by a line of corresponding conductance parameter (FLWRIT(J)) and length of each elemental strip (DELZW(J)).

For the gas example, the following outputs are listed on the printout sheet, reading from left to right:

AH total header area, sq ft

DNE maximum inside diameter of inlet header, ft

DTW maximum inside diameter of outlet header, ft

BIGN number of tubes

WT tube weight, lb

WF fin weight, lb

WH header weight, lb

W	total radiator weight, lb
ZBIG	tube length, ft
HI	inside film heat-transfer coefficient, Btu/(sec)(sq ft)(^{o}R)
AT	total tube area, sq ft
AHT	ratio of header area to tube area
ZN	total tube length, ft
DELTA	tube and header armor thickness, ft
DIAT	outside tube diameter, ft
PANEL	panel planform area, sq ft
UHETP	overall heat-transfer coefficient, Btu/(hr)(sq ft)(^{o}R)
VNE	inlet fluid velocity, ft/sec
TLIT	fin thickness, in.
REYN	Reynolds number

For the liquid example, most of the symbols are the same as for the gas example. The outputs and their symbols, that follow, are not used in the gas example.

WLQ	total radiator weight, lb
WLQH	header weight, lb
WLQI	liquid content weight, lb
DH	header inside diameter, ft
TLITT	fin thickness, in.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, March 8, 1965.

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GAS, LIQUID, LIQUID METAL RADIATOR

NOTE - THE COMPUTED TEMP.,LAMDA AND DEL Z PROFILES ARE PRINTED OUT BELOW

THE OUTPUT IS FOR TURBULENT FLOW EQUAS., UNLESS OTHERWISE STATED

INPUT CATA - GAS
   0.16400E 05    0.53000E 00    0.19600E-04    0.20000E 02    0.12400E-00    0.96700E 03    0.53600E 03    0.38700E 02
   C.95000E 03    C.16900E 03    0.16900E 03    0.16900E 03    0.64000E-01    0.80000E-02    0.11100E-03    0.37000E-05
   C.40000E 03    C.10500E 03    0.17130E-08    0.53000E-10    0.13400E 01    0.66667E 00    0.44000E-00    0.98400E 05
   C.90000E 00    1.00000E 00    0.36500E 03    0.90000E 00    0.17500E 01    1.00000E-04    1.00000E-04    1.00000E-02
   1.00000E 01    1.00000E-02   -0.            -0.            -0.

 DI= 0.625000E-01    FLR= C.600000E 01   FLAMRD= 1.000000E 00
  739.03     717.10     694.71     671.77     647.61     622.87     597.41     570.79     543.17     514.64
  1.0000     0.9136     C.8307     0.7511     0.6729     0.5987     0.5282     0.4607     0.3970     0.3377
  0.7311     C.8146     C.9172     1.0452     1.2030     1.4092     1.6873     2.0684     2.6252     3.5166
 AH= 0.542371E 02   DNE= 0.437958E-00    DTW= 0.395752E-00   BIGN= 0.390000E 02      WT= 0.491592E 03     WF= 0.645332E 02
 WH= C.178913E 03     W= 0.735039E 03   ZBIG= 0.160179E 02     HI= 0.250773E-02      AT= 0.193898E 03    AHT= 0.279532E-00
 ZN= 0.610571E 03 DELTA= 0.167927E-01   DIAT= 0.101085E-00  PANEL= 0.432039E 03   UHETP= 0.558180E 01    VNE= 0.174492E 03
TLIT= 0.123738E-01  REYN= 0.141249E 05

INPUT CATA - LIQUID
   0.16600E 05    0.14245E 01    0.36500E-02    0.50000E 02    0.39000E-00    0.70600E 03    0.67000E 03    0.69500E 02
   0.16900E 03    0.16900E 03    0.16900E 03    0.14400E 04    0.28800E 03    0.11000E 03    0.22600E-04    0.40000E 03
   0.10500E 03    0.17130E-C8    0.53000E-10    0.13400E 01    0.66667E 00    0.44000E-00    0.98400E 05    0.90000E 00
   1.00000E 00    0.36500E 03    C.90000E 00    0.17500E 01    1.00000E-04    1.00000E-04    1.00000E-02    1.00000E 01
   1.00000E 00   -0.            -0.

 DI= 0.625000E-C1    FLR= C.600000E 01   FLAMRD= 1.000000E 00
  688.20     684.88     681.56     678.24     674.91     671.59     668.26     664.94     661.61     658.27
 16.1786    16.4682    16.7668    17.0747    17.3923    17.7200    18.0583    18.4074    18.7679    19.1403
 WLQ= C.284288E 03  WLQH= 0.763420E 00   WLQI= 0.676851E 02      WT= 0.194143E 03     WF= 0.216968E 02     DH= 0.211329E-01
DIAT= 0.936189E-C1 PANEL= 0.207831E C3  UHETP= 0.524863E 02   DELTA= 0.130594E-01   BIGN= 0.200000E 01   ZBIG= 0.175975E 03
 ZN= 0.317138E C3     HI= 0.218387E-01    VNE= 0.334040E 01   TLITT= 0.864825E-02   REYN= 0.397530E 04

*01* UNITC5, EOF.
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