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BNWL-2180 Vol. III
UC-12

A User's Manual for the BNW-I Optimization Code for Dry-Cooled Power Plants

Volume III

January 1977

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Battelle
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NOTICE

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A USER'S MANUAL FOR THE BNW-I OPTIMIZATION CODE FOR DRY-COOLED POWER PLANTS

VOLUME III

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January 1977

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PREFACE

This document has been issued in four volumes to facilitate handling. Volume I is a narrative description of the code algorithms, as well as logic, input and output information. Volumes II through IV are appendices of Volume I, providing listings of the BNW-I optimization code for each of three dry-cooled heat rejection systems. These are:

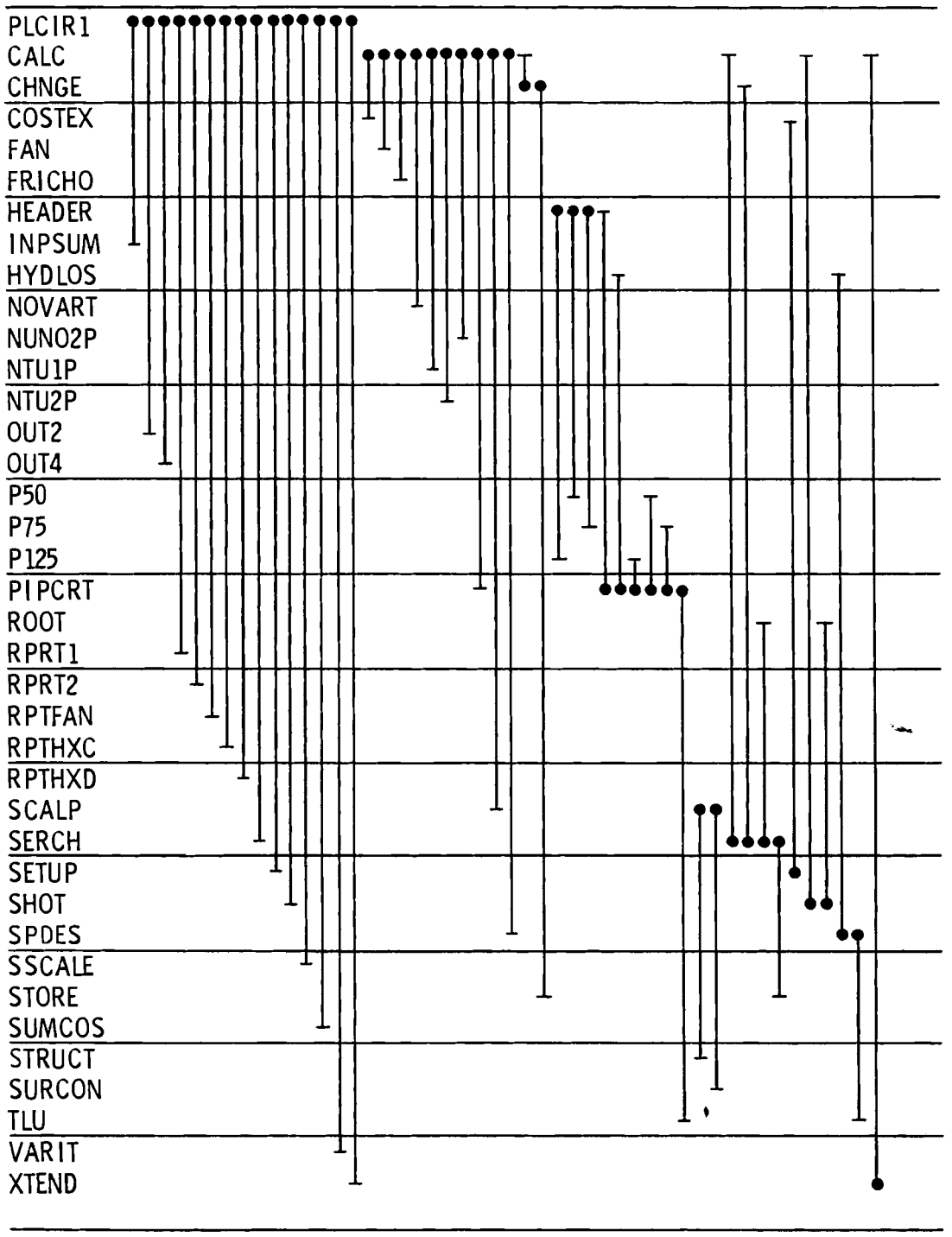
Volume II - Metal Finned Tube Versions of the BNW-I Computer Code
Volume III - Plastic System Versions of the BNW-I Computer Code
Volume IV - Ammonia System Versions of the BNW-I Computer Code

Complete distribution has been given only to Volume I. Copies of one or more of the other three volumes may be obtained by writing the National Technical Information Service, U.S. Department of Commerce, 5281 Port Royal Road, Springfield, VA, 22151.

APPENDIX F

PLASTIC VERSION OF THE BNW-I COMPUTER CODE

Figure F-1 is a subroutine linkage chart indicating which subroutines may call or may be called by others. This chart should be of assistance in using the listing making up the remainder of this appendix.



- ● INDICATES CALLING PROGRAM
- – INDICATES CALLED PROGRAM

FIGURE F-1. Plastic Circular Model Subroutine Linkages

```
      PROGRAM PLCIR1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C          PROGRAM PLCIR1 IS A VERSION OF THE BNW1 COMPUTER
C          OPTIMIZATION CODE DEVELOPED BY PNL FOR ERDA UNDER THE
C          DRY COOLING TOWER PROGRAM.  IT DETERMINES THE OPTIMUM
C          DRY COOLING TOWER DESIGN FOR A PARTICULAR SIZE POWER
C          PLANT WITH A PLASTIC TUBE COOLING SURFACE AND CIRCULAR
C          TOWER ARRANGEMENT OF THE TUBE BUNDLES.
C
      DIMENSION PCST(8)
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTOCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, RDESEL, RDEELA, RDOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBANG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDERI, XW, XD
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPO1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FRAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTHP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CS1, WATER1, WSTRC1, CFDJN1, HJBOI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
```

```
      $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
      $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
      $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
      $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
      $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
      $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
      $,  WTHDR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
      $,  AIREF,  WATEF,  XNMOD,  TCTPF, FOCPF, FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /VARVAR/  TPER(16), TA(15)
      COMMON /INDIS/ DIST
      COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
   81 FORMAT("1TD USED IN THE FOLLOWING CALCULATIONS IS ="F8.3)
  930 FORMAT(T02,"AMBIENT TURBINE", T28,"HEAT", T83,"COST TO",
     $ T93,"POWER COST", T105,"PCT TIME",T115,"PORTION OF")
  931 FORMAT(T04,"TEMP", T10,"OUTLET", T20,"BACK", T28,"RATE",T50,"HX"
     $,T57,"HX", T64,"POWER", T72,"CHANGE IN", T83,"REPLACE",
     $,T93,"AT AMBIENT", T104,"AT AMBIENT", T115,"INCREMENTAL")
  932 FORMAT(T11,"TEMP",T18,"PRESSURE",T27,"FACTOR", T35,"RANGE"
     $,T42,"TTDP", T49,"LMTD", T57,"ITD", T62,"GENERATED"
     $,T72,"FUEL COST", T83,"LOST CAP", T95,"TEMP", T106,"TEMP"
     $,T115,"POWER COST")
  933 FORMAT( T02,131("-"), T9," ",T17," ", T26," ", T33," ", T40," "
     $,T47," ", T54," ", T61," ", T71," ", T81," ", T92," ", T103," "
     $, T114," ")
  934 FORMAT( T03,"DEG F", T11,"DEG F", T19,"IN. HG", T35,"DEG F"
     $,T41,"DEG F", T48,"DEG F", T56,"DEG F", T62,"MEGAWATTS"
     $, T72,"MILLS/KWH", T82,"MILLS/KWH", T93,"MILLS/KWH"
     $,T106,"PERCENT", T115,"MILLS/KWH")
  944 FORMAT(1H0,T91,"FINAL INCREMENTAL COST",G11.5)
  945 FORMAT(1H0,T96"CAPACITY CHARGE $",G15.8)
      FIRST=.TRUE.
   15 NUCASE = 0
C
C          READ IN THE EXTERNALLY FIXED PARAMETERS OF THE DRY COOLING
C          TOWER SYSTEM AND THE INITIAL STARTING POINT OF THE
C          OPTIMIZATION ROUTINE. A DESCRIPTION OF THE INPUT CARDS
C          IS GIVEN IN SUBROUTINE SETUP
C
      CALL SETUP(TSTAR,TEND,NUCASE)
   20 CONTINUE
C
C          INPUT PRINTOUT SUMMARY
C
      CALL INPSUM
C
C          THE FOLLOWING IS A ROUTINE WHICH USES PATTERNED AND
C          GRADIENT SEARCH ROUTINES TO DETERMINE THE OPTIMUM DRY
C          COOLING TOWER DESIGN
C
      DO 7 IS=1,5
    7 VAR(IS)=0.0
      TD=TSTAR
    1 WRITE(6,81)TD
```

```
      K=4
C
C           SCALING THE STEAM SUPPLY AND TURBINE TO ACCOUNT FOR CHANGE
C           IN HEAT RATE OF TURBINE
C
      CALL SCALF
C
C           COURSE PATTERN SEARCH FOR OPTIMUM POINT
    4 CALL SHOT(1)
      IF(TCOS1.GT.0.0) GO TO 5
      VAS(4)=VAS(4)/4.
      GO TO 4
    5 L=0
C
C           EXTENDING THE SEARCH BEYOND THE LIMITS OF THE PATTERN
C           SEARCH
      CALL XTEND(L)
      IF(L.EQ.1) GO TO 4
C
C           FINE PATTERN SEARCH FOR THE OPTIMUM POINT
      CALL SHOT(2)
    2 JCONS=0
C
C           GRADIENT SEARCH FOR THE OPTIMUM POINT
      CALL SERCH
      IF(JCONS.EQ.0) GO TO 10
      K=K-1
      IF(K.GT.0) GO TO 2
   10 CONTINUE
C
C           PRINTOUT OF DRY COOLING TOWER DESIGN
C
      CALL OUT2(RBP,HRFAC1,SSCD,CASSS1,PLANCT1,PLANC1)
      CALL OUT4(1)
      CALL OUT4(2)
      CALL RPTHXD
      CALL RPTHXC(AFRO1)
      CALL RPRT1(DESVEL, POHCIR)
      CALL RPRT2(EFFC1,CONMAT,CONMA2)
       CALL RPTFAN
      WRITE(6,100)
  100 FORMAT(1H1)
      WRITE(6,930)
      WRITE(6,931)
      WRITE(6,932)
      WRITE(6,933)
      WRITE(6,934)
      WRITE(6,933)
      CLSUM=0.0
      FCSUM = 0.0
C
C           CALCULATION AND PRINTOUT OF THE PERFORMANCE PARAMETERS OF
C           THE DRY COOLING TOWER AND POWER PLANT FOR A YEARLY
C           TEMPERATURE PROFILE
C
      DO 3 I=1,NTA
    3 CALL VARIT(TA(I),TPER(I),PCST(I),I,CLSUM,FCSUM)
```

```
      ACOS=0.0
      DO 8 I=1,NTA
      ACOS=ACOS+PCST(I)
    8 CONTINUE
      WRITE(6,944) ACOS
      WRITE(6,945) CAPCS1
C
C          CAPITAL AND OPERATION COST SUMMARY PRINTOUT
C
      CALL SUMCOS(FCR, PSIZE, CAPF, CCOS1, CPIP1, CONBA1, ATUBC1, CPLEN1
     $ ,FBAC1, FMCS1, STRUC1, CFOUN1, CAPCS1, SPCD1, SSCD, HRFAC1
     $ ,HRFAPS, YEPMIN, PLANC, CLAN1, CLSUM, FCSUM, COSM1, CSTLV1
     $ ,CSTHS1, CFANE1*XNFAN1, CYLRN1*XNFAN1)
      TD=TD + 5.
      FIRST = .TRUE.
      KALEXT = 0
      WRITE(6,100)
      IF(TD.LE.TEND) GOTO 1
    6 CONTINUE
      NUCASE=1
      CALL SETUP(TSTAR,TEND,NUCASE)
      IF(NUCASE.EQ.0) GOTO 15
      GO TO 20
      END
```

```
      SUBROUTINE CALC(T1,RANGE,CWARA,AFRON,WLRAT,M)
C
C
C     SUBROUTINE CALC OF THE PLASTIC TUBE DRY COOLING TOWER SYSTEM
C     CODE DETERMINES THE DIMENSIONS AND DESIGN PARAMETERS OF THE
C     HEAT EXCHANGER.  THE COST OF THE HEAT EXCHANGER SURFACE IS
C     FOUND BY A SEPARATE ROUTINE INITIATED FROM THIS SUBROUTINE.
C     THE DESIGN AND COSTING OF THE FAN AND PIPING SYSTEMS ARE DONE
C     BY SEPARATE ROUTINES ALSO INTIATED FROM THE CALC SUBROUTINE.
C
C
C     THE INPUT PARAMETERS ARE SUPPLIED TO THE CALC SUBROUTINE
C     BY THE OPTIMIZATION ROUTINE DEVELOPED BY M.I.T.  IT IS A
C     COMBINATION OF A PATTERN AND GRADIENT SEARCH ROUTINE.  THE
C     PURPOSE OF THE OPTIMIZATION PART OF THE CODE IS TO MINIMIZE
C     THE INCREMENTAL COST OF DRY COOLING BY VARYING THE DESIGN
C     OF THE DRY COOLING TOWER.  IT THEREFORE SUPPLIES FIVE DESIGN
C     VARIABLES TO SUBROUTINE CALC AND IN RETURN AN INCREMENTAL
C     COST IS FOUND.
C
C
C     THE FOLLOWING ARE THE INPUT PARAMETERS TO SUBROUTINE CALC
C     T1      - STEAM TURBINE EXHAUST TEMPERATURE (DEGREES F)
C     RANGE   - TEMPERATURE DIFFERENCE OF THE WATER ENTERING AND
C               LEAVING THE HEAT EXCHANGER (DEGREES F)
C     CWARA   - RATIO OF THE HEAT CAPACITY OF THE WATER TO THE
C               AIR (DIMENSIONLESS)
C     AFRON   - FRONTAL AREA OF THE HEAT EXCHANGER IN THE DIRECTION
C               OF AIR FLOW (SQ FT)
C     WLRAT   - RATIO OF THE WIDTH TO THE LENGTH OF THE HEAT
C               EXCHANGER (DIMENSIONLESS)
C     M       - PARAMETER WHICH SPECIFIES WHICH OF THE ABOVE HAS
C               BEEN VARIED BY THE OPTIMIZIATION ROUTINE SINCE THE
C               LAST TIME THROUGH CALC
C
C
C     DEFINITIONS OF VARIABLES
C
C     AAIR    - AIR SIDE HEAT TRANSFER AREA (SQ FT)
C     AFC     - CAPITAL COST OF FAN SYSTEM ($)
C     ANTU    - HEAT EXCHANGER NUMBER OF TRANSFER UNITS (DIMENSION-
C               LESS)
C     BAR     - ATMOSPHERIC PRESSURE FOR A PARTICULAR ELEVATION
C               (IN HGA)
C     CMIN    - THE SMALLEST HEAT TRANSFER CAPACITY BETWEEN THE AIR
C               AND THE WATER (BTU/HR DEG F)
C     CONL    - THERMAL CONDUCTIVITY OF THE TUBE WALL (BTU/HR FT
C               DEG F)
C     DEEPL   - UPPER OR LOWER LIMIT ON THE NUMBER OF TUBES IN
C               DEPTH (DIMENSIONLESS)
C     DELPA   - AIR SIDE PRESSURE DROP ACROSS THE HEAT EXCHANGER
C               BUNDLE (LBF/SQ FT)
C     DELPIP  - PRESSURE DROP THROUGH THE SUPPLY AND RETURN PIPING
C               SYSTEM (LBF/SQ FT)
C     DELPWC  - PRESSURE DROP THROUGH THE CONDENSER (LBF/SQ FT)
C     DELPWT  - PRESSURE DROP THROUGH THE HEAT EXCHANGER BUNDLE
C               (LBF/SQ FT)
```

```
C     DEPTH   - DEPTH OF THE HEAT EXCHANGER PARALLEL TO THE AIR
C               FLOW (FT)
C     DI      - INSIDE DIAMETER OF THE HEAT EXCHANGER TUBE (IN)
C     EFF     - HEAT EXCHANGER EFFECTIVENESS (DIMENSIONLESS)
C     EFFP    - PUMP EFFICIENCY (PERCENT)
C     ELENG   - LENGTH OF HEAT EXCHANGER TUBES (FT)
C     ELEV    - SITE ELEVATION (FT)
C     FAIR    - AIR SIDE FRICTION FACTOR (DIMENSIONLESS)
C     FIXL    - THE FIXED LENGTH OF HEAT EXCHANGER TUBES SPECIFIED
C               BY INPUT TO THE CODE (FT)
C     GAIR    - MASS FLUX OF AIR THROUGH THE TRANSVERSE AREA BE-
C               TWEEN TUBES OF THE HEAT EXCHANGER (LBM/SQ FT HR)
C     GAIRD   - MASS FLUX OF AIR THROUGH THE DIAGONAL AREA BETWEEN
C               TUBE ROWS OF THE HEAT EXCHANGER (LBM/SQ FT HR)
C     GWAT    - MASS FLUX OF WATER THROUGH THE EXCHANGER TUBES
C               (LBM/SQ FT HR)
C     HI      - WATER SIDE HEAT TRANSFER COEFFICIENT THROUGH THE
C               HEAT EXCHANGER TUBES (BTU/HR SQ FT DEG F)
C     HO      - AIR SIDE HEAT TRANSFER COEFFICIENT THROUGH THE
C               HEAT EXCHANGER BUNDLE (BTU/HR SQ FT DEG F)
C     HPWAT   - HORSEPOWER REQUIREMENTS OF WATER PUMPING SYSTEM
C               FOR THE CONDENSER, PIPING SYSTEM, AND COOLING
C               TOWER (HP)
C     HRFAC1  - HEAT RATE FACTOR OF STEAM TURBINE AT THE RATED BACK
C               PRESSURE (DIMENSIONLESS)
C     HRFAC2  - HEAT RATE FACTOR OF STEAM TURBINE AT THE DESIGN
C               TEMPERATURE (DIMENSIONLESS)
C     HYNP    - NUMBER OF PASSES OF WATER THROUGH THE HEAT EXCHANG-
C               ER (DIMENSIONLESS)
C     IHEAT   - INTERNAL VARIABLE FOR SELECTING THE FRICTION FACTOR
C               AND HEAT TRANSFER COEFFICIENT FOR THE INLINE OR
C               STAGGERED TUBE SPACING (DIMENSIONLESS)
C     KCONV   - INTERNAL VARIABLE FOR SPECIFYING THAT THE SET OF
C               INPUT VARIABLES LEAD TO UNREASONABLE ANSWERS
C               (DIMENSIONLESS)
C     NTUCAL  - SPECIFIES THE TYPE OF NTU-EFFECTIVENESS CALCULATION
C               TO BE USED BY THE CODE (DIMENSIONLESS)
C     NUMTOW  - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C     NW      - NUMBER OF HEAT EXCHANGER TUBES IN
C               WIDTH (DIMENSIONLESS)
C     ODL     - OUTSIDE DIAMETER OF HEAT EXCHANGER TUBES (IN)
C     P       - STEAM TURBINE BACK PRESSURE (IN HGA)
C     PBOW    - POWER REQUIREMENTS OF WATER PUMPING SYSTEM FOR
C               THE CONDENSER PIPING SYSTEM AND COOLING TOWER (KW)
C     PSIZE   - POWER OUTPUT OF PLANT (MW)
C     QIN     - HEAT SUPPLIED BY THE STEAM SUPPLY SYSTEM (BTU/HR)
C     QREJ    - HEAT REJECTED BY THE DRY COOLING TOWER (BTU/HR)
C     REAIRE  - REYNOLDS NUMBER OF THE AIR FLOWING THROUGH THE
C               MINIMUM CROSS-SECTIONAL AREA OF THE HEAT EXCHANGER
C               (DIMENSIONLESS)
C     REFF    - EFFECTIVE HEAT EXCHANGER TUBE WALL THICKNESS
C               BASED ON AIR SIDE TUBE AREA (FT)
C     REWAT   - REYNOLDS NUMBER OF THE WATER FLOWING THROUGH THE
C               HEAT EXCHANGER TUBES (DIMENSIONLESS)
C     TCOS    - INCREMENTAL COST FOR THE USE OF DRY COOLING
C               TOWERS (MILLS/KWH)
C     TCWFCS  - TOTAL COST OF THE PIPING SYSTEM (K$)
```

```
C          TEFF    - RATED BACK PRESSURE EFFICIENCY OF THE STEAM
C                    TURBINE (PERCENT)
C          TEFFM   - EFFICIENCY OF THE STEAM TURBINE AT THE DESIGN
C                    TEMPERATURE (PERCENT)
C          TPO     - COEFFICIENTS OF THIRD ORDER CURVE FIT OF HEAT
C                    RATE FACTOR VERSUS TURBINE BACK PRESSURE
C                    (DIMENSIONLESS)
C          TTD     - TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE STEAM
C                    AND WATER TEMPERATURES OF THE CONDENSER (DEG F)
C          T4      - EXIT TEMPERATURE OF THE AIR FROM THE HEAT EXCHANGER
C                    BUNDLE (DEG F)
C          U       - OVERALL HEAT TRANSFER COEFFICIENT OF THE HEAT
C                    EXCHANGER (BTU/HR SQ FT DEG F)
C          VAAV    - AVERAGE SPECIFIC VOLUME OF THE AIR IN THE HEAT
C                    EXCHANGER BUNDLE (CU FT/LBM)
C          VAIN    - SPECIFIC VOLUME OF THE AIR ENTERING THE HEAT
C                    EXCHANGER BUNDLE (CU FT/LBM)
C          VAIR    - VELOCITY OF THE AIR IN THE MINIMUM CROSS-SECTIONAL
C                    AREA OF THE HEAT EXCHANGER (FT/SEC)
C          VAOUT   - SPECIFIC VOLUME OF THE AIR LEAVING THE HEAT EX-
C                    CHANGER BUNDLE (CU FT/LBM)
C          VOL     - TOTAL VOLUME OF THE HEAT EXCHANGER (CU FT)
C          VWAT    - WATER VELOCITY THROUGH THE HEAT EXCHANGER TUBES
C                    (FT/SEC)
C          WIDTH   - TOTAL HEAT EXCHANGER WIDTH (FT)
C          W3      - MASS FLOW RATE OF WATER THROUGH THE COOLING TOWER
C                    (LBM/HR)
C          W4      - MASS FLOW RATE OF AIR THROUGH THE COOLING TOWER
C                    (LBM/HR)
C          XD      - LONGITUDINAL PITCH BETWEEN ADJACENT TUBE ROWS
C                    OF THE HEAT EXCHANGER FROM CENTERLINE TO
C                    CENTERLINE (IN)
C          XDG     - LONGITUDINAL DIAGONAL PITCH BETWEEN TUBES IN
C                    ADJACENT ROWS OF THE HEAT EXCHANGER CENTERLINE TO
C                    CENTERLINE MEASUREMENT (IN)
C          XW      - TRANSVERSE PITCH BETWEEN ADJACENT TUBES IN THE SAME
C                    TUBE ROW OF THE HEAT EXCHANGER FROM CENTERLINE
C                    TO CENTERLINE (IN)
C          ZD      - NUMBER OF HEAT EXCHANGER TUBES IN DEPTH
C
C          HEAT EXCHANGER DIMENSIONAL RELATIONSHIP
C
C          AT      - INSIDE TUBE AREA (SQ FT/FT)
C          OSA     - OUTER TUBE SURFACE AREA (SQ FT/FT)
C          ATOT    - TOTAL OUTER SURFACE AREA (SQ FT/FT)
C          VOLP    - HEAT EXCHANGER VOLUME (CU FT/FT)
C          ART     - CROSS SECTIONAL ROOT TUBE AREA (SQ FT/FT)
C          ACS     - UNIT CROSS-SECTIONAL AREA (SQ FT/FT)
C          ALPHA   - TUBE SURFACE AREA PER UNIT HEAT EXCHANGER VOLUME
C                    (SQ FT/FT)
C          SIGMA   - RATIO OF FREE FLOW AREA TO TOTAL FRONTAL
C                    AREA (DIMENSIONLESS)
C
      LOGICAL EXTLNG
      LOGICAL FIRST, EXTEMP
      COMMON
     $ AFTR, ALPHA
```

```
$ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMB2,CAFI
$ ,CBU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
$ ,DEEPL, DESVEL, DANGLE
$ ,EFFP
$ ,FCR, FIRST, FIXL, FCOS, FXTEMP
$ ,GBEFF
$ ,HXNP, HPCST
$ ,IHEAT
$ ,ITMAX, ITMIN
$ ,JCONS
$ ,KCONV, KALEXT
$ ,MXEXT
$ ,NTUCAL(2), NTA
 COMMON
$ CDR
$ ,PSIZE, PER, PWCOS, PLANC, PFACT
$ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
$ ,QREJ, QREDUCE
$ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
$ ,SAAF, SIGMA, SPAMAT(2)
$ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
$ ,TUBAGG, TW
$ ,UCS, UWS
$ ,VAS(5)
$ ,WFV
$ ,XDEPA, XW, XD
 COMMON /SUPPLY/ VAL(5), CPIP, CCOS, W3, COSM, EFF
$, CLAND, REAIR, Z,HRFAC2, W4, U, PPOW,
$ FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
$ REWAT, NW,PLANC2,PSIZ12, SPBP, SW4, SW3,
$ SPC,PTOTAL,PLANC3,SAFRON, AAIR, YFP, SPCD,PSIZ13, WT2,
$ BP2, NW2, TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
$, TLAX, UCON, FMCST, FBACC, EFFC, CH, CA, CS
$, CLTC, CFC, CPCC, FITCO, CSC,CEPREP,DELPIP, AST
$,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL, WHX, NTTUB, ADIA, ABLN
$, WTHOR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN, ANTU
$, AIREF, WATEF, XNMOD, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP
$, ACTBPD, ADJBPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
$, CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN, CSE, CHF
$ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
 COMMON /SINK/ VAR(5), CPIP1, CCOS1, W31, COSM1, EFF1
$, CLAN1, REAI1, Z1,HRFA2S, W41, U1, PPOW1,
$ FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, HI1, HO1, T41,
$ REWA1, NW1,ZPLNC2,ZSIZ12, ZSPBP, SW41, SW31,
$ SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
$ BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
$, TLA1, UCON1, FMCS1, FBAC1, EFFC1, CH1, CA1, CS1
$, CLTC1, CFC1, CPCC1,FITCO1, CSC1,CEPRE1,DEPIP1, AST1
$,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1, WH1, NTTU1, ADI1, ABL1
$, WTHO1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
$, AIREF1, WATEF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
$, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
$, CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1, CSE1, CHF1
$ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
 COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
$ GAIR, FAIR, HPAIR, HPWAT, PLANCT1
 COMMON/DJB/DI,XDG,SF
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      COMMON /FLSW/ FXTLNG
      COMMON /INDIS/ DIST
      COMMON /HEADEX/ DUML2(16), WB
      COMMON /HXO/ AI, ATOT
      COMMON /LACALL/ SRN
      COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
      COMMON /SURFEX/ DDL, DUMLST(15)
      COMMON/TUBE/KGA,FGA(7),LD,ESA(6),TID(7,6),FTFI(7,6)
      COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF, FBCPF,
     $VELREC,AFC,EL-EV,EHR
  300 FORMAT(" CALC M=",I1,3X,"T1=",1PE11.4,3X,"RANGE=",E11.4,3X,
     $"CWARA=",E11.4,3X,"AFRON=",E11.4,3X,"WLRAT=",E11.4)
  301 FORMAT(" CALC M=",I1,3X,"T1=",1PE11.4,3X,"RANGE=",E11.4,3X,
     $"CWARA=",E11.4,3X,"AFRON=",E11.4,3X,"WLRAT=",E11.4,T110,"TCOS=",
     $ E11.4)
    8 FORMAT("0ZERO DIVISOR IN SUBROUTINE CALC. AFRON=",1PE13.4,6X,
     $ "SIGMA=",E13.4)
  305 FORMAT(" /CALC/ ","T1=",E9.3," HRFAC2=",E9.3," TEFFM=",E9.3,
     $" QIN=",E9.3,"QREJ=","W3=",E9.3," W4=",E9.3)
  316 FORMAT(" IN SUBROUTINE CALC A VALUE OF",G13.5," FOR AFRON WAS IGNO
     $RED BECAUSE IT PRODUCES ZERO VALUE FOR NW")
  903 FORMAT("0ERROR IN DEPTH CALCULATION LOOP IN SUBROUTINE CALC."
     $ /1X,"W,W3,DI,ZD,AAIR,VOL,AFRON",I3,6G13.5)
  303 FORMAT(1X,I3," ITERATIONS IN CALC WITHOUT CONVERGING ON DEPTH, PZD
     $=",G13.5," ZD=",G13.5," AFRON=",G13.5)
      DATA MSTR /0/
C
C          THE FOLLOWING ARE BRANCH POINTS OF THE SUBROUTINE
C          DEPENDING ON THE PARAMETER WHICH HAS BEEN VARIED SINCE THE
C          LAST TIME THROUGH CALC, THE PROGRAM BY PASSES THOSE
C          CALCULATIONS THAT DO NOT HAVE TO BE RECALCULATED
C
      IF(FXTLNG.AND.LVC.EQ.M.AND.M.EQ.5) RETURN
      KCONV=0
      IF(M.EQ.5) GO TO 23
      IF(M.EQ.4) GO TO 22
      IF(M.EQ.3) GO TO 21
      IF(M.EQ.2) GO TO 20
C
C          THE BACK PRESSURE OF THE TURBINE IS GIVEN HERE AS A
C          FUNCTION OF THE STEAM TURBINE EXHAUST TEMPERATURE (IN HGA)
C
      P=EXP(17.168-9240./(T1+460.))
      BP2=P
C
C          THE HEAT RATE FACTOR OF THE TURBINE IS CALCULATED HERE
C          AS A FUNCTION OF THE TURBINE BACK PRESSURE (DIMENSIONLESS)
C
C       HEAT RATE FACTOR CURVE FIT
C
      HRFAC2=TPO(1) +TPO(2)*P +TPO(3)*P**2 + TPO(4)*P**3
C
C          THE OFF DESIGN TURBINE EFFICIENCY IS GIVEN BY THE
C          FOLLOWING (PERCENT)
C
      TEFFM=TEFF/HRFAC2
C
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C          THE TOTAL HEAT CONSUMPTION OF (BTU/HR) THE PLANT IS
C          GIVEN AS A FUNCTION OF POWER OUTPUT OF THE PLANT
C          (MW) AND THE TURBING EFFICIENCY
C
      QIN=3413.*PSIZE*1000./TEFFM
C
C          THE HEAT REJECTED BY THE DRY COOLING TOWER (BTU/HR)
C          IS THE FOLLOWING
C
      QREJ=QIN*(1.-TEFFM)
C
C          KNOWING THE AMOUNT HEAT REJECTED BY THE DRY COOLING
C          TOWER AND THE RANGE OF THE WATER, THE MASS FLOW RATE OF THE
C          WATER FLOWING THROUGH THE TOWER CAN BE CALCULATED (LBM/HR)
C
   20 W3=QREJ/RANGE
C
C          GIVEN THE CAPCITY RATIO OF THE AIR TO THE WATER, THE
C          MASS AIR FLOW RATE CAN BE CALCULATED (LBM/HR)
C
   21 W4=W3/(CWARA*.24)
C
C          THE DESIGN OF THE HEAT EXCHANGER IS HANDLED BY THE
C          FAMILIAR  NTU- EFFECTIVENESS RELATIONSHIP, DEPENDING
C          UPON THE VALUE OF THE CAPACITY RATIO THE EFFECTIVENESS
C          (DIMENSIONLESS) IS DEFINED BY EITHER OF THE FOLLOWING TWO
C          RELATIONSHIPS
C
      IF (CWARA.GE.1.) GO TO 30
C
C          CAPACITY RATIO LESS THAN ONE
C
      EFF = RANGE/(T1 - TTD - TD)
      CMIN=W3
      G=1.
      GO TO 31
C
C          CAPACITY RATIO GREATER THAN ONE
C
   30 EFF = CWARA*RANGE/(T1 - TTD - TD)
      CMIN=W4*.24
      G=CWARA
   31 H = CWARA*RANGE/(T1-TTD - TD)
      IDB=0
C
C          THE HEAT TRANSFER CAPACITY OF A HEAT EXCHANGER IS REP-
C          RESENTED BY THE NONDIMENSIONED NUMBER OF HEAT TRANSFER UNITS
C          NTU.  THIS PARAMETER IS DEPENDENT UPON THE FLOW ARRANGMENTS
C          OF THE COLD AND HOT FLUIDS
C
C          COUNTER FLOW HEAT EXCHANGER ARRANGEMENT
C
   33 IF(NTUCAL(1).EQ."COUNTER FL") CALL NUNO2P(T1,TD,TTD,CWARA,RANGE,W3
     $ ,W4,ANTU)
C
C          CROSS FLOW HEAT EXCHANGER ARRANGEMENT
C
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```
      IF(NTUCAL(1).EQ."CROSS FLOW") ANTU=-G*ALOG(1.+ALOG(1.-H)/CWARA)
C
C           SINGLE PASS HEAT EXCHANGER
C
      IF (HXNP .EQ. 1. .AND. NTUCAL(1) .EQ. "TABLE     ") CALL
     $ NTU1P (CWARA,EFF,ANTU)
C
C           TWO PASS HEAT EXCHANGER
C
      IF (HXNP .EQ. 2. .AND. NTUCAL(1) .EQ. "TABLE     ") CALL
     $ NTU2P (CWARA,EFF,ANTU)
   22 CONTINUE
C
C           HEAT EXCHANGER DIMENSIONS
C
C           INSIDE TUBE AREA
      AI=3.14159*DI*12./144.
C
C           OUTER TUBE SURFACE AREA
      OSA=3.14159*ODL*12./144.
C
C           TOTAL OUTER SURFACE AREA
      ATOT=OSA
C
C           HEAT EXCHANGER UNIT VOLUME
      VOLP=XW*XD*1./144.
C
C           RATIO OF HEAT EXCHANGER SURFACE AREA TO VOLUME OF HEAT
C           EXCHANGER
      ALPHA=ATOT/VOLP
C
C           UNIT CROSS-SECTIONAL AREA
      ACS = XW/12.0
      ACSD = 2.0*XDG/12.0
C
C           CROSS-SECTIONAL TUBE AREA
      ART = ODL/12.0
      ARTD = 2.0*ART
C
C           RATIO OF FREE AIR FLOW AREA TO TOTAL FLOW AREA
      SIGMA = (ACS - ART)/ACS
      SIGMAD = (ACSD - ARTD)/ACS
C
C           THE AIR FLOW AREA (SQ FT) NORMAL TO THE DIRECTION OF AIR
C           FLOW IS CHECKED TO DETERMINE IF IT IS A REASONABLE VALUE
C
      IF(AFRON*SIGMA.EQ.0.0)WRITE(6,300)M,T1,RANGE,CWARA,AFRON,WLRAT
      IF(AFRON*SIGMA.EQ.0.0)WRITE(6,301) TCOS
      IF(AFRON*SIGMA.EQ.0.0) WRITE(6,8) AFRON,SIGMA
C
C           THE AIR MASS FLUX IS DETERMINED FOR THE MINIMUM CROSS-
C           SECTIONAL FLOW AREA
C
      GAIR= W4/(AFRON*SIGMA)
      GAIRD = W4/(AFRON*SIGMAD)
      GAIR1 = GAIR
      IF(GAIRD .GT. GAIR) GAIR1 = GAIRD
```

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      IF (IHEAT .EQ. 3) GAIR1 = GAIR
C
C          THE AIR SIDE REYNOLDS NUMBER FOR THE MINIMUM CROSS-
C          SECTIONAL FLOW AREA IS FOUND BASED ON THE OUTSIDE TUBE
C          DIAMETER
C
      REAIR=ODL*GAIR1/(.046*12.0)
C
C          THE AIR SIDE HEAT TRANSFER (BTU/HR SQ FT DEG F) COEFFICIENT
C          AND FRICTION FACTOR IS DETERMINED
C
      CALL FRICHO(FAIR,HO,ODL,XW,XD,XDG,GAIR1,IHEAT)
C
C          THE WIDTH (FT) OF THE HEAT EXCHANGER IS CALCULATED
C          DEPENDING ON IF THE LENGTH OF THE HEAT EXCHANGER TUBES IS
C          FIXED OR ALLOWED TO FLOAT
C
   23 IF(FXTLNG) WIDTH=AFRON/FIXL
      IF(.NOT.FXTLNG) WIDTH=SQRT(WLRAT*AFRON)
C
C          THE NUMBER OF TUBES IN WIDTH
C
      NW=WIDTH/XW*12
C
C          A CHECK ON THE NUMBER OF TUBES IN WIDTH
C
      IF(NW.LT.1) WRITE(6,316) AFRON
      IF(NW.LT.1) MKTR = MKTR + 1
      IF(MKTR.GT.200) STOP"AFRON IS BEING DRIVEN TO ZERO"
      IF(NW.LT.1) GOTO 10
      WT2=WIDTH
      NW2=NW
C
C          THIS IS THE START OF THE ITERATION LOOP FOR DETERMINING
C          THE NUMBER OF TUBES IN DEPTH OF THE HEAT EXCHANGER
C
      KN=0
      ZD=2.
C
C          WATER SIDE REYNOLDS NUMBER
C
    5 REWAT=48.*W3/(3.14*1.65*DI*(ZD/HXNP)*NW)
C
C          WATER SIDE HEAT TRANSFER COEFFICIENT (BTU/HR SQ FT DEG F)
C
C          DITTUS BOELTER RELATIONSHIP
      HI=.1836*(REWAT**.8)/DI
C
C          NUSSELT LAMINAR FLOW RELATIONSHIP
      IF (REWAT .LT. 2400.) HI = 3.66*0.354/(DI/12.)
C
C          CHECK ON WATER SIDE HEAT TRANSFER COEFFICIENT TO
C          DETERMINE IF IT IS A REASONABLE VALUE
C
      IF(LEGVAR(HI).EQ.0) GOTO 6
      WRITE(6,903)NW,W3,DI,ZD,AAIR,VOL,AFRON
      STOP
```

```
    6 CONTINUE
C
C         OVERALL HEAT TRANSFER CALCULATION BASED ON THE OUTSIDE
C         SURFACE AREA (BTU/HR SQ FT DEG F)
C
      REFF = ATOT / (2.*3.14159)
      U = 1.0/ (1.0/HO +
     $    REFF * ALOG(ODL/DI) / CONL +
     $    ATOT / (AI*HI) )
C
C         AIR SIDE HEAT TRANSFER SURFACE AREA (SQ FT)
C
      AAIR=ANTU*CMIN/U
C
C         VOLUME OF THE HEAT EXCHANGER (CU FT)
C
      VOL=AAIR/ALPHA
C
C         DEPTH OF THE HEAT EXCHANGER (FT)
C
      DEPTH=VOL/AFRON
C
C         THE NUMBER OF TUBES IN DEPTH
C
      PZD=ZD
      ZD=12.*DEPTH/XD
C
C         CONVERGENCE CRITERION OF ITERATION LOOP
C
      IF (ABS(ZD-PZD)/PZD.LT.0.001) GOTO 11
C
C         CHECK ON THE NUMBER OF TIMES THROUGH ITERATIVE LOOP
C
      KN=KN+1
      IF(KN.GT.70) WRITE(6,303) KN,PZD,ZD,AFRON
      IF(KN.GT.80) GOTO 10
      Z=ZD
      GOTO 5
   10 KCONV=1
      LVC=M
      RETURN
C
C         RESTRICTING THE NUMBER OF TUBES IN DEPTH BY EXTERNAL
C         VARIABLE DEEPL
C
   11 TEST = " "
      IF (DEEPL .LT. 0.0) TEST = ".GT."
      IF(DEEPL .GT. 0.0) TEST = ".LT."
      IF ( TEST .EQ. ".GT." .AND. ZD .GT. ABS(DEEPL))  GOTO 10
      IF ( TEST .EQ. ".LT." .AND. ZD .LT. DEEPL )     GOTO 10
C
C         WATER SIDE FRICTION FACTOR AND PRESSURE DROP CALCULATION
C         OF THE HEAT EXCHANGER
C
      GWAT = HXNP * 576. * W3 / (3.14159*DI*DI*ZD*NW)
C
C         VELOCITY OF WATER THROUGH THE TUBES
```

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C
      VWAT=GWAT/(62.*3600.)
C
C          HEAT EXCHANGER TUBE LENGTH
C
      IF(FXTLNG) ELENG=FIXL
      IF(.NOT.FXTLNG) ELENG=WIDTH/WLRAT
C
C          WATER SIDE FRICTION FACTOR
C
      IF(REWAT.GT.2000.) GO TO 12
      FWAT=16./REWAT
      GO TO 14
   12 IF(REWAT.GT.1.E5) GO TO 13
      FWAT=.0791/(REWAT**.25)
      GO TO 14
   13 FWAT=.046/(REWAT**.2)
C
C          WATER SIDE PRESSURE DROP THROUGH THE HEAT EXCHANGER
C
   14 DELPWT = HXNP * 48. * FWAT * ELENG * (GWAT/3600.)**2 /
     $ (DI * 62. * 64.4)
      AIREF = FAIR
      WATEF = FWAT
C
C          CONDENSER DESIGN
C
      CALL SPDES(TD,T1,RANGE,TTD,XNS,QREJ,VELD,RHO,ARPS,TLA,XNTS,HDLOS)
      DELPWC=HDLOS*62.
C
C          COSTING OF THE HEAT EXCHANGER SURFACE AND HEADERS
C
      CALL COSTEX(ATOT)
C
C          FAN SYSTEM DESIGN
C
      T4=CWARA*RANGE+TD
      BARLN=3.39953-3.81835E-5*ELEV
      BAR=EXP(BARLN)
C
C          SPECIFIC VOLUME OF AIR FOR THE INLET TO THE HEAT EX-
C          CHANGER BUNDLE AND THE EXIT OF THE FAN (CU FT/LBM)
      SPVOL=(T4+459.67)/1.325/BAR
      VAIN=      (TD+459.67)/(1.325*BAR)
      VAOUT=      (T4+459.67)/(1.325*BAR)
      VAAV=(VAIN+VAOUT)/2.
      VAIR=GAIR1*VAAV/3600.
C
C          AIR SIDE PRESSURE DROP THROUGH THE HEAT EXCHANGER
      DELPA = (GAIR1/3600.)**2 * Z * (4.*FAIR) * VAAV/64.4
      DPTPSF=DELPA
      DPTINW = DPTPSF/ 5.2022
      IF((DPTINW*.07495*SPVOL).GT.1.35) RETURN
C
C          DESIGN AND COST OF THE FAN SYSTEM
      CALL FAN (DPTINW)
C
```

```
C          AFC GREATER THAN .49E+9 MEANS NO SUITABLE FAN WAS FOUND BY
C          SUBROUTINE FAN, SET TCOS TO HIGH VALUE TO THROW OUT THIS
C          POINT IN THE SEARCH FOR A MINIMUM
C
      IF( AFC .GT. .49E+9) TCOS = 1.E+38
      IF( AFC .GT. .49E+9) RETURN
C
C          DESIGN AND COST OF THE WATER PIPING SYSTEM
C
      CALL PIPCRT(T1, W3, TTD, RANGE, CTOWD, DELPWT, DELPWC, DIST
     $            ,DESVEL, REDUCE, QREDUCE, WB, ZD, XW, TCWFCS, NUMTOW
     $            ,DELPIP, EPDP, HPWAT, RHO, CDANG, POHCIR, POHLEC, EFFP)
      DELPW = DELPWT + DELPWC + DELPIP
      IF(TCWFCS .GT. 1.E+39) TCOS = 1.E+38
      IF(TCWFCS .GT. 1.E+39) RETURN
      PPOW=HPWAT/(1.341*EFFP)
C
C          SCALING UP THE POWER PLANT AND THE DRY COOLING TOWER TO
C          MEET THE POWER REQUIREMENTS OF THE FAN AND PIPING SYSTEMS
C
      CALL SCALP (RANGE, CWARA, AFRON, WLRAT, TCWFCS, NUMTOW)
C
C          DETERMINE THE INCREASED COST OF PRODUCING ELECTRICAL
C          POWER FROM POWER PLANT USING A DRY COOLING TOWER AS THE HEAT
C          REJECTION SYSTEM
C
      CALL NOVART (CWARA,TCOS)
      LVC=M
      RETURN
      END
```

```
      SUBROUTINE CHNGE(M)
C
C     THIS ROUTINE IS CALLED BY SUBROUTINE SERCH WHEN PRESSURE DROP RE-
C     STRICTION IS ENCOUNTERED.  IT SEARCHES BY CHANGING A VARIABLE
C     OTHER THAN THAT SELECTED BY SUBROUTINE SERCH.
C
      LOGICAL FXTLNG
      DIMENSION DP(5),DV(5),VAJ(5)
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CBU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPI, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCP, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBAG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCO,PSIZ13,   WT2,
     $     CP2,    NW2,   TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,    CFC,  CPCC, FITCO,    CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHDR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIREF,  WATFF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF,  THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
```

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      $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
      $  RP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
      $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
      $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
      $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
      $,  WTHR1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
      $, AIRFF1, WATFF1, XNWOD1, TCTPF1, FOCPF1, FMTRC1, ACTTP1, ADJTP1
      $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
      $,   CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
      $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /FLSW/ FXTLNG
      COMMON /LACALL/SRN
      COMMON /TINE/ XNS,TTD,TLA,XNTS,ARPS
      L=0
      K1=0
      DO 1 I=1,3
    1 DV(I)=.05
      DO 2 I=1,2
    2 DV(I+3)=.2
      DO 3 I=1,5
      VAJ(I)=VAR(I)
    3 VAL(I)=VAR(I)
    4 VAL(M)=(1.+DV(M))*VAR(M)
      IF(FXTEMP) VAL(1) = TFIX
      IF(FXTEMP) VAL(2) = RFIX
      IF(VAL(M).LE.0.0) GO TO 36
      IF(M.GT.3) GO TO 10
      IF(VAL(1) .LE. 0.0) GOTO 36
      H = VAJ(3)*VAJ(2)/(VAJ(1)-TTD-TD)
   41 IF(H.GE.1.) GO TO 36
      IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 36
   10 SRN="/CHNGE-1/ "
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),1)
      IF(KCONV.EQ.1) GO TO 36
      PA=DELPA
      PA1=DEPA1
      DP(M)=DELPA-DEPA1
      IIB=1
      IF(FXTLNG) IIB=2
      DO 35 II=IIB,5
      I=6-II
      IF(I.EQ.5.AND.DV(1).GT..005) GO TO 35
      IF(I.EQ.M) GO TO 35
   11 VAL(I)=(1.+DV(I))*VAR(I)
      IF(VAL(I).LE.0.0) GO TO 34
      VAJ(I)=VAL(I)
      IF(FXTEMP) VAJ(1) = TFIX
      IF(FXTEMP) VAJ(2) = RFIX
      IF(I.GT.3) GO TO 17
      IF(VAJ(1) .LE. 0.0) GOTO 12
      H = VAJ(3)*VAJ(2)/(VAJ(1)-TTD-TD)
   43 IF(H.GE.1.) GO TO 12
      IF(ALOG(1.-H)/VAJ(3).LE.-1.) GO TO 12
      GO TO 17
   12 VAJ(I)=VAR(I)
      GO TO 34
   17 J=I
```

```
      IF(M.LT.I) J=M
      SRN="/CHNGE-2/ "
      CALL CALC(VAJ(1),VAJ(2),VAJ(3),VAJ(4),VAJ(5),J)
      VAJ(I)=VAR(I)
      IF(KCONV.EQ.1) GO TO 34
      PA=DELPA
      PA1=DEPA1
      DP(I)=DELPA-DEPA1
      E=0.
      C=1.
      D=1.
   18 VAL(I)=(1.+DV(I)*(E-DP(M))/DP(I))*VAR(I)
      IF(FXTEMP) VAL(1) = TFIX
      IF(FXTEMP) VAL(2) = RFIX
      IF(VAL(I).LE.0.0) GO TO 34
      IF(I.GT.3) GO TO 24
      IF (VAL(1) .LE. 0.0) GOTO 34
      H = VAL(3)*VAL(2)/(VAL(1)-TTD-TD)
   45 IF(H.GE.1.) GO TO 34
      IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 34
   24 SRN="/CHNGE-3/ "
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),J)
      IF(KCONV.EQ.1) GO TO 34
      IF(DELPA.GE.XDEPA.AND.DELPA.LE.1.01*XDEPA) GO TO 26
      IF(DELPA.GE.1.01*XDEPA) GO TO 25
      C=D/10.
      IF(C.LT..001) GO TO 34
      E=E+C
      GO TO 18
   25 D=C/10.
      IF(D.LT..001) GO TO 34
      E=E-D
      GO TO 18
   26 IF(TCOS.GE.TCOS1) GO TO 34
      CALL STORE
      L=1
      DO 27 IJ=1,5
   27 VAJ(IJ)=VAR(IJ)
      VAL(M)=(1.+DV(M))*VAR(M)
      IF(FXTEMP) VAL(1) = TFIX
      IF(FXTEMP) VAL(2) = RFIX
      IF(VAL(M).LE.0.0) GO TO 36
      IF(M.GT.3) GO TO 33
      IF(VAL(1).GE.170..OR.VAL(1).LT.110.) GO TO 36
      H = VAL(3)*VAL(2)/(VAL(1)-TTD-TD)
   47 IF(H.GE.1.) GO TO 36
      IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 36
   33 SRN="/CHNGE-4/"
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
      IF(KCONV.EQ.1) GO TO 36
      PA1=DEPA1
      PA=DELPA
      DP(M)=DELPA-DEPA1
      GO TO 11
   34 VAL(I)=VAR(I)
   35 CONTINUE
   36 DO 37 I=1,5
```

```
   37 DV(I)=-DV(I)
      K1=K1+1
      IF(K1.EQ.1) GO TO 4
      K1=0
      IF(DV(I).LE..005) GO TO 39
      DO 38 I=1,5
   38 DV(I)=DV(I)/5.
      GO TO 4
   39 RETURN
      END
```

```
      SUBROUTINE COSTEX(ATOT)
C
C     SUBROUTINE COSTEX DETERMINES THE COST OF THE HEAT EXCHANGER
C     BUNDLES OF THE DRY COOLING TOWERS.  THE COST OF THE HEAT
C     EXCHANGER BUNDLE IS BROKEN DOWN INTO SEVERAL SUBCOMPONENTS
C                1.  HEADER
C                2.  TUBING
C                3.  TUBING SEALANT
C                4.  SPACERS
C                5.  BUNDLE FRAME
C                6.  BUNDLE ASSEMBLY
C     THE WEIGHT OF THE HEAT EXCHANGER BUNDLE AND THE WATER ARE
C     ALSO CALCULATED.
C
C     DEFINITION OF VARIABLES
C     ABC      - HOLE FACTOR FOR THE HEADER COSTS (DIMENSIONLESS)
C     AT       - CROSS-SECTIONAL AREA OF THE TUBE (SQ IN)
C     BSECF    - BUNDLE SHIPPING AND ERECTION FACTOR OF THE HEAT
C                EXCHANGER (DECIMAL)
C     CA       - BUNDLE ASSEMBLY AND FRAME COSTS ($)
C     CBA      - BUNDLE ASSEMBLY COST ($)
C     CBJ      - COST OF BOLTED HEADER JOINT ($/FT)
C     CELAST   - COST OF THE ELASTOMER ($/LBF)
C     CEPREP   - COST OF END PREPARATION FOR EACH TUBE ($/TUBE)
C     CFS      - UNIT FRAME COSTS ($/LBF)
C     CH       - COST OF THE HEADER FOR EACH BUNDLE
C     CHC      - STEEL HEADER COSTS ($/LBF)
C     CHF      - BUNDLE FRAME COST ($)
C     CHX      - COST OF THE HEAT EXCHANGER ($)
C     CP       - UNIT PLASTIC COSTS ($/LBF)
C     CS       - COOLING SURFACE COST ($)
C     CSC      - TUBE SPACER COSTS ($/TUBE-SPACER)
C     CSE      - COST OF SEALING PLATE AND SEALANT ($)
C     CSEALP   - COST OF SEAL PLATE ($/LBF)
C     DI       - INSIDE DIAMETER OF TUBE (IN)
C     ELENG    - LENGTH OF THE HEAT EXCHANGER TUBES (FT)
C     FA       - TOTAL TUBE FLOW AREA PER PASS SQ (IN)
C     FACT     - HEADER FACTOR WHICH DEPENDS ON THE TYPE OF HEADER
C                (DIMENSIONLESS)
C     FITCO    - TUBING COST ($/FT)
C     FP       - PRESSURE FACTOR (DIMENSIONLESS)
C     FT       - HEADER DEPTH MATERIAL FACTOR (IN)
C     FW       - HEADER WIDTH MATERIAL FACTOR (IN)
C     HD       - HEADER DEPTH PER PASS(IN)
C     HEDMAT   - TYPE OF HEADER MATERIAL (DIMENSIONLESS)
C     HEDTUB   - NUMBER OF TUBES PER HEADER
C     HEDTYP   - TYPE OF HEADER
C     HEDVOL   - HEADER VOLUME (CU FT)
C     HW       - HEADER WIDTH (IN)
C     HXNP     - NUMBER OF PASSES THROUGH THE HEAT EXCHANGER
C                (DIMENSIONLESS)
C     NW       - NUMBER OF HEAT EXCHANGER TUBES IN WIDTH
C                (DIMENSIONLESS)
C     ODL      - OUTSIDE DIAMETER OF TUBE (IN)
C     PCF      - PROCURMENT COST FACTOR (DECIMAL)
C     PCHBAF   - INDIRECT CONSTRUCTION COST FOR HEAT EXCHANGER
C                BUNDLE (DECIMAL)
```

```
C          ROEELA  - DENSITY OF THE SEALING ELASTOMER (LBM/CU IN)
C          ROEL    - TUBING MATERIAL DENSITY (LBM/CU IN)
C          ROESEL  - DENSITY OF STEEL SEALER PLATE (LBM/CU IN)
C          SPAMA   - SPACER MATERIAL (DIMENSIONELSS)
C          SS      - SPACING BETWEEN SPACERS (FT)
C          TELAST  - THICKNESS OF ELASTOMER LAYER (IN)
C          TS      - THICKNESS OF SPACER MATERIAL (IN)
C          TUBVOL  - VOLUME OF WATER INSIDE THE TUBES (CU FT)
C          TW      - THICKNESS OF THE HEADER WALLS (IN)
C          WATERW  - TOTAL WEIGHT OF THE WATER IN THE HEAT EXCHANGER
C                    BUNDLE (LBF)
C          WB      - WIDTH OF THE HEAT EXCHANGER BUNDLE (F)
C          WHX     - WEIGHT OF MATERIAL MAKING UP THE EXCHANGER (LBF)
C          WL      - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
C          WTFRM   - WEIGHT OF THE HEAT EXCHANGER FRAME (LBF)
C          WTHDR   - WEIGHT OF THE HEAT EXCHANGER HEADER (LBF)
C          WTTUB   - WEIGHT OF THE TUBES IN THE HEAT EXCHANGER (LBF)
C          XD      - LONGITUDINAL TUBE SPACING BETWEEN TUBE ROWS (IN)
C          XNBUN   - NUMBER OF HEAT EXCHANGER BUNDLES (DIMENSIONLESS)
C          XW      - TRANSVERSE TUBE PITCH NORMAL TO AIR FLOW (IN)
C          Z       - NUMBER OF HEAT EXCHANGER TUBES IN DEPTH
C                    (DIMENSIONLESS)
C
C     ARRAYS
C          TUBMA - LINER MATERIAL
C          CL    - LINER FIXED COSTS ($)
C          CLM   - LINER MATERIAL COSTS ($/LB)
C          ROEL  - DENSITY OF LINER MATERIALS (LB/CU IN)
C          GAGLI - LINER GAGE
C          THKLIN- THICKNESS OF LINER (IN)
C          FINTY - TYPE OF FIN
C          CFM   - FIN MATERIAL COSTS ($/LB)
C          CF    - FINNING FIXED COSTS ($/FT)
C          DOLINE- COMMON DIAMETERS OF LINER (IN)
C          MAXFH - MAXIMUM FIN HEIGHT (IN)
C          STANFT- STANDARD FIN THICKNESS (IN)
C          FPL   - LOWEST FIN PITCH (FPI)
C          FPH   - HIGHEST FIN PITCH (FPI)
C          HEDTY - TYPE OF HEADER
C          HEDMA - HEADER MATERIAL
C          ROEHM - HEADER MATERIAL DENSITY (LB/CU IN)
C          CHM   - COST OF HEADER MATERIAL ($/LB)
C          CHW   - COST OF HEADER MACHINING AND WELDING ($/FT)
C          CN    - NOZZEL AND ATTACHING COST ($/HOLE)
C          CHH   - TUBE AND PLUGHOLE PREPARATION ($/HOLE)
C          FF    - COST LENGTH FACTOR FOR TUBES (DIMENSIONLESS)
C          FINMA - TYPE OF FIN MATERIAL
C          FPL   - LOWER LIMIT ON STANDARD FIN PITCHES THAT ARE
C                  COMMERCIALLY AVAILABLE (FINS/IN)
C          FPH   - UPPER LIMIT ON STANDARD FIN PITCHES THAT ARE
C                  COMMERCIALLY AVAILABLE (FINS/IN)
C          MAXFH - MAXIMUM FIN HEIGHT FOUND COMMERCIALLY (IN)
C          ROEF  - DENSITY OF FIN MATERIAL (LBM/CU IN)
C          STANFT- FIN THICKNESS LIMITS FOUND COMMERCIALLY (IN)
C
      REAL NTUB
C
```

```
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CRJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANCLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMPI
     $ ,GBEFF
     $ ,HKNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBO, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(6)
     $ ,WFN
     $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFFI
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHOR, WTFRM,STRJCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /DJB/ DI,XDG,SF
      COMMON / PLCOST / WPL
      COMMON /ESCAL/ BSECF
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /HEADEX/ CHH,CN,CHM,CMW,CRJ,CWJ,CST,CMO,CSR,CSM,PITCHF,CPMW,
     1PRESS,HEDMAT,HEDTYP,NPASS,WB
      COMMON /SURFEX/ ODL,GAGLIN,NTUB,TUBMAT,FINTYP,FINMAT,CFB,APLATE,
     $          COATC, ZINCC, CASTC,SS,EPREPC,XTUBMA,XHEDTY,XFINTY
      COMMON / RPRT3 / TUBCST,SHLCST,FETCST,CHX
C
      DIMENSION TUBMA(2),CL(2),CLM(2),ROEL(2)
      DIMENSION HEDTY(4), HEDMA(3), ROEHM(3), CHC(4), CHMAT(3)
      DIMENSION ROES(2), SPAMA(2), CP(2)
```

```
C
C
C                    TABLE I
C              LINER TUBING COSTS AND DENSITY
C
      DATA CL /0.0, 0.002/
      DATA CLM /0.72, 0.775/
      DATA ROEL /0.035, 0.033/
      DATA CP /1.10, 2.20/
      DATA ROES /.044, .0314/
      DATA TUBMA/ "POLYETHYLEN", "POLYPROPYL"/
      DATA SPAMA /"POLYVINYLCH", "POLYCARBON"/
C
C                    TABLE II
C              HEADER FABRICATION COSTS
C
      DATA HEDTY / "WELD REMOV", "WELD PLUG ", "FORM REMOV",
     +             "FORM PLUG " /
      DATA (WEDMA(I),I=1,3)/"STEEL     ","ALUMINUM  ","GALVANIZED"/
      DATA ROEHM / .284, .09751, .284/
      DATA CWMAT / .53, 1.3, .57/
      DATA CWC / 1.05, 1.00, 0.95, 0.90 /
C
C              DEFINING THE CASE UNDER CONSIDERATION
C
      IF(.NOT.FIRST) GOTO 55
      LFLAG=0
      DO 10 I=1,8
      ITUBMA = I
      IF (TUBMAT .EQ. TUBMA(I)) GO TO 25
   10 CONTINUE
      PRINT 11
      LFLAG=1
   11 FORMAT(5X,"NO MATCH FOR LINER MATERIAL")
   25 DO 30 I=1,2
      ISPAMA = I
      IF(SPAMAT(1) .EQ. SPAMA(I)) GOTO 45
   30 CONTINUE
      PRINT 31
      LFLAG = 1
   31 FORMAT(5X,"NO MATCH FOR SPACER MATERIAL")
   45 CONTINUE
      IF(LFLAG.NE.0) STOP
   55 CONTINUE
      IF (FIRST) GOTO 125
C
C              LINER TUBING COSTS
C
      WL = 37.63911*ROEL(ITUBMA)*(ODL**2.0 - DI**2.0)/4.0
      CLTC = (CLM(ITUBMA) * WL + CL(ITUBMA))
      PCF = 1.10
      CLTC = CLTC*PCF
      FITCO = CLTC
C
C              TUBE SPACER COSTS
C
      TS = .364
```

```
      HD = XD * (Z/HXNP) + 1.0
      AT = 3.14159 * ODL * ODL / 4.
      CSC = CP(ISPAMA) * (XW * HXNP * HD/Z - AT) * TS * ROES(ISPAMA)
C
C           END PREPARATION COST
C
      CEPREP = EPREPC
C
C           COOLING SURFACE COST
C
      CS = Z*NW*(FITCO*ELENG+CSC*((ELENG**5*SS)/SS)+CEPREP)
      CS = CS * POHBAF
C
C
C           DEFINING THE CASE FOR THE HEADER
C
  125 IF (.NOT. FIRST) GOTO 145
      DO 130 I=1,4
      IHEDTY = I
      IF (HEDTYP .EQ. HEDTY(I)) GO TO 135
  130 CONTINUE
      PRINT 131
      STOP
  131 FORMAT(5X,"NO MATCH FOR HEADER TYPE")
  135 DO 140 I=1,3
      IHEDMA=I
      IF(HEDMAT.EQ.HEDMA(I)) GOTO 142
  140 CONTINUE
      PRINT 141
      STOP
  141 FORMAT(5X,"NO MATCH FOR HEADER MATERIAL")
  142 FIRST=.FALSE.
      RETURN
C
C           HEADER AND NOZZEL COSTS
C
  145 CONTINUE
C
C           NUMBER OF BUNDLES IN COOLING TOWERS
      XNBUN = NW*XW/(12.0*WB)
      XNMOD = XNBUN/8.0
C
C           NUMBER OF TUBES PER BUNDLE
      HEDTUB = 12.*Z *WB/XW
      ABC=1.0
      IF(IHEDTY.EQ.2.OR.IHEDTY.EQ.4) ABC=2.0
      FP=1.00
      FA = .785398*DI*DI*HEDTUB/HXNP
C
C           HEADER DEPTH AND WIDTH
      HD = XD * (Z/HXNP) + 1.0
      HW = FA / (2.0 * HD) + 2.0
      F1 = 2.0 * HXNP * HXNP * HD / 10.0
      F2 = 2.0*HXNP*FA/(20.0*HD)
      IF(IHEDTY.EQ.1.OR.IHEDTY.EQ.2) FACT=2.*F1+4.
      IF(IHEDTY.EQ.3.OR.IHEDTY.EQ.4) FACT=2.*F1
C
```

```
C           HEADER COSTS
      CHM= CHMAT(IHEDMA)
      CH=(CHM*ROEHM(IHEDMA)*(12.*WB*TW*(2.*F1*HD +(F2+2.)*HW)+F1*FA*
     $ TW ) + CMW*(FACT*WB +(4.0*F1*HD + 2.0*(F2 +2.0)*HW)/12.0)+
     $ 4.0 * CBJ* (HXNP*HD/12. + WB) +
     1CHH*(24.0*ABC*Z*WB/XW) + 4.0*CN*SQRT(FA/3.14159))*XNBUNLEP
      CH = CH * POHBAF
      IF (WB .GT. 14.0) PRINT 150
  150 FORMAT(5X,"THE SPECIFIED HEADER LENGTH IS BEYOND THE PRACTICAL LIM
     +IT")
C
C           COST OF HEADER SEALANT
      CSE = 2. * (CSEALP * ROESEL * TSEALP * 12. * WB * HXNP * HD
     $ + CELAST * ROFELA * TELAST * (12. * WB * HXNP * HD - HEDTUB
     $ * AT )) * XNBUN
      CSE = CSE * POHBAF
C
C           BUNDLE ASSEMBLE AND FRAME COSTS
C
C           BUNDLE FRAME COST
      CVF = CFS*ELENG*(86.0 + 2.0*WB)*XNBUN
      CVF = CVF * POHBAF
      CHF = CVF
C
C           BUNDLE ASSEMBLY COST
      CBA = (1150. * SQRT(Z*ELENG)/42. + 650.* SQRT(ELENG)/9.5
     $ + 400. *SQRT(WB) / 3.5  + 500.) * XNBUN
      CBA = CBA * POHBAF
      CA = CVF + CBA
C
C           WEIGHT OF HEAT EXCHANGER
C
C           TUBE MATERIAL WEIGHT OF COOLING TOWERS
      WTTUB = Z * NW * ELENG * WL
C
C           HEADER MATERIAL WEIGHT OF COOLING TOWERS
      WTHDR = ROEHM(IHEDMA) * (12.*WB*TW * (2.*F1*HD+(F2+2.)*HW)+
     $ F1*FA*TW) * XNBUN
C
C           TOTAL FRAME WEIGHT
      WTFRM = 20.0 * ELENG * (2.+WB/(2.*SS)) * SQRT(Z/6.)*XNBUN
C
C           TOTAL WEIGHT OF WATER IN HEAT EXCHANGER
      TUBVOL = Z*NW*ELENG*3.14159*DI*DI/(144.0*4.0)
      HEDVOL = 2.0 * HXNP * HD * NW * WB / 144. * XNBUN
      WATERW = (TUBVOL + HEDVOL)*62.4
C
C           TOTAL MATERIAL WEIGHT OF HEAT EXCHANGER
      WHX = WTTUB + WTHDR + WTFRM
C
C           TOTAL HEAT EXHANGER COSTS
C
      BSECF = 1.12
      CHX = BSECF * (CS + CH + CA + CSE)
      RETURN
      END
```

```
      SUBROUTINE FAN (OPTINW)
C
C     SUBROUTINE FAN SELECTS THE OPTIMUM FAN SYSTEM FOR THE PARTIC-
C     ULAR HEAT EXCHANGER GEOMETRY SELECTED.  FOR THE PARTICULAR
C     FAN SYSTEM THE FOLLOWING PARAMETER ARE SPECIFIED-
C              1.  BLADE DIAMETER
C              2.  HUB DIAMETER
C              3.  NUMBER OF BLADES PER FAN
C              4.  BLADE ANGLE
C     KNOWING THE NUMBER OF FANS AND THE PACKING FACTOR OF THE
C     FANS, THE CIRCUALR TOWER DIAMETER CAN EASILY BE
C     DETERMINED.  THE COST OF THE FAN SYSTEM IS THEN FOUND.  THE
C     FAN SYSTEM RESULTING IN THE MINIMUM COST IS SPECIFIED AS THE
C     OPTIMUM.
C     IN THIS SUBROUTINE THERE ARE TWO ARRAYS WHICH CONTAIN DATA
C     FOR THE FOLLOWING FAN DIAMETERS (24,26,28,30,40,60).  FOR
C     EACH FAN DIAMETER THERE IS PERFORMANCE DATA FOR FANS WITH
C     DIFFERENT NUMBER OF BLADES AND BLADE ANGLES.  THE DATA
C     ARRAYS FANDAP CONTAINS THE FOLLOWING INFORMATION-
C     FANDAP(I,J)
C     J=1,5    - COEFFICIENTS FOR THIRD ORDER CURVE FIT OF VOLU-
C                METRIC FLOW RATE VERSUS TOTAL PRESSURE DROP ACROSS
C                THE FAN
C     J=6      - LOWER PRESSURE DROP LIMIT (IN WATER)
C     J=7      - UPPOR PRESSURE DROP LIMIT (IN WATER)
C     J=8      - DIAMETER OF FAN(FT)
C     J=9      - NUMBER OF BLADES PER FAN
C     J=10     - BLADE ANGLE (DEGREES)
C     I=1,153  - DIFFERENT SETS OF DATA FOR EACH FAN AND
C                PERFORMANCE POINT
C     THE DATA ARRAY FANDAH CONTAINS THE FOLLOWING INFORMATION-
C     FANDAH (I,J)
C     J=1,5    - COEFFICIENTS FOR FOURTH ORDER CURVE FIT OF
C                HORSEPOWER VERSUS VOLUMETRIC FLOW RATE
C     J=6      - LOWER LIMIT ON VOLUMETRIC FLOW RATE OF AIR THROUGH
C                THE FAN FOR WHICH DATA IS AVAILABLE
C     J=7      - UPPER LIMIT ON VOLUMETRIC FLOW RATE OF AIR THROUGH
C                THE FAN FOR WHICH DATA IS AVAILABLE
C     J=8      - DIAMETER OF FAN(FT)
C     J=9      - NUMBER OF BLADES PER FAN
C     J=10     - BLADE ANGLE (DEGREES)
C
C     DEFINITION OF VARIABLES
C     A        - AIR FLOW AREA OF THE FAN (SQ FT)
C     ABLN     - NUMBER OF FAN BLADES (DIMENSIONLESS)
C     ADIA     - FAN DIAMETER (FT)
C     ANFCOS   - ANNUAL FAN COSTS ($)
C     ANSFPC   - ANNUAL CAPITAL COST OF PLENUM, FOUNDATION, AND
C                STRUCTURES ($)
C     ANSFPF   - TOTAL ANNUAL COST OF THE FAN SYSTEM AND STRUCTURE
C     BAR      - BAROMETRIC PRESSURE (IN HGA)
C     BLDANG   - FAN BLADE ANGLE (DEGREES)
C     CAPF     - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER
C                (PERCENT)
C     COANG    - COSINE OF THE ANGLE FOR THE DELTA HEAT EXCHANGER
C                ARRANGEMENT (DIMENSIONLESS)
C     CFM      - ESTIMATE OF THE VOLUMETRIC FLOW RATE OF AIR THROUGH
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C                 EACH FAN (CU FT/MIN)
C       CFROS   - FAN STACK COSTS WITH AND WITHOUT VELOCITY RECOVERY
C                 ($)
C       CT      - CONVERGENCE PARAMETER FOR THE VOLUMETRIC FLOW RATE
C                 THROUGH EACH FAN (DIMENSIONLESS)
C       CINC    - INCREMENTAL VOLUMETRIC FLOW RATE OF AIR USED IN
C                 DETERMINING THE FAN PERFORMANCE POINT (CU FT/MIN)
C       CMOT    - COST OF FAN MOTORS PER FAN ($)
C       CPL     - COST OF PLENUM FOR THE ENTIRE TOWER SYSTEM ($)
C       CPM     - COST OF PLENUM MATERIAL ($/LBM)
C       CSR     - COST OF THE SPEED REDUCER ($)
C       CVM     - FAN RING MATERIAL UNIT COST ($/LBF)
C       DIST    - DISTANCE FROM THE CONDENSER ROOM TO THE FIRST
C                 CIRCULAR TOWER (FT)
C       DPTINW  - PRESSURE DROP ACROSS THE HEAT EXCHANGER (IN H2O)
C       DSGTM   - DISTANCE FROM THE SWITCH GEAR TO THE MOTOR (FT)
C       DTOW    - DIAMETER OF THE CIRCULAR TOWERS (FT)
C       DTTSG   - DISTANCE FROM THE TOWER TO THE SWITCH GEAR (FT)
C       ESCSF   - ESCALATION FACTOR FOR FAN COST (DIMENSIONLESS)
C       EHR     - HEAT RATE OF PLANT (BTU/KW-HR)
C       ELENG   - LENGTH OF HEAT EXCHANGER TUBES (FT)
C       ELEV    - PLANT ELEVATION FROM SEA LEVEL (FT)
C       FDIAD   - FAN DIAMETER (FT)
C       FANLEC  - ELECTRICAL WIRING COSTS FOR THE FAN SYSTEM ($)
C       FCOS    - PLANT FUEL COST (CENTS/MMBTU)
C       FCR     - FIXED CHARGE RATE ON CAPITAL FOR ONE
C                 YEAR (FRACTIONAL)
C       FCST    - CAPITAL COST OF THE FAN ($)
C       FMC     - FAN MOTOR COST PER HORSEPOWER FOR MOTORS OF SMALL
C                 HORSEPOWER ($/HP)
C       FNDC    - FOUNDATION COSTS FOR THE CIRCULAR TOWERS ($)
C       FPOW    - POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
C       GREFF   - GEAR BOX EFFICIENCY OF THE FAN SYSTEM (PERCENT)
C       HB      -
C       HFR     - HEIGHT OF THE FAN RING (FT)
C       HPAIR   - HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
C       HPF     - HORSEPOWER REQUIREMENTS OF EACH FAN (HP)
C       HUBDIA  - DIAMETER OF THE FAN HUB (FT)
C       I       - PERFORMANCE POINT OF A FAN (DIMENSIONLESS)
C       ITMAX   - MAXIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
C                 (DIMENSIONLESS)
C       ITMIN   - N
C       ITMIN   - MINIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
C                 (DIMENSIONLESS)
C       ITOWN   - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C       LBF,LFE - VARIABLES USED IN SPECIFYING WHICH FANS ARE TO BE
C                 CONSIDERED FOR USE IN THE FAN SYSTEM
C                 (DIMENSIONLESS)
C       NOF     - NUMBER OF FANS MAKING UP THE FAN SYSTEM
C                 (DIMENSIONLESS)
C       PFACT   - PACKING FACTOR, RATIO OF CIRCULAR TOWER ROOF AREA
C                 TO FAN SWEPT AREA (DIMENSIONLESS)
C       PLANC   - BASE PLANT COSTS ($/KW)
C       POHFAN  - INDIRECT COST FACTOR FOR FANS (DECIMAL)
C       POHSTC  - INDIRECT COST FACTOR FOR CIRCULAR TOWER STRUCTURES
C                 (DECIMAL)
C       ROOFL   - CIRCULAR TOWER ROOF LOAD (LBF/SQ FT)
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C          SAAF     - SHIPPING AND ASSEMBLY FACTOR (DECIMAL)
C          SPVOL    - SPECIFIC VOLUME OF THE AIR EXITING THE HEAT
C                     EXCHANGER (LBM/CU FT)
C          STRUCC   - CIRCULAR TOWER STRUCTURE COST ($)
C          TAN19    - TANGENT OF 19 DEGREES TO BE USED IN COSTING OF
C                     ENTRY BELL TO THE FAN (DECIMAL)
C          TAN 8    - TANGENT OF 8 DEGREES TO BE USED IN COSTING OF EXIT
C                     STACK FROM THE FAN (DECIMAL)
C          TCSTF    - TOTAL COST OF THE FAN SYSTEM ($)
C          TCSTPF   - TOTAL COST OF A FAN ($)
C          TOTCFM   - TOTAL VOLUMETRIC FLOW RATE FOR THE AIR THROUGH
C                     THE FAN SYSTEM (CU FT/MIN)
C          TOTHP    - TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM (HP)
C          TP       - TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN (IN H2O)
C          TA       - AIR EXIT TEMPERATURE FROM THE HEAT EXCHANGER
C                     (DEG F)
C          UCS      - UNIT COST OF THE STACK ($/LBF)
C          UWS      - UNIT WEIGHT OF THE STACK (LBF/CU FT)
C          VEL      - AVERAGE VELOCITY OF THE AIR LEAVING THE FAN
C                     (FT/SEC)
C          VELREC   - SPECIFIES WHETHER VELOCIY RECOVERY STACKS ARE
C                     GOING TO BE USED OR NOT (DIMENSIONLESS)
C          VO       - NON RECOVERABLE AIR VELOCITY HEAT EXITING THE FAN
C                     (IN H2O)
C          WATERW   - WEIGHT OF WATER IN THE HEAT EXCHANGER TUBES AND
C                     BUNDLES (LBF)
C          WEV      - UNIT WEIGHT OF THE ENTRY BELL (LBF/SQ FT)
C          WHX      - WIEGHT OF THE HEAT EXCHANGER (LBF)
C          WIDTH    - WIDTH OF THE HEAT EXCHANGER (F)
C          WPL      - WIEGHT OF THE PLENUM MOTERIAL (LBF/ SQ FT)
C          W4       - MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER
C                     (LBM/HR)
C          XNFAN    - NUMBER OF FANS (DIMENSIONLESS)
C
      REAL NOF
      COMMON /FAN/ FANDAP(153,10),FANHAH(153,10),FMCPF, FBCPF,
     $VELREC,AFC,ELEV,EHR
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAPI
     $ ,CBU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ OOR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
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$ ,QREJ, QREDUCE
$ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
$ ,SAAF, SIGMA, SPAMAT(2)
$ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
$ ,TJBAOG, TW
$ ,UCS, UWS
$ ,VAS(5)
$ ,WFV
$ ,XDERA, XW, XD
 COMMON /SUPPLY/ VAL(5), CPIP, CCOS,    W3, COSM,   EFF
$,  CLAMD, REAIR,     Z,HRFAC2,    W4,     U, PPOW,
$    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
$   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
$     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
$     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
$,   TLOX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
$,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
$,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
$,  WTHOR, WTFRM,STRJCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
$,  AIREF,  WATEF,  XNMOD,  TCTPFL,  FDCPF,  FMTRC, ACCTTP,  ADJTP
$, ACTBOD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
$,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
$ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
 COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
$  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
 COMMON /HEADEX/ CHH,CN,CHM,CMW,CRJ,CWJ,CST,CMO,CSR,CSM,PITCHF,CPM,
SPRESS,HEDMAT,HEDTYP,NPASS,WB
 COMMON /ENLOOP/ LFB,LFE
 COMMON /PLCOST/ WPL
 COMMON /INDIS/ DIST
 COMMON /PME/ PMELEC
 DATA (FANDAP(  1,J),J=1,10) /
$ .7961      ,.6520      ,-6.316     ,11.944     ,-8.252     ,
$ .19        ,.625       ,  24. ,  5. ,  6. /
 DATA (FANDAP(  2,J),J=1,10) /
$ 1.059      ,-.8172     ,-.1262     ,.2533      ,-.2331     ,
$ .25        ,.765       ,  24. ,  6. ,  8. /
 DATA (FANDAP(  3,J),J=1,10) /
$ 1.346      ,-1.635     ,1.685      ,-1.666     ,.5886      ,
$ .31        ,.91        ,  24. ,  5. , 10. /
 DATA (FANDAP(  4,J),J=1,10) /
$ .5643      ,4.692      ,-14.336    ,15.960     ,-6.562     ,
$ .365       ,.94        ,  24. ,  6. , 12. /
 DATA (FANDAP(  5,J),J=1,10) /
$ .4015      ,5.087      ,-16.629    ,17.327     ,-6.713     ,
$ .42        ,.98        ,  24. ,  6. , 14. /
 DATA (FANDAP(  6,J),J=1,10) /
$ 1.337      ,.9316      ,-4.655     ,5.368      ,-2.424     ,
$ .477       ,.95        ,  24. ,  6. , 16. /
 DATA (FANDAP(  7,J),J=1,10) /
$ -3.074     ,26.409     ,-57.905    ,54.456     ,-19.277    ,
$ .532       ,1.01       ,  24. ,  5. , 18. /
 DATA (FANDAP(  8,J),J=1,10) /
$ 1.226      ,3.829      ,-11.905    ,12.904     ,-5.303     ,
$ .605       ,.98        ,  24. ,  6. , 20. /
 DATA (FANDAP(  9,J),J=1,10) /
$ -17.189    ,96.0       ,-182.414   ,152.343    ,-47.879    ,
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      $ .68        ,1.015      ,  24. ,  6. , 22. /
      DATA (FANDAP( 10,J),J=1,10) /
      $ .9109      ,-.6216     ,-.0576     ,.09596     ,-.0758     ,
      $ .205       ,.795       ,  24. ,  8. ,  6. /
      DATA (FANDAP( 11,J),J=1,10) /
      $ 1.059      ,-.7222     ,.0581      ,.0384      ,-.0676     ,
      $ .264       ,.969       ,  24. ,  8. ,  8. /
      DATA (FANDAP( 12,J),J=1,10) /
      $ 1.194      ,-.6306     ,-.0933     ,.01957     ,-.00947    ,
      $ .327       ,1.138      ,  24. ,  8. , 10. /
      DATA (FANDAP( 13,J),J=1,10) /
      $ 1.442      ,-1.399     ,1.550      ,-1.418     ,.4356      ,
      $ .393       ,1.12       ,  24. ,  8. , 12. /
      DATA (FANDAP( 14,J),J=1,10) /
      $ .4597      ,4.638      ,-10.373    ,8.728      ,-2.718     ,
      $ .445       ,1.21       ,  24. ,  8. , 14. /
      DATA (FANDAP( 15,J),J=1,10) /
      $ 1.533      ,-.5932     ,-.5343     ,.6805      ,-.3261     ,
      $ .529       ,1.14       ,  24. ,  8. , 16. /
      DATA (FANDAP( 16,J),J=1,10) /
      $ .244       ,7.202      ,-14.895    ,12.133     ,-3.683     ,
      $ .612       ,1.25       ,  24. ,  8. , 18. /
      DATA (FANDAP( 17,J),J=1,10) /
      $ 2.321      ,-2.232     ,1.862      ,-.7451     ,-.0714     ,
      $ .684       ,1.15       ,  24. ,  8. , 20. /
      DATA (FANDAP( 18,J),J=1,10) /
      $ -12.148    ,55.65      ,-83.947    ,55.657     ,-13.939    ,
      $ .756       ,1.24       ,  24. ,  8. , 22. /
      DATA (FANDAP( 19,J),J=1,10) /
      $ .8525      ,-.2121     ,-.6814     ,.5934      ,-.1894     ,
      $ .214       ,.95        ,  24. , 10. ,  6. /
      DATA (FANDAP( 20,J),J=1,10) /
      $ 1.307      ,-2.057     ,3.129      ,-2.760     ,.8712      ,
      $ .276       ,1.16       ,  24. , 10. ,  8. /
      DATA (FANDAP( 21,J),J=1,10) /
      $ 1.140      ,-.3050     ,-.4077     ,.2543      ,-.0612     ,
      $ .34        ,1.365      ,  24. , 10. , 10. /
      DATA (FANDAP( 22,J),J=1,10) /
      $ 1.211      ,-.1516     ,-.5856     ,.3418      ,-.07576    ,
      $ .397       ,1.34       ,  24. , 10. , 12. /
      DATA (FANDAP( 23,J),J=1,10) /
      $ 1.247      ,.0813      ,-.6502     ,.1965      ,-.01166    ,
      $ .455       ,1.4        ,  24. , 10. , 14. /
      DATA (FANDAP( 24,J),J=1,10) /
      $ 1.314      ,.5641      ,-1.534     ,.8592      ,-.1989     ,
      $ .55        ,1.37       ,  24. , 10. , 16. /
      DATA (FANDAP( 25,J),J=1,10) /
      $ .5757      ,4.363      ,-7.5248    ,4.961      ,-1.231     ,
      $ .652       ,1.55       ,  24. , 10. , 18. /
      DATA (FANDAP( 26,J),J=1,10) /
      $ -.076      ,6.982      ,-10.793    ,6.833      ,-1.667     ,
      $ .745       ,1.44       ,  24. , 10. , 20. /
      DATA (FANDAP( 27,J),J=1,10) /
      $ -168.996   ,548.34     ,-659.02    ,350.82     ,-69.909    ,
      $ 1.02       ,1.48       ,  24. , 10. , 22. /
      DATA (FANDAP( 28,J),J=1,10) /
      $ 1.090      ,-1.005     ,.2432      ,.1717      ,-1.515     ,
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      $ .205      ,.55        ,  26. ,  6. ,  6. /
       DATA (FANDAP( 29,J),J=1,10) /
      $ 1.144     ,-.0621     ,-3.590     ,6.245      ,-4.382     ,
      $ .248      ,.66        ,  26. ,  6. ,  8. /
       DATA (FANDAP( 30,J),J=1,10) /
      $ 1.196     ,.1327      ,-2.291     ,1.492      ,-.2707     ,
      $ .235      ,.778       ,  26. ,  6. , 10. /
       DATA (FANDAP( 31,J),J=1,10) /
      $ 1.576     ,-1.413     ,1.077      ,-.8904     ,-.2331     ,
      $ .35       ,.84        ,  26. ,  6. , 12. /
       DATA (FANDAP( 32,J),J=1,10) /
      $ -.3976    ,13.678     ,-38.403    ,44.263     ,-19.254    ,
      $ .41       ,.87        ,  26. ,  6. , 14. /
       DATA (FANDAP( 33,J),J=1,10) /
      $ 2.497     ,-4.479     ,5.789      ,-2.571     ,-1.061     ,
      $ .456      ,.85        ,  26. ,  6. , 16. /
       DATA (FANDAP( 34,J),J=1,10) /
      $ -31.553   ,200.29     ,-450.42    ,445.5      ,-164.67    ,
      $ .525      ,.89        ,  26. ,  6. , 18. /
       DATA (FANDAP( 35,J),J=1,10) /
      $ -37.986   ,229.06     ,-493.03    ,468.48     ,-166.93    ,
      $ .585      ,.88        ,  26. ,  6. , 20. /
       DATA (FANDAP( 36,J),J=1,10) /
      $ 199.88    ,-940.76    ,1663.3     ,-1295.9    ,373.75     ,
      $ .65       ,.90        ,  26. ,  6. , 22. /
       DATA (FANDAP( 37,J),J=1,10) /
      $ 1.166     ,-1.456     ,2.750      ,-4.222     ,1.818      ,
      $ .22       ,.605       ,  26. ,  8. ,  6. /
       DATA (FANDAP( 38,J),J=1,10) /
      $ 1.178     ,-.1032     ,-2.070     ,3.033      ,-1.935     ,
      $ .275      ,.755       ,  26. ,  8. ,  8. /
       DATA (FANDAP( 39,J),J=1,10) /
      $ 1.431     ,-.9074     ,.04604     ,.5361      ,-.6993     ,
      $ .333      ,.885       ,  26. ,  8. , 10. /
       DATA (FANDAP( 40,J),J=1,10) /
      $ 1.330     ,.5823      ,-3.196     ,3.499      ,-1.643     ,
      $ .37       ,.985       ,  26. ,  8. , 12. /
       DATA (FANDAP( 41,J),J=1,10) /
      $ .8602     ,3.760      ,-8.974     ,7.814      ,-2.708     ,
      $ .45       ,1.083      ,  26. ,  8. , 14. /
       DATA (FANDAP( 42,J),J=1,10) /
      $ 1.829     ,-.6431     ,-.5586     ,.9619      ,-.6993     ,
      $ .513      ,1.03       ,  26. ,  8. , 16. /
       DATA (FANDAP( 43,J),J=1,10) /
      $ -6.205    ,44.085     ,-97.055    ,72.068     ,-22.635    ,
      $ .586      ,1.14       ,  26. ,  8. , 18. /
       DATA (FANDAP( 44,J),J=1,10) /
      $ -13.827   ,76.312     ,-138.97    ,111.051    ,-33.333    ,
      $ .65       ,1.06       ,  26. ,  8. , 20. /
       DATA (FANDAP( 45,J),J=1,10) /
      $ -14.507   ,69.914     ,-108.62    ,75.63      ,-20.0      ,
      $ .74       ,1.125      ,  26. ,  8. , 22. /
       DATA (FANDAP( 46,J),J=1,10) /
      $ 1.034     ,-.5941     ,.3743      ,-.6713     ,.2083      ,
      $ .23       ,.78        ,  26. , 11. ,  6. /
       DATA (FANDAP( 47,J),J=1,10) /
      $ 1.284     ,-.9283     ,.9886      ,-1.0606    ,.303       ,
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      $ .29        ,.98        ,  26. , 11. ,  8. /
       DATA (FANDAP( 48,J),J=1,10) /
      $ 1.320      ,-.09006    ,-1.233     ,1.396      ,-.6345     ,
      $ .355       ,1.15       ,  26. , 11. , 10. /
       DATA (FANDAP( 49,J),J=1,10) /
      $ 1.385      ,.3155      ,-1.958     ,1.880      ,-.7164     ,
      $ .415       ,1.28       ,  26. , 11. , 12. /
       DATA (FANDAP( 50,J),J=1,10) /
      $ 1.376      ,.7735      ,-2.250     ,1.701      ,-.5449     ,
      $ .49        ,1.415      ,  26. , 11. , 14. /
       DATA (FANDAP( 51,J),J=1,10) /
      $ .4584      ,5.911      ,-11.267    ,8.504      ,-2.414     ,
      $ .57        ,1.444      ,  26. , 11. , 16. /
       DATA (FANDAP( 52,J),J=1,10) /
      $ -6.278     ,34.035     ,-53.2555   ,35.676     ,-8.8359    ,
      $ .65        ,1.525      ,  26. , 11. , 18. /
       DATA (FANDAP( 53,J),J=1,10) /
      $ -25.743    ,103.427    ,-144.837   ,89.298     ,-20.622    ,
      $ .75        ,1.38       ,  26. , 11. , 20. /
       DATA (FANDAP( 54,J),J=1,10) /
      $ -67.904    ,225.828    ,-273.144   ,146.373    ,-29.455    ,
      $ 1.11       ,1.46       ,  26. , 11. , 22. /
       DATA (FANDAP( 55,J),J=1,10) /
      $ 1.141      ,-.331      ,-1.453     ,-1.591     ,2.453      ,
      $ .19        ,.54        ,  28. ,  6. ,  6. /
       DATA (FANDAP( 56,J),J=1,10) /
      $ 1.045      ,2.745      ,-16.574    ,30.038     ,-20.517    ,
      $ .23        ,.63        ,  28. ,  6. ,  8. /
       DATA (FANDAP( 57,J),J=1,10) /
      $ .9281      ,5.303      ,-23.573    ,36.246     ,-20.781    ,
      $ .28        ,.71        ,  28. ,  6. , 10. /
       DATA (FANDAP( 58,J),J=1,10) /
      $ 1.058      ,5.352      ,-22.775    ,33.866     ,-18.871    ,
      $ .33        ,.71        ,  28. ,  6. , 12. /
       DATA (FANDAP( 59,J),J=1,10) /
      $ -3.092     ,37.887     ,-111.734   ,139.178    ,-64.532    ,
      $ .39        ,.78        ,  28. ,  6. , 14. /
       DATA (FANDAP( 60,J),J=1,10) /
      $ -1.439     ,26.222     ,-79.847    ,102.926    ,-50.00     ,
      $ .435       ,.72        ,  28. ,  6. , 16. /
       DATA (FANDAP( 61,J),J=1,10) /
      $ -22.914    ,167.722    ,-422.785   ,467.638    ,-193.335   ,
      $ .49        ,.785       ,  28. ,  6. , 18. /
       DATA (FANDAP( 62,J),J=1,10) /
      $ -4.125     ,46.711     ,-131.308   ,158.511    ,-71.4578   ,
      $ .53        ,.76        ,  28. ,  6. , 20. /
       DATA (FANDAP( 63,J),J=1,10) /
      $ -99.262    ,607.748    ,-1365.5    ,1350.4     ,-508.349   ,
      $ .58        ,.79        ,  28. ,  6. , 22. /
       DATA (FANDAP( 64,J),J=1,10) /
      $ 1.149      ,-.0283     ,-3.051     ,3.750      ,-1.911     ,
      $ .20        ,.67        ,  28. ,  8. ,  6. /
       DATA (FANDAP( 65,J),J=1,10) /
      $ 1.386      ,-.4003     ,-2.450     ,3.275      ,-1.655     ,
      $ .255       ,.79        ,  28. ,  8. ,  8. /
       DATA (FANDAP( 66,J),J=1,10) /
      $ 1.479      ,-.4131     ,-.8639     ,-.0806     ,.3017      ,
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      $ .3        ,.9         ,  28. ,  8. , 10. /
       DATA (FANDAP( 67,J),J=1,10) /
      $ 1.342     ,1.115      ,-6.969     ,9.507      ,-4.848     ,
      $ .35       ,.9         ,  28. ,  8. , 12. /
       DATA (FANDAP( 68,J),J=1,10) /
      $ .4543     ,9.668      ,-26.867    ,28.991     ,-11.655    ,
      $ .44       ,.98        ,  28. ,  8. , 14. /
       DATA (FANDAP( 69,J),J=1,10) /
      $ -.1496    ,13.991     ,-36.402    ,38.619     ,-15.385    ,
      $ .43       ,.94        ,  28. ,  8. , 16. /
       DATA (FANDAP( 70,J),J=1,10) /
      $ -1.526    ,22.206     ,-51.296    ,49.975     ,-18.322    ,
      $ .557      ,.98        ,  28. ,  8. , 18. /
       DATA (FANDAP( 71,J),J=1,10) /
      $ -15.419   ,94.430     ,-191.291   ,170.303    ,-56.97     ,
      $ .6        ,.96        ,  28. ,  8. , 20. /
       DATA (FANDAP( 72,J),J=1,10) /
      $ -182.795  ,850.555    ,-1466.4    ,1121.9     ,-321.938   ,
      $ .8        ,1.01       ,  28. ,  8. , 22. /
       DATA (FANDAP( 73,J),J=1,10) /
      $ 1.907     ,-8.155     ,26.542     ,-39.870    ,20.833     ,
      $ .203      ,.72        ,  28. ,  9. ,  6. /
       DATA (FANDAP( 74,J),J=1,10) /
      $ 1.707     ,-2.471     ,5.482      ,-7.257     ,3.078      ,
      $ .3        ,1.025      ,  28. ,  9. , 10. /
       DATA (FANDAP( 75,J),J=1,10) /
      $ -5.491    ,43.171     ,-95.551    ,90.264     ,-31.495    ,
      $ .443      ,1.045      ,  28. ,  9. , 14. /
       DATA (FANDAP( 76,J),J=1,10) /
      $ -11.476   ,71.058     ,-139.628   ,119.048    ,-37.792    ,
      $ .555      ,1.08       ,  28. ,  9. , 18. /
       DATA (FANDAP( 77,J),J=1,10) /
      $ -111.138  ,485.02     ,-778.16    ,553.442    ,-147.595   ,
      $ .57       ,1.11       ,  28. ,  9. , 22. /
       DATA (FANDAP( 78,J),J=1,10) /
      $ .9182     ,-.6397     ,.1263      ,-1.283     ,1.08       ,
      $ .118      ,.54        ,  28. , 10. ,  2. /
       DATA (FANDAP( 79,J),J=1,10) /
      $ 1.191     ,-.5515     ,-.045      ,-.974      ,.6976      ,
      $ .2        ,.8         ,  28. , 10. ,  6. /
       DATA (FANDAP( 80,J),J=1,10) /
      $ 1.478     ,-.2616     ,-2.549     ,3.408      ,-1.70      ,
      $ .31       ,1.03       ,  28. , 10. , 10. /
       DATA (FANDAP( 81,J),J=1,10) /
      $ 0.4844    ,8.207      ,-20.171    ,19.338     ,-6.894     ,
      $ .45       ,1.15       ,  28. , 10. , 14. /
       DATA (FANDAP( 82,J),J=1,10) /
      $ -12.856   ,75.341     ,-141.915   ,115.921    ,-35.119    ,
      $ .53       ,1.17       ,  28. , 10. , 18. /
       DATA (FANDAP( 83,J),J=1,10) /
      $ -131.140  ,528.522    ,-784.764   ,516.323    ,-127.273   ,
      $ .71       ,1.21       ,  28. , 10. , 22. /
       DATA (FANDAP( 84,J),J=1,10) /
      $ .9394     ,-.6355     ,.3496      ,-1.169     ,.7752      ,
      $ .122      ,.64        ,  28. , 12. ,  2. /
       DATA (FANDAP( 85,J),J=1,10) /
      $ 1.205     ,-.51       ,.1897      ,-1.018     ,.6163      ,
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      $ .216        ,.94        ,  28. , 12. ,  6. /
       DATA (FANDAP( 86,J),J=1,10) /
      $ 1.504       ,-.1562     ,-1.506     ,1.699      ,-.7334     ,
      $ .33         ,1.2        ,  28. , 12. , 10. /
       DATA (FANDAP( 87,J),J=1,10) /
      $ .6086       ,6.967      ,-15.551    ,13.341     ,-4.216     ,
      $ .43         ,1.32       ,  28. , 12. , 14. /
       DATA (FANDAP( 88,J),J=1,10) /
      $ 1.227       ,4.416      ,-9.275     ,7.309      ,-2.178     ,
      $ .62         ,1.44       ,  28. , 12. , 18. /
       DATA (FANDAP( 89,J),J=1,10) /
      $ 1.036       ,-.4416     ,-6.142     ,15.126     ,-14.698    ,
      $ .12         ,.38        ,  30. ,  8. ,  2. /
       DATA (FANDAP( 90,J),J=1,10) /
      $ 2.034       ,-5.822     ,13.159     ,-16.404    ,6.562      ,
      $ .22         ,.64        ,  30. ,  8. ,  6. /
       DATA (FANDAP( 91,J),J=1,10) /
      $ 1.109       ,6.519      ,-26.233    ,35.842     ,-18.121    ,
      $ .32         ,.79        ,  30. ,  8. , 10. /
       DATA (FANDAP( 92,J),J=1,10) /
      $ -9.489      ,76.086     ,-183.815   ,190.216    ,-73.502    ,
      $ .48         ,.85        ,  30. ,  8. , 14. /
       DATA (FANDAP( 93,J),J=1,10) /
      $ -1009.5     ,5246.17    ,-10188.02  ,8781.48    ,-2836.03   ,
      $ .7          ,.88        ,  30. ,  8. , 18. /
       DATA (FANDAP( 94,J),J=1,10) /
      $ 5.9446      ,-4.875     ,0.         ,0.         ,0.         ,
      $ .83         ,.91        ,  30. ,  8. , 22. /
       DATA (FANDAP( 95,J),J=1,10) /
      $ 1.055       ,-.7416     ,-2.354     ,5.096      ,-6.699     ,
      $ .12         ,.4         ,  30. , 10. ,  2. /
       DATA (FANDAP( 96,J),J=1,10) /
      $ 1.611       ,-1.705     ,1.163      ,-1.643     ,.7516      ,
      $ .23         ,.7         ,  30. , 10. ,  6. /
       DATA (FANDAP( 97,J),J=1,10) /
      $ .5192       ,9.050      ,-26.525    ,29.287     ,-12.083    ,
      $ .34         ,.9         ,  30. , 10. , 10. /
       DATA (FANDAP( 98,J),J=1,10) /
      $ -9.716      ,71.057     ,-157.856   ,150.679    ,-53.458    ,
      $ .46         ,1.0        ,  30. , 10. , 14. /
       DATA (FANDAP( 99,J),J=1,10) /
      $ -504.715    ,2209.6     ,-3604.36   ,2607.84    ,-706.956   ,
      $ .82         ,1.045      ,  30. , 10. , 18. /
       DATA (FANDAP(100,J),J=1,10) /
      $ -3513.3     ,13939.07   ,-20703.7   ,13672.5    ,-3385.42   ,
      $ .97         ,1.08       ,  30. , 10. , 22. /
       DATA (FANDAP(101,J),J=1,10) /
      $ 1.076       ,-.9295     ,-.3826     ,.4669      ,-.8643     ,
      $ .12         ,.44        ,  30. , 11. ,  2. /
       DATA (FANDAP(102,J),J=1,10) /
      $ 1.555       ,-1.08      ,-.4653     ,.5259      ,-.2670     ,
      $ .24         ,.765       ,  30. , 11. ,  6. /
       DATA (FANDAP(103,J),J=1,10) /
      $ .9216       ,6.142      ,-18.702    ,18.968     ,-7.415     ,
      $ .35         ,.98        ,  30. , 11. , 10. /
       DATA (FANDAP(104,J),J=1,10) /
      $ -18.274     ,109.841    ,-218.930   ,188.787    ,-60.351    ,
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      $ .576        ,1.07        ,  30. , 11. , 14. /
      DATA (FANDAP(105,J),J=1,10) /
      $ -3000.2     ,12053.9     ,-18124.3  ,12096.4    ,-3024.19   ,
      $ .917        ,1.11        ,  30. , 11. , 18. /
      DATA (FANDAP(106,J),J=1,10) /
      $ -39.918     ,78.558      ,-36.938   ,0.0        ,0.0        ,
      $ 1.07        ,1.16        ,  30. , 11. , 22. /
      DATA (FANDAP(107,J),J=1,10) /
      $ 1.032       ,-.2723      ,-3.275    ,5.874      ,-5.731     ,
      $ .125        ,.485        ,  30. , 12. ,  2. /
      DATA (FANDAP(108,J),J=1,10) /
      $ 1.523       ,-.8049      ,-.869     ,.9265      ,-.397      ,
      $ .245        ,.83         ,  30. , 12. ,  6. /
      DATA (FANDAP(109,J),J=1,10) /
      $ 1.151       ,4.199       ,-12.180   ,11.996     ,-4.465     ,
      $ .35         ,1.05        ,  30. , 12. , 10. /
      DATA (FANDAP(110,J),J=1,10) /
      $ -14.005     ,83.829      ,-160.549  ,132.788    ,-40.673    ,
      $ .51         ,1.14        ,  30. , 12. , 14. /
      DATA (FANDAP(111,J),J=1,10) /
      $ -4739.04    ,17939.56    ,-25154.2  ,15654.5    ,-3648.91   ,
      $ .978        ,1.19        ,  30. , 12. , 18. /
      DATA (FANDAP(112,J),J=1,10) /
      $ 1.876       ,-.1865      ,-15.858   ,53.187     ,-69.015    ,
      $ .13         ,.385        ,  40. ,  8. ,  2. /
      DATA (FANDAP(113,J),J=1,10) /
      $ 2.508       ,-2.762      ,6.513     ,-15.566    ,9.394      ,
      $ .225        ,.64         ,  40. ,  8. ,  6. /
      DATA (FANDAP(114,J),J=1,10) /
      $ 1.969       ,6.766       ,-22.052   ,24.257     ,-11.119    ,
      $ .32         ,.83         ,  40. ,  8. , 10. /
      DATA (FANDAP(115,J),J=1,10) /
      $ -6.169      ,63.616      ,-156.602  ,163.373    ,-63.846    ,
      $ .447        ,.91         ,  40. ,  8. , 14. /
      DATA (FANDAP(116,J),J=1,10) /
      $ -5.464      ,55.577      ,-127.737  ,128.57     ,-49.557    ,
      $ .54         ,.96         ,  40. ,  8. , 18. /
      DATA (FANDAP(117,J),J=1,10) /
      $ -191.805    ,955.903     ,-1748.194 ,1419.63    ,-433.33    ,
      $ .675        ,1.0         ,  40. ,  8. , 22. /
      DATA (FANDAP(118,J),J=1,10) /
      $ 1.902       ,.454        ,-11.977   ,27.924     ,-27.683    ,
      $ .14         ,.38         ,  40. , 10. ,  2. /
      DATA (FANDAP(119,J),J=1,10) /
      $ 2.222       ,2.029       ,-2.762    ,10.041     ,-3.528     ,
      $ .253        ,.72         ,  40. , 10. ,  6. /
      DATA (FANDAP(120,J),J=1,10) /
      $ 1.717       ,10.358      ,-31.846   ,35.638     ,-16.245    ,
      $ .367        ,.92         ,  40. , 10. , 10. /
      DATA (FANDAP(121,J),J=1,10) /
      $ -10.728     ,85.651      ,-189.552  ,179.696    ,-63.371    ,
      $ .495        ,1.02        ,  40. , 10. , 14. /
      DATA (FANDAP(122,J),J=1,10) /
      $ -90.812     ,472.054     ,-875.215  ,713.056    ,-216.564   ,
      $ .59         ,1.073       ,  40. , 10. , 18. /
      DATA (FANDAP(123,J),J=1,10) /
      $ -251.346    ,1060.7      ,-1650.93  ,1141.51    ,-296.667   ,
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      $ .80        ,1.127       ,  40. , 10. , 22. /
       DATA (FANDAP(124,J),J=1,10) /
      $ 1.920      ,-1.696      ,3.019       ,-8.274      ,3.907       ,
      $ .14        ,.44         ,  40. , 12. ,  2. /
       DATA (FANDAP(125,J),J=1,10) /
      $ 2.561      ,-1.195      ,.1299       ,-1.262      ,.399        ,
      $ .255       ,.84         ,  40. , 12. ,  6. /
       DATA (FANDAP(126,J),J=1,10) /
      $ .4204      ,17.453      ,-43.184     ,42.370      ,-15.566     ,
      $ .39        ,1.06        ,  40. , 12. , 10. /
       DATA (FANDAP(127,J),J=1,10) /
      $ -11.44     ,75.814      ,-145.248    ,117.676     ,-35.539     ,
      $ .52        ,1.17        ,  40. , 12. , 14. /
       DATA (FANDAP(128,J),J=1,10) /
      $ -7.134     ,51.677      ,-90.389     ,58.768      ,-19.929     ,
      $ .635       ,1.24        ,  40. , 12. , 18. /
       DATA (FANDAP(129,J),J=1,10) /
      $ -448.199   ,1598.46     ,-2115.83    ,1245.43     ,-275.191    ,
      $ .99        ,1.3         ,  40. , 12. , 22. /
       DATA (FANDAP(130,J),J=1,10) /
      $ 1.843      ,-.07846     ,-6.985      ,17.722      ,-17.908     ,
      $ .145       ,.48         ,  40. , 14. ,  2. /
       DATA (FANDAP(131,J),J=1,10) /
      $ 2.525      ,-1.142      ,.7597       ,-2.214      ,1.017       ,
      $ .27        ,.93         ,  40. , 14. ,  6. /
       DATA (FANDAP(132,J),J=1,10) /
      $ .8452      ,13.03       ,-29.085     ,25.619      ,-8.539      ,
      $ .40        ,1.19        ,  40. , 14. , 10. /
       DATA (FANDAP(133,J),J=1,10) /
      $ -3.555     ,39.492      ,-78.853     ,64.69       ,-19.54      ,
      $ .573       ,1.28        ,  40. , 14. , 14. /
       DATA (FANDAP(134,J),J=1,10) /
      $ -39.186    ,178.576     ,-272.955    ,181.609     ,-44.911     ,
      $ .68        ,1.35        ,  40. , 14. , 18. /
       DATA (FANDAP(135,J),J=1,10) /
      $ -118.82    ,406.731     ,-504.396    ,279.236     ,-57.944     ,
      $ .86        ,1.435       ,  40. , 14. , 22. /
       DATA (FANDAP(136,J),J=1,10) /
      $ 4.988      ,-2.081      ,-24.207     ,55.248      ,-45.947     ,
      $ .155       ,.492        ,  60. , 12. ,  4. /
       DATA (FANDAP(137,J),J=1,10) /
      $ 5.529      ,-.2277      ,-27.832     ,50.082      ,-33.077     ,
      $ .195       ,.59         ,  60. , 12. ,  6. /
       DATA (FANDAP(138,J),J=1,10) /
      $ 2.068      ,38.609      ,-157.75     ,240.715     ,-137.116    ,
      $ .235       ,.66         ,  60. , 12. ,  8. /
       DATA (FANDAP(139,J),J=1,10) /
      $ 2.644      ,37.353      ,-146.207    ,215.777     ,-119.45     ,
      $ .28        ,.73         ,  60. , 12. , 10. /
       DATA (FANDAP(140,J),J=1,10) /
      $ -41.668    ,396.76      ,-1195.8     ,1548.1      ,-740.92     ,
      $ .333       ,.744        ,  60. , 12. , 12. /
       DATA (FANDAP(141,J),J=1,10) /
      $ -7.944     ,124.78      ,-369.35     ,456.25      ,-210.91     ,
      $ .397       ,.76         ,  60. , 12. , 14. /
       DATA (FANDAP(142,J),J=1,10) /
      $ -40.774    ,349.5       ,-929.9      ,1076.8      ,-468.43     ,
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      $ .45        ,.76        ,  60. , 12. , 16. /
       DATA (FANDAP(143,J),J=1,10) /
      $ -1619.9    ,9561.7     ,-21439.7   ,21080.3    ,-7758.4    ,
      $ .51        ,.786       ,  60. , 12. , 18. /
       DATA (FANDAP(144,J),J=1,10) /
      $ 4.129      ,-3.795     ,.7758      ,-8.697     ,8.977      ,
      $ .12        ,.48        ,  60. , 16. ,  2. /
       DATA (FANDAP(145,J),J=1,10) /
      $ 4.804      ,-3.225     ,-1.142     ,-3.317     ,2.953      ,
      $ .134       ,.62        ,  60. , 16. ,  4. /
       DATA (FANDAP(146,J),J=1,10) /
      $ 5.296      ,-.8909     ,-9.21      ,8.711      ,-3.366     ,
      $ .202       ,.76        ,  60. , 16. ,  6. /
       DATA (FANDAP(147,J),J=1,10) /
      $ 6.217      ,-3.071     ,-1.696     ,-2.459     ,2.489      ,
      $ .25        ,.76        ,  60. , 16. ,  8. /
       DATA (FANDAP(148,J),J=1,10) /
      $ 5.008      ,14.169     ,-55.056    ,58.651     ,-31.803    ,
      $ .31        ,.93        ,  60. , 16. , 10. /
       DATA (FANDAP(149,J),J=1,10) /
      $ 5.504      ,13.941     ,-45.551    ,47.755     ,-19.574    ,
      $ .356       ,.90        ,  60. , 16. , 12. /
       DATA (FANDAP(150,J),J=1,10) /
      $ -34.30     ,265.14     ,-612.11    ,604.01     ,-220.51    ,
      $ .435       ,.98        ,  60. , 16. , 14. /
       DATA (FANDAP(151,J),J=1,10) /
      $ 25.353     ,-96.07     ,197.51     ,-185.15    ,62.299     ,
      $ .48        ,.91        ,  60. , 16. , 16. /
       DATA (FANDAP(152,J),J=1,10) /
      $ -220.65    ,1153.5     ,-2169.     ,1802.6     ,-562.09    ,
      $ .55        ,.98        ,  60. , 16. , 18. /
       DATA (FANDAP(153,J),J=1,10) /
      $ -390.636   ,841.7      ,-445.22    ,0.0        ,0.0        ,
      $ .95        ,1.0        ,  60. , 16. , 22. /
       DATA (FANDAH(  1,J),J=1,10) /
      $ -93.866    ,983.678    ,-2376.14   ,2520.20    ,-1060.61   ,
      $ 400000.    ,760000.    ,  24. ,  6. ,  6. /
       DATA (FANDAH(  2,J),J=1,10) /
      $ 7.793      ,288.38     ,-481.24    ,349.65     ,-139.86    ,
      $ 400000.    ,860000.    ,  24. ,  6. ,  8. /
       DATA (FANDAH(  3,J),J=1,10) /
      $ -115.79    ,1005.09    ,-1846.07   ,1498.74    ,-486.6     ,
      $ 400000.    ,950000.    ,  24. ,  6. , 10. /
       DATA (FANDAH(  4,J),J=1,10) /
      $ 80.754     ,-163.62    ,729.59     ,-848.42    ,281.73     ,
      $ 400000.    ,1025000.   ,  24. ,  6. , 12. /
       DATA (FANDAH(  5,J),J=1,10) /
      $ 155.98     ,-527.75    ,1464.53    ,-1447.9    ,460.03     ,
      $ 400000.    ,1100000.   ,  24. ,  6. , 14. /
       DATA (FANDAH(  6,J),J=1,10) /
      $ -196.02    ,1138.28    ,-1400.75   ,749.81     ,-163.17    ,
      $ 650000.    ,1180000.   ,  24. ,  6. , 16. /
       DATA (FANDAH(  7,J),J=1,10) /
      $ 205.61     ,-579.29    ,1312.33    ,-1087.12   ,296.36     ,
      $ 500000.    ,1250000.   ,  24. ,  6. , 18. /
       DATA (FANDAH(  8,J),J=1,10) /
      $ 705.77     ,-2402.05   ,3785.21    ,-2521.68   ,601.4      ,
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      $ 800000.   ,1330000.   ,  24. ,  6. , 20. /
       DATA (FANDAH( 9,J),J=1,10) /
      $ 721.32    ,-2194.49   ,3143.5     ,-1889.81   ,405.8      ,
      $ 750000.   ,1400000.   ,  24. ,  6. , 22. /
       DATA (FANDAH( 10,J),J=1,10) /
      $ 177.57    ,-697.3     ,1776.89    ,-2003.05   ,757.58     ,
      $ 400000.   ,780000.    ,  24. ,  8. ,  6. /
       DATA (FANDAH( 11,J),J=1,10) /
      $ 185.52    ,-582.33    ,1372.23    ,-1437.06   ,501.17     ,
      $ 400000.   ,880000.    ,  24. ,  8. ,  8. /
       DATA (FANDAH( 12,J),J=1,10) /
      $ 143.97    ,-192.78    ,439.12     ,-444.8     ,119.46     ,
      $ 400000.   ,970000.    ,  24. ,  8. , 10. /
       DATA (FANDAH( 13,J),J=1,10) /
      $ 169.15    ,-256.19    ,512.11     ,-361.99    ,36.131     ,
      $ 500000.   ,1050000.   ,  24. ,  8. , 12. /
       DATA (FANDAH( 14,J),J=1,10) /
      $ -77.675   ,1050.7     ,-1876.53   ,1567.15    ,-530.3     ,
      $ 500000.   ,1140000.   ,  24. ,  8. , 14. /
       DATA (FANDAH( 15,J),J=1,10) /
      $ 148.08    ,-168.6     ,627.63     ,-604.74    ,160.84     ,
      $ 700000.   ,1240000.   ,  24. ,  8. , 16. /
       DATA (FANDAH( 16,J),J=1,10) /
      $ 142.97    ,-189.66    ,786.1      ,-749.69    ,204.99     ,
      $ 650000.   ,1330000.   ,  24. ,  8. , 18. /
       DATA (FANDAH( 17,J),J=1,10) /
      $ -235.94   ,1539.71    ,-2094.92   ,1360.06    ,-354.31    ,
      $ 900000.   ,1400000.   ,  24. ,  8. , 20. /
       DATA (FANDAH( 18,J),J=1,10) /
      $ -112.66   ,649.65     ,-906.93    ,564.88     ,-163.17    ,
      $ 900000.   ,1400000.   ,  24. ,  8. , 22. /
       DATA (FANDAH( 19,J),J=1,10) /
      $ 22.074    ,483.11     ,-1316.1    ,1603.54    ,-833.33    ,
      $ 400000.   ,780000.    ,  24. , 10. ,  6. /
       DATA (FANDAH( 20,J),J=1,10) /
      $ 58.107    ,431.89     ,-1131.38   ,1196.97    ,-524.48    ,
      $ 400000.   ,880000.    ,  24. , 10. ,  8. /
       DATA (FANDAH( 21,J),J=1,10) /
      $ 112.44    ,139.49     ,-323.24    ,300.12     ,-145.69    ,
      $ 400000.   ,970000.    ,  24. , 10. , 10. /
       DATA (FANDAH( 22,J),J=1,10) /
      $ -100.95   ,1345.91    ,-2651.05   ,2365.19    ,-839.16    ,
      $ 550000.   ,1060000.   ,  24. , 10. , 12. /
       DATA (FANDAH( 23,J),J=1,10) /
      $ -196.47   ,1864.5     ,-3537.84   ,3061.97    ,-1031.47   ,
      $ 580000.   ,1140000.   ,  24. , 10. , 14. /
       DATA (FANDAH( 24,J),J=1,10) /
      $ -436.64   ,2801.51    ,-4681.25   ,3571.12    ,-1051.86   ,
      $ 720000.   ,1250000.   ,  24. , 10. , 16. /
       DATA (FANDAH( 25,J),J=1,10) /
      $ -27.599   ,620.01     ,-768.57    ,558.36     ,-191.62    ,
      $ 650000.   ,1330000.   ,  24. , 10. , 18. /
       DATA (FANDAH( 26,J),J=1,10) /
      $ -752.28   ,3309.25    ,-4177.96   ,2502.21    ,-599.65    ,
      $ 850000.   ,1400000.   ,  24. , 10. , 20. /
       DATA (FANDAH( 27,J),J=1,10) /
      $ -279.88   ,1653.67    ,-2140.73   ,1475.52    ,-414.92    ,
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      $ 900000.    ,1400000.   ,  24. , 10. , 22. /
       DATA (FANDAH( 28,J),J=1,10) /
      $ -59.966    ,641.02     ,-1263.86   ,1123.39    ,-414.92    ,
745   $ 500000.    ,900000.    ,  26. ,  6. ,  6. /
       DATA (FANDAH( 29,J),J=1,10) /
      $ 147.44     ,-436.19    ,915.07     ,-784.62    ,209.79     ,
      $ 500000.    ,990000.    ,  26. ,  6. ,  8. /
       DATA (FANDAH( 30,J),J=1,10) /
750   $ 46.130     ,166.75     ,-282.52    ,272.1      ,-126.46    ,
      $ 500000.    ,1080000.   ,  26. ,  6. , 10. /
       DATA (FANDAH( 31,J),J=1,10) /
      $ 133.94     ,-252.12    ,498.13     ,-354.08    ,67.873     ,
      $ 500000.    ,1180000.   ,  26. ,  6. , 12. /
755    DATA (FANDAH( 32,J),J=1,10) /
      $ 172.97     ,-372.85    ,722.82     ,-517.47    ,114.80     ,
      $ 500000.    ,1270000.   ,  26. ,  6. , 14. /
       DATA (FANDAH( 33,J),J=1,10) /
      $ -.3206     ,452.26     ,-648.81    ,493.49     ,-156.59    ,
760   $ 750000.    ,1350000.   ,  26. ,  6. , 16. /
       DATA (FANDAH( 34,J),J=1,10) /
      $ 130.3      ,-92.296    ,235.95     ,-117.56    ,2.759      ,
      $ 700000.    ,1430000.   ,  26. ,  6. , 18. /
       DATA (FANDAH( 35,J),J=1,10) /
765   $ 162.10     ,-194.34    ,432.03     ,-278.64    ,53.34      ,
      $ 900000.    ,1500000.   ,  26. ,  6. , 20. /
       DATA (FANDAH( 36,J),J=1,10) /
      $ 322.67     ,-447.74    ,423.14     ,-95.091    ,-15.494    ,
      $ 940000.    ,1300000.   ,  26. ,  6. , 22. /
770    DATA (FANDAH( 37,J),J=1,10) /
      $ -350.23    ,2212.31    ,-4250.     ,3636.36    ,-1212.12   ,
      $ 600000.    ,940000.    ,  26. ,  8. ,  6. /
       DATA (FANDAH( 38,J),J=1,10) /
      $ 83.709     ,.7433      ,115.75     ,-152.03    ,23.31      ,
775   $ 600000.    ,1040000.   ,  26. ,  8. ,  8. /
       DATA (FANDAH( 39,J),J=1,10) /
      $ 160.08     ,-245.62    ,483.82     ,-364.34    ,67.599     ,
      $ 600000.    ,1150000.   ,  26. ,  8. , 10. /
       DATA (FANDAH( 40,J),J=1,10) /
780   $ 77.044     ,115.59     ,-11.038    ,-49.109    ,-3.771     ,
      $ 600000.    ,1250000.   ,  26. ,  8. , 12. /
       DATA (FANDAH( 41,J),J=1,10) /
      $ 175.39     ,-257.33    ,533.44     ,-449.33    ,100.18     ,
      $ 600000.    ,1340000.   ,  26. ,  8. , 14. /
785    DATA (FANDAH( 42,J),J=1,10) /
      $ -474.23    ,2189.22    ,-2769.15   ,1597.82    ,-363.64    ,
      $ 840000.    ,1440000.   ,  26. ,  8. , 16. /
       DATA (FANDAH( 43,J),J=1,10) /
      $ 193.58     ,-238.44    ,578.44     ,-479.25    ,100.02     ,
790   $ 600000.    ,1520000.   ,  26. ,  8. , 18. /
       DATA (FANDAH( 44,J),J=1,10) /
      $ -559.84    ,2354.58    ,-2794.35   ,1546.54    ,-335.66    ,
      $ 1050000.   ,1570000.   ,  26. ,  8. , 20. /
       DATA (FANDAH( 45,J),J=1,10) /
795   $ -4347.74   ,13226.42   ,-14504.08  ,7162.39    ,-1342.66   ,
      $ 1150000.   ,1600000.   ,  26. ,  8. , 22. /
       DATA (FANDAH( 46,J),J=1,10) /
      $ -324.08    ,2261.12    ,-4454.17   ,3924.24    ,-1363.64   ,
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      $ 600000.    ,970000.    ,  26. , 11. ,  6. /
      DATA (FANDAH( 47,J),J=1,10) /
      $ 297.49     ,-674.34    ,923.08     ,-453.77    ,0.0        ,
      $ 500000.    ,1080000.   ,  26. , 11. ,  8. /
      DATA (FANDAH( 48,J),J=1,10) /
      $ 165.74     ,-105.07    ,169.48     ,-24.391    ,-71.678    ,
      $ 600000.    ,1190000.   ,  26. , 11. , 10. /
      DATA (FANDAH( 49,J),J=1,10) /
      $ -121.21    ,1158.54    ,-1704.69   ,1170.09    ,-335.11    ,
      $ 600000.    ,1300000.   ,  26. , 11. , 12. /
      DATA (FANDAH( 50,J),J=1,10) /
      $ -34.067    ,818.08     ,-1116.29   ,766.02     ,-230.43    ,
      $ 600000.    ,1390000.   ,  26. , 11. , 14. /
      DATA (FANDAH( 51,J),J=1,10) /
      $ 12.913     ,602.92     ,-670.08    ,415.16     ,-126.02    ,
      $ 600000.    ,1500000.   ,  26. , 11. , 16. /
      DATA (FANDAH( 52,J),J=1,10) /
      $ 223.46     ,-.088      ,80.012     ,1.166      ,-34.965    ,
      $ 600000.    ,1600000.   ,  26. , 11. , 18. /
      DATA (FANDAH( 53,J),J=1,10) /
      $ -3.929     ,1038.49    ,-1360.42   ,847.22     ,-208.33    ,
      $ 1000000.   ,1600000.   ,  26. , 11. , 20. /
      DATA (FANDAH( 54,J),J=1,10) /
      $ -3555.68   ,11081.15   ,-11777.08  ,5652.78    ,-1041.67   ,
      $ 1170000.   ,1600000.   ,  26. , 11. , 22. /
      DATA (FANDAH( 55,J),J=1,10) /
      $ 32.976     ,97.99      ,-185.86    ,213.99     ,-116.55    ,
      $ 500000.    ,1020000.   ,  28. ,  6. ,  6. /
      DATA (FANDAH( 56,J),J=1,10) /
      $ 80.295     ,-71.86     ,154.45     ,-110.7     ,11.083     ,
      $ 500000.    ,1110000.   ,  28. ,  6. ,  8. /
      DATA (FANDAH( 57,J),J=1,10) /
      $ 85.09      ,-39.55     ,76.619     ,-26.452    ,-17.992    ,
      $ 500000.    ,1220000.   ,  28. ,  6. , 10. /
      DATA (FANDAH( 58,J),J=1,10) /
      $ 163.79     ,-352.71    ,588.45     ,-352.27    ,56.818     ,
      $ 730000.    ,1330000.   ,  28. ,  6. , 12. /
      DATA (FANDAH( 59,J),J=1,10) /
      $ -30.521    ,391.0      ,-386.5     ,205.0      ,-55.028    ,
      $ 500000.    ,1450000.   ,  28. ,  6. , 14. /
      DATA (FANDAH( 60,J),J=1,10) /
      $ 522.91     ,-1352.27   ,1663.48    ,-841.6     ,145.26     ,
      $ 1030000.   ,1560000.   ,  28. ,  6. , 16. /
      DATA (FANDAH( 61,J),J=1,10) /
      $ 744.29     ,-1005.79   ,2170.      ,-1022.22   ,166.67     ,
      $ 1000000.   ,1630000.   ,  28. ,  6. , 18. /
      DATA (FANDAH( 62,J),J=1,10) /
      $ 550.31     ,-1015.79   ,914.44     ,-298.92    ,21.461     ,
      $ 1250000.   ,1700000.   ,  28. ,  6. , 20. /
      DATA (FANDAH( 63,J),J=1,10) /
      $ -190.67    ,1135.05    ,-1362.37   ,760.4      ,-159.66    ,
      $ 1280000.   ,1760000.   ,  28. ,  6. , 22. /
      DATA (FANDAH( 64,J),J=1,10) /
      $ -51.432    ,688.46     ,-1396.44   ,1273.01    ,-461.14    ,
      $ 500000.    ,1050000.   ,  28. ,  8. ,  6. /
      DATA (FANDAH( 65,J),J=1,10) /
      $ 27.126     ,271.6      ,-455.18    ,381.06     ,-143.86    ,
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      $ 530000.    ,1180000.   ,  28. ,  8. ,  8. /
       DATA (FANDAH( 66,J),J=1,10) /
      $ 157.28     ,-318.65    ,623.34     ,-446.78    ,91.05      ,
      $ 550000.    ,1280000.   ,  28. ,  8. , 10. /
       DATA (FANDAH( 67,J),J=1,10) /
      $ 297.63     ,-873.87    ,1501.18    ,-1021.21   ,231.07     ,
      $ 650000.    ,1400000.   ,  28. ,  8. , 12. /
       DATA (FANDAH( 68,J),J=1,10) /
      $ 177.36     ,-395.03    ,889.58     ,-672.74    ,160.98     ,
      $ 600000.    ,1540000.   ,  28. ,  8. , 14. /
       DATA (FANDAH( 69,J),J=1,10) /
      $ 79.603     ,-25.755    ,395.79     ,-348.17    ,80.492     ,
      $ 900000.    ,1600000.   ,  28. ,  8. , 16. /
       DATA (FANDAH( 70,J),J=1,10) /
      $ 250.75     ,-520.49    ,949.34     ,-600.17    ,122.38     ,
      $ 930000.    ,1700000.   ,  28. ,  8. , 18. /
       DATA (FANDAH( 71,J),J=1,10) /
      $ 311.62     ,-376.48    ,398.49     ,-114.14    ,-4.087     ,
      $ 1200000.   ,1750000.   ,  28. ,  8. , 20. /
       DATA (FANDAH( 72,J),J=1,10) /
      $ -237.36    ,1167.2     ,-1145.64   ,581.78     ,-120.54    ,
      $ 1250000.   ,1770000.   ,  28. ,  8. , 22. /
       DATA (FANDAH( 73,J),J=1,10) /
      $ -13.151    ,483.04     ,-828.15    ,703.03     ,-274.70    ,
      $ 500000.    ,1050000.   ,  28. ,  9. ,  6. /
       DATA (FANDAH( 74,J),J=1,10) /
      $ 102.65     ,7.178      ,38.104     ,39.954     ,-66.374    ,
      $ 500000.    ,1290000.   ,  28. ,  9. , 10. /
       DATA (FANDAH( 75,J),J=1,10) /
      $ 125.18     ,-50.934    ,318.54     ,-250.86    ,51.636     ,
      $ 600000.    ,1570000.   ,  28. ,  9. , 14. /
       DATA (FANDAH( 76,J),J=1,10) /
      $ 183.11     ,-95.277    ,404.55     ,-307.01    ,61.861     ,
      $ 950000.    ,1770000.   ,  28. ,  9. , 18. /
       DATA (FANDAH( 77,J),J=1,10) /
      $ -7314.5    ,19307.41   ,-18251.29  ,7656.64    ,-1207.28   ,
      $ 1250000.   ,1770000.   ,  28. ,  9. , 22. /
       DATA (FANDAH( 78,J),J=1,10) /
      $ 1415.94    ,-8770.24   ,21005.05   ,-22060.6   ,8484.84    ,
      $ 500000.    ,830000.    ,  28. , 10. ,  2. /
       DATA (FANDAH( 79,J),J=1,10) /
      $ -88.9      ,810.41     ,-1370.82   ,1144.03    ,-422.      ,
      $ 550000.    ,1070000.   ,  28. , 10. ,  6. /
       DATA (FANDAH( 80,J),J=1,10) /
      $ 131.94     ,-73.089    ,191.55     ,-68.245    ,-48.205    ,
      $ 570000.    ,1320000.   ,  28. , 10. , 10. /
       DATA (FANDAH( 81,J),J=1,10) /
      $ 224.08     ,-284.12    ,540.09     ,-336.88    ,55.138     ,
      $ 500000.    ,1580000.   ,  28. , 10. , 14. /
       DATA (FANDAH( 82,J),J=1,10) /
      $ 713.7      ,-1798.52   ,2459.26    ,-1336.48   ,259.29     ,
      $ 850000.    ,1770000.   ,  28. , 10. , 18. /
       DATA (FANDAH( 83,J),J=1,10) /
      $ -1153.75   ,4181.1     ,-4529.62   ,2243.76    ,-426.4     ,
      $ 1200000.   ,1770000.   ,  28. , 10. , 22. /
       DATA (FANDAH( 84,J),J=1,10) /
      $ 1151.37    ,-6675.67   ,14912.2    ,-14463.5   ,5109.47    ,
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      $ 500000.    ,860000.    ,  28. , 12. ,  2. /
       DATA (FANDAH( 85,J),J=1,10) /
      $ -257.57    ,1727.79    ,-2934.3    ,2274.14    ,-724.96    ,
      $ 550000.    ,1180000.   ,  28. , 12. ,  6. /
       DATA (FANDAH( 86,J),J=1,10) /
      $ 90.637     ,287.08     ,-415.77    ,341.86     ,-146.78    ,
      $ 570000.    ,1340000.   ,  28. , 12. , 10. /
       DATA (FANDAH( 87,J),J=1,10) /
      $ 454.87     ,-1066.     ,1726.52    ,-1108.2    ,233.1      ,
      $ 500000.    ,1630000.   ,  28. , 12. , 14. /
       DATA (FANDAH( 88,J),J=1,10) /
      $ 553.85     ,-920.47    ,1271.64    ,-674.16    ,108.39     ,
      $ 650000.    ,1770000.   ,  28. , 12. , 18. /
       DATA (FANDAH( 89,J),J=1,10) /
      $ 71.003     ,-131.14    ,292.2      ,-268.88    ,66.078     ,
      $ 500000.    ,920000.    ,  30. ,  8. ,  2. /
       DATA (FANDAH( 90,J),J=1,10) /
      $ .6823      ,399.64     ,-784.08    ,705.5      ,-243.37    ,
      $ 500000.    ,1220000.   ,  30. ,  8. ,  6. /
       DATA (FANDAH( 91,J),J=1,10) /
      $ 140.32     ,-267.88    ,605.71     ,-460.68    ,109.65     ,
      $ 500000.    ,1490000.   ,  30. ,  8. , 10. /
       DATA (FANDAH( 92,J),J=1,10) /
      $ 223.24     ,-353.83    ,529.46     ,-270.74    ,40.306     ,
      $ 500000.    ,1770000.   ,  30. ,  8. , 14. /
       DATA (FANDAH( 93,J),J=1,10) /
      $ -469.74    ,1952.01    ,-2176.9    ,1114.75    ,-216.07    ,
      $ 1000000.   ,1770000.   ,  30. ,  8. , 18. /
       DATA (FANDAH( 94,J),J=1,10) /
      $ -2790.78   ,7918.48    ,-7719.83   ,3355.91    ,-546.08    ,
      $ 1400000.   ,1770000.   ,  30. ,  8. , 22. /
       DATA (FANDAH( 95,J),J=1,10) /
      $ -2116.64   ,11988.3    ,-24400.    ,21818.2    ,-7272.73   ,
      $ 600000.    ,940000.    ,  30. , 10. ,  2. /
       DATA (FANDAH( 96,J),J=1,10) /
      $ -135.27    ,1062.      ,-1749.98   ,1364.18    ,-420.48    ,
      $ 600000.    ,1260000.   ,  30. , 10. ,  6. /
       DATA (FANDAH( 97,J),J=1,10) /
      $ 70.014     ,279.3      ,-479.95    ,404.31     ,-128.79    ,
      $ 600000.    ,1530000.   ,  30. , 10. , 10. /
       DATA (FANDAH( 98,J),J=1,10) /
      $ 48.586     ,424.58     ,-556.3     ,368.77     ,-94.019    ,
      $ 600000.    ,1870000.   ,  30. , 10. , 14. /
       DATA (FANDAH( 99,J),J=1,10) /
      $ 1838.82    ,-4736.59   ,5146.6     ,-2386.56   ,400.67     ,
      $ 1110000.   ,1870000.   ,  30. , 10. , 18. /
       DATA (FANDAH(100,J),J=1,10) /
      $ 3840.5     ,-8553.07   ,7718.76    ,-3055.38   ,449.55     ,
      $ 1440000.   ,1870000.   ,  30. , 10. , 22. /
       DATA (FANDAH(101,J),J=1,10) /
      $ 573.86     ,-2682.76   ,5269.32    ,-4489.9    ,1363.64    ,
      $ 600000.    ,950000.    ,  30. , 11. ,  2. /
       DATA (FANDAH(102,J),J=1,10) /
      $ 104.31     ,-77.393    ,160.7      ,-29.672    ,-47.348    ,
      $ 600000.    ,1280000.   ,  30. , 11. ,  6. /
       DATA (FANDAH(103,J),J=1,10) /
      $ -156.28    ,1106.85    ,-1431.07   ,844.31     ,-197.5     ,
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970          $ 600000.   ,1560000.  ,  30. , 11. , 10. /
              DATA (FANDAH(104,J),J=1,10) /
             $ 108.35    ,142.38    ,-19.234   ,-15.095   ,-2.55    ,
             $ 700000.   ,1870000.  ,  30. , 11. , 14. /
              DATA (FANDAH(105,J),J=1,10) /
975          $ 1252.38   ,-3070.33  ,3409.94   ,-1571.34  ,255.69   ,
             $ 1040000.  ,1870000.  ,  30. , 11. , 18. /
              DATA (FANDAH(106,J),J=1,10) /
             $ 6428.32   ,-14958.5  ,13695.    ,-5504.54  ,821.78   ,
             $ 1450000.  ,1870000.  ,  30. , 11. , 22. /
980           DATA (FANDAH(107,J),J=1,10) /
             $ -58.06    ,308.5     ,102.27    ,-616.16   ,303.03   ,
             $ 600000.   ,950000.   ,  30. , 12. ,  2. /
              DATA (FANDAH(108,J),J=1,10) /
             $ -272.65   ,1420.3    ,-1840.91  ,1030.3    ,-227.27  ,
985          $ 600000.   ,1290000.  ,  30. , 12. ,  6. /
              DATA (FANDAH(109,J),J=1,10) /
             $ -107.44   ,844.15    ,-980.16   ,527.      ,-119.46  ,
             $ 600000.   ,1580000.  ,  30. , 12. , 10. /
              DATA (FANDAH(110,J),J=1,10) /
990          $ 172.04    ,-76.343   ,334.05    ,-244.14   ,48.077   ,
             $ 700000.   ,1870000.  ,  30. , 12. , 14. /
              DATA (FANDAH(111,J),J=1,10) /
             $ 867.44    ,-1854.72  ,2097.31   ,-952.54   ,148.6    ,
             $ 1050000.  ,1870000.  ,  30. , 12. , 18. /
995           DATA (FANDAH(112,J),J=1,10) /
             $ 642.55    ,-1667.56  ,1862.59   ,-928.03   ,170.45   ,
             $ 1000000.  ,1620000.  ,  40. ,  8. ,  2. /
              DATA (FANDAH(113,J),J=1,10) /
             $ -234.9    ,936.78    ,-837.06   ,339.56    ,-55.0    ,
1000         $ 1000000.  ,2160000.  ,  40. ,  8. ,  6. /
              DATA (FANDAH(114,J),J=1,10) /
             $ 59.02     ,212.2     ,-81.972   ,14.603    ,-2.878   ,
             $ 1000000.  ,2570000.  ,  40. ,  8. , 10. /
              DATA (FANDAH(115,J),J=1,10) /
1005         $ 420.1     ,-458.47   ,450.55    ,-159.26   ,18.324   ,
             $ 1200000.  ,3040000.  ,  40. ,  8. , 14. /
              DATA (FANDAH(116,J),J=1,10) /
             $ 502.08    ,-434.25   ,352.15    ,-95.755   ,7.843    ,
             $ 1700000.  ,3320000.  ,  40. ,  8. , 18. /
1010          DATA (FANDAH(117,J),J=1,10) /
             $ -256.24   ,1014.48   ,-557.16   ,149.48    ,-15.597  ,
             $ 2200000.  ,3550000.  ,  40. ,  8. , 22. /
              DATA (FANDAH(118,J),J=1,10) /
             $ 2870.11   ,-7688.44  ,3325.59   ,-3609.81  ,625.0    ,
1015         $ 1200000.  ,1700000.  ,  40. , 10. ,  2. /
              DATA (FANDAH(119,J),J=1,10) /
             $ -904.43   ,2572.63   ,-2225.35  ,866.9     ,-130.21  ,
             $ 1200000.  ,2260000.  ,  40. , 10. ,  6. /
              DATA (FANDAH(120,J),J=1,10) /
1020         $ 29.548    ,465.32    ,-341.49   ,132.62    ,-22.035  ,
             $ 1200000.  ,2740000.  ,  40. , 10. , 10. /
              DATA (FANDAH(121,J),J=1,10) /
             $ -555.9    ,1461.13   ,-834.02   ,221.53    ,-23.765  ,
             $ 1270000.  ,3180000.  ,  40. , 10. , 14. /
1025          DATA (FANDAH(122,J),J=1,10) /
             $ 621.15    ,-428.07   ,299.22    ,-60.185   ,1.457    ,
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      $ 1800000.  ,3460000.  ,  40. , 10. , 18. /
       DATA (FANDAH(123,J),J=1,10) /
      $ 9055.63   ,-11236.6  ,5513.37   ,-1173.03  ,91.146    ,
1030  $ 2500000.  ,3740000.  ,  40. , 10. , 22. /
       DATA (FANDAH(124,J),J=1,10) /
      $ -230.79   ,658.96    ,-336.11   ,37.037    ,0.0       ,
      $ 1200000.  ,1720000.  ,  40. , 12. ,  2. /
       DATA (FANDAH(125,J),J=1,10) /
1035  $ -234.45   ,908.1     ,-574.52   ,157.2     ,-18.939   ,
      $ 1200000.  ,2330000.  ,  40. , 12. ,  6. /
       DATA (FANDAH(126,J),J=1,10) /
      $ -151.19   ,779.21    ,-444.03   ,119.08    ,-14.569   ,
      $ 1200000.  ,2830000.  ,  40. , 12. , 10. /
1040   DATA (FANDAH(127,J),J=1,10) /
      $ 543.7     ,-459.81   ,452.62    ,-152.95   ,16.208    ,
      $ 1300000.  ,3270000.  ,  40. , 12. , 14. /
       DATA (FANDAH(128,J),J=1,10) /
      $ 1111.47   ,-1181.9   ,794.01    ,-202.17   ,16.754    ,
1045  $ 1850000.  ,3610000.  ,  40. , 12. , 18. /
       DATA (FANDAH(129,J),J=1,10) /
      $ -13201.1  ,17641.5   ,-8397.4   ,1786.5    ,-143.23   ,
      $ 2540000.  ,3750000.  ,  40. , 12. , 22. /
       DATA (FANDAH(130,J),J=1,10) /
1050  $ -6179.5   ,17637.9   ,-18314.6  ,8430.56   ,-1458.33  ,
      $ 1200000.  ,1730000.  ,  40. , 14. ,  2. /
       DATA (FANDAH(131,J),J=1,10) /
      $ 227.15    ,112.24    ,-105.4    ,60.29     ,-16.572   ,
      $ 1200000.  ,2330000.  ,  40. , 14. ,  6. /
1055   DATA (FANDAH(132,J),J=1,10) /
      $ 181.38    ,234.11    ,-57.838   ,4.7284    ,-1.093    ,
      $ 1200000.  ,2870000.  ,  40. , 14. , 10. /
       DATA (FANDAH(133,J),J=1,10) /
      $ -103.26   ,946.19    ,-428.34   ,105.65    ,-11.837   ,
1060  $ 1270000.  ,3360000.  ,  40. , 14. , 14. /
       DATA (FANDAH(134,J),J=1,10) /
      $ 754.94    ,-702.92   ,618.55    ,-182.21   ,16.936    ,
      $ 1920000.  ,3720000.  ,  40. , 14. , 18. /
       DATA (FANDAH(135,J),J=1,10) /
1065  $ 1717.77   ,-1161.5   ,466.83    ,-55.358   ,-.8156    ,
      $ 2640000.  ,3750000.  ,  40. , 14. , 22. /
       DATA (FANDAH(136,J),J=1,10) /
      $ -27.579   ,253.49    ,-106.3    ,21.961    ,-2.126    ,
      $ 2000000.  ,4250000.  ,  60. , 12. ,  4. /
1070   DATA (FANDAH(137,J),J=1,10) /
      $ -15.899   ,293.64    ,-122.47   ,25.347    ,-2.262    ,
      $ 2000000.  ,4750000.  ,  60. , 12. ,  6. /
       DATA (FANDAH(138,J),J=1,10) /
      $ 253.5     ,-26.009   ,41.5      ,-9.273    ,.4242     ,
1075  $ 2000000.  ,5220000.  ,  60. , 12. ,  8. /
       DATA (FANDAH(139,J),J=1,10) /
      $ 218.06    ,37.044    ,28.83     ,-8.833    ,.5606     ,
      $ 2000000.  ,5650000.  ,  60. , 12. , 10. /
       DATA (FANDAH(140,J),J=1,10) /
1080  $ 417.      ,-96.1665  ,67.171    ,-11.709   ,.5361     ,
      $ 2250000.  ,5170000.  ,  60. , 12. , 12. /
       DATA (FANDAH(141,J),J=1,10) /
      $ -750.05   ,915.56    ,-243.21   ,30.626    ,-1.576    ,
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```
      $ 3230000.  ,6700000.  ,  60. , 12. , 14. /
      DATA (FANDAH(142,J),J=1,10) /
      $ -1403.86  ,1518.16   ,-419.53   ,53.4      ,-2.615    ,
      $ 4100000.  ,7000000.  ,  60. , 12. , 16. /
      DATA (FANDAH(143,J),J=1,10) /
      $ 2257.4    ,-1224.36  ,330.671   ,-36.      ,1.33      ,
      $ 4500000.  ,7000000.  ,  60. , 12. , 18. /
      DATA (FANDAH(144,J),J=1,10) /
      $ -135.98   ,544.46    ,-304.18   ,79.677    ,-8.757    ,
      $ 2000000.  ,3700000.  ,  60. , 16. ,  2. /
      DATA (FANDAH(145,J),J=1,10) /
      $ -75.05    ,442.02    ,-203.89   ,41.82     ,-3.658    ,
      $ 2000000.  ,4250000.  ,  60. , 16. ,  4. /
      DATA (FANDAH(146,J),J=1,10) /
      $ 70.414    ,251.15    ,-86.013   ,14.616    ,-1.285    ,
      $ 2000000.  ,4650000.  ,  60. , 16. ,  6. /
      DATA (FANDAH(147,J),J=1,10) /
      $ -94.021   ,440.34    ,-147.35   ,24.961    ,-1.903    ,
      $ 2700000.  ,5250000.  ,  60. , 16. ,  8. /
      DATA (FANDAH(148,J),J=1,10) /
      $ -20.122   ,394.28    ,-107.34   ,14.133    ,-.9016    ,
      $ 2000000.  ,5930000.  ,  60. , 16. , 10. /
      DATA (FANDAH(149,J),J=1,10) /
      $ 502.59    ,-132.89   ,102.98    ,-19.495   ,1.03      ,
      $ 3170000.  ,6370000.  ,  60. , 16. , 12. /
      DATA (FANDAH(150,J),J=1,10) /
      $ 390.34    ,84.842    ,12.235    ,-3.344    ,.0746     ,
      $ 2500000.  ,7000000.  ,  60. , 16. , 14. /
      DATA (FANDAH(151,J),J=1,10) /
      $ -1499.49  ,1558.69   ,-401.72   ,48.621    ,-2.345    ,
      $ 4700000.  ,7000000.  ,  60. , 16. , 16. /
      DATA (FANDAH(152,J),J=1,10) /
      $ 5636.16   ,-3754.3   ,1080.28   ,-133.41   ,6.        ,
      $ 4200000.  ,7000000.  ,  60. , 16. , 18. /
      DATA (FANDAH(153,J),J=1,10) /
      $ 1251.03   ,-90.429   ,13.143    ,0.0       ,0.0       ,
      $ 5250000.  ,7000000.  ,  60. , 16. , 22. /
      DATA PI /3.14159265/
      DATA TAN8 /.1405/, TAN19/.344/, HB/5./
C
C          SPECIFIC VOLUME OF AIR LEAVING THE HEAT EXCHANGER AT THE
C          ELEVATION SPECIFIED FOR THE PLANT
C
      BARLN=3.39853-3.81835E-5*ELEV
      BAR=EXP(BARLN)
      SPVOL=(T4+459.67)/1.325/BAR
C
C          TOTAL VOLUMETRIC FLOW RATE OF THE FAN SYSTEM
C
      TOTCFM=W4*SPVOL/60.
      AFC=5.E08
      AC=0.
      AHP=0.
      ADIA=0.
      ABLN=0.
      AVELE=0.
      IF(LFE.LT.1) LFE = 153
```

```
      IF(LFB.LT.1) LFB = 1
C
C          START OF ITERATIVE LOOP FOR DETERMINING THE OPTIMUM FAN
C          SYSTEM
C
      DO 400 I=LFB,LFE
C
C          INITIALIZATION OF FAN OPTIMIZATION PARAMETERS
C
      TP=0.
      RCFMPF=0.
      CFMPF=0.
      NOF=0
      HPPF=0.
      TOTHP=0.
      FCST=0.
      CMOT=0.
      CSR=0.
      CPL=0.
      TCSTPF=0.
      TCSTF=0.
      VEL=0.
      CINC=80000.
      CFM=400000.
      FLOVP=0.
      TP=0.
      DF=0.
      CI=0.
C
C          CROSS-SECTIONAL FLOW AREA FOR THE FAN DEPENDING ON THE FAN
C          DIAMETER
C
      IF(I.LE.27) A=429.08
      IF(I.GT.27.AND.I.LE.54) A=495.96
      IF(I.GT.54.AND.I.LE.88) A=584.5
      IF(I.GT.88.AND.I.LE.111) A=658.37
      IF(I.GT.111.AND.I.LE.135) A=1123.91
      IF(I.GT.135) A=2680.4
C
C          DETERMINE THE NUMBER FANS, THE VOLUMETRIC FLOW RATE THROUGH
C          EACH FAN, AND THE TOTAL PRESSURE DROP ACROSS EACH FAN
C
      K=0
   50 CONTINUE
      K=K+1
      IF(K.GT.100) GO TO 59
C
C          THE PRESSURE DIFFERENTIAL ACROSS EACH FAN IS DEPENDENT UPON
C          THE METHOD OF AIR DISCHARGE FROM THE FAN, WITH OR WITHOUT
C          VELOCITY RECOVERY STACKS
C          VELREC=0        NO VELOCITY RECOVERY
C          VELREC=1        VELOCITY RECOVERY
C
C          THE VELOCITY RECOVERY IS BASED ON 13 FT HIGH STACKS WITH
C          8 DEGREE SIDESAND FOR A 28 FT DIAMETER FAN THE EFFECTIVE-
C          NESS OF THE STACK HAS BEEN TAKEN TO BE 80 PERCENT
C
```

```
C          AIR VELOCITY EXCITING THE FAN OR STACK
      IF(VELREC.EQ. 0.) VEL=CFM/60./A
      FAND = FANDAP(I,8)
      IF(VELREC.EQ.1.) VEL=CFM/60./(FAND**2.*13./28.*FAND*.14054)**2*4./
     *3.1416
      FLOVP=CFM/1000000.
      IF(VELREC.EQ. 0.)  VP=VEL**2/4452.852
      IF(VELREC.EQ. 1.)  VP=0.2*((CFM/60./A)**2/4452.852+4.*VEL**2/4452.
     *852)
C
C          TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN
      TP=DPTINW*.07495*SPVOL+VP
C
C          CHECK IF PRESSURE DIFFERENTIAL AND VOLUMETRIC FLOW RATE ARE
C          WITHIN SPECIFIED LIMITS
      IF(TP.GT.FANDAP(I,7)) GO TO 62
      IF(CFM.GT.FANDAH(I,7)) GO TO 54
      IF(CFM.LT.FANDAH(I,6)) GO TO 55
      IF(TP.LT.FANDAP(I,6)) GO TO 55
      IF(VP.GT.FANDAP(I,6)) GO TO 54
C
C          CALCULATION OF VOLUMETRIC FLOW RATE THROUGH THE FAN FOR THE
C          SPECIFIED PRESSURE DIFFERENTIAL ACROSS THE FAN
      RCFMPF=FANDAP(I,1)+FANDAP(I,2)*TP+FANDAP(I,3)*TP**2+FANDAP(I,4)*
     *TP**3+FANDAP(I,5)*TP**4
C
C          SELECTION OF A VOLUMETRIC FLOW RATE TO CLOSER MATCH THE
C          REQUIRED PRESSURE DIFFERENTIAL ACROSS THE FAN
      DF=RCFMPF-FLOVP
      IF(ABS(DF).LE.0.01) GO TO 57
      CI=1.+DF/RCFMPF
      IF(CI.GT.1..AND.CI*CFM.GT.(CFM+CINC)) GO TO 55
      IF(CI.LT.1..AND.CI*CFM.LT.(CFM-CINC)) GO TO 54
      CFM=CFM*CI
      GO TO 50
   55 CFM=CFM+CINC
      GO TO 50
   54 CFM=CFM-CINC
      GO TO 50
   59 CONTINUE
      GO TO 400
   62 CONTINUE
      GO TO 400
   57 CFMPF=RCFMPF*1000000.
C
C          CALCULATION OF THE NUMBER OF FANS IN THE FAN SYSTEM
C
      NOF=TOTCFM/CFMPF
      IF(CFMPF.LT.FANDAH(I,6).OR.CFMPF.GT.FANDAH(I,7)) GO TO 400
      HPPF=FANDAH(I,1)+FANDAH(I,2)*RCFMPF+FANDAH(I,3)*RCFMPF**2+FANDAH(I
     *,4)*RCFMPF**3+FANDAH(I,5)*RCFMPF**4
      HPPF=HPPF/.07495/SPVOL
C
C          CALCULATION OF HORSEPOWER REQUIREMENTS OF EACH FAN
C
       HPPF = HPPF/GBEFF
C
```

```
C          CALCULATION OF THE NUMBER OF CIRCULAR TOWERS BASED ON AN
C          ALLOWABLE FAN PACKING FACTOR
C
      TOWN = (WIDTH * COANG /(PI * FANDAP(I,8))) **2 / (NOF * PFACT)
      ITOWN = TOWN
      IF (ITOWN .LT. ITMIN) GOTO 400
      IF (ITOWN .GT. ITMAX) GOTO 400
C
C          CALCULATION OF THE DIAMETER OF THE TOWERS
      DTOW = WIDTH * COANG /(PI * ITOWN)
C
C          FAN ELECTRICAL WIRING COSTS
C
      VM=2300.
      IF (HPPF .LT. 250.) VM = 480.
      IF(HPPF .GT. 2000.) VM = 6900.
      DPTTWR = DIST
      DTTSG = DTOW / 4. *(ITOWN*(3./2.) + 1.)
      DSGTM = DTOW / 2.  + DTTSG / 2.
      IF(HPPF .LT. 251.) TRMA = 225000./NOF + 7.88*HPPF + (116. - .159
     $                  * HPPF) * HPPF
      IF (HPPF .GE. 251.) TRMA =225000./NOF + 7.88*HPPF +
     $                    870./SQRT(HPPF) *HPPF
      VS = 7200.
      IF (HPPF .LT. 2000.) VS = 13800.
      TRMB = (DPTTWR+DTTSG-1000.) * (37. + .47*HPPF*NOF/ SQRT(VS)
     $ + .5 * NOF) / NOF
      TRMC = (100. + 1.1*HPPF) * (DSGTM-250.) / SQRT(VM)
      CSR = HPPF * 55. + HPPF** 1.5 + 1000.
      FANLEC = TRMA + TRMB + TRMC
C
C          FAN MOTOR COSTS
C
      FMC = 26.62
      IF (HPPF .GT. 300.) FMC = 24.33
      BIGMC = 0.0
      IF (HPPF .GT. 300.) BIGMC = 8000.
      CMOT = HPPF * FMC + BIGMC
C
C          TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM
C
   70 TOTHP=HPPF*NOF
C
C          CAPITAL COSTS OF THE FAN
C
      IF(I.LT.88)FCST=FANDAP(I,9)*(22.4*FANDAP(I,8)-60.)+19.2*FANDAP(I,8
     *)
      IF(I.GE.88)FCST=FANDAP(I,9)*(51.2*FANDAP(I,8)-950.)+136.6*FANDAP(I
     *,8)-2700.
      EFCSF = 1.05
      FCST = FCST * EFCSF
      SAAFI = 1.15
      HFR = 13. / 28. * FAND
C
C          STACK COSTS WITH VELOCITY RECOVERY
      IF(VELREC.EQ.1.) CFROS= UCS * U S * PI * (FAND+HFR*TAN8) * HFR
     $                          * SQRT(1. + TAN8**2)
```

```
     $                                  + UCS * UWS * PI * (FAND+HB*TAN19) * HB
     $                                  * SQRT(1. + TAN19**2)
C
C          STACK COSTS WITH OUT VELOCITY RECOVERY
      IF(VELDEC .EQ.0.) CFROS = CVM * WFV * PI * FAND**2 / 6.
     $                                  + UCS * UWS * PI *(FAND + HB * TAN19) * HB
     $                                  * SQRT(1. + TAN19**2)
C
C          INCREASING THE FAN COSTS TO TAKE INTO ACCOUNT FOR SHIPPING
C          AND ASSEMBLY OF FAN SYSTEM COMPONENTS
      CFROS = CFROS * SAAF * POHFAN
      FCST = POHFAN * SAAF * FCST
      CSR  = POHFAN * SAAF * CSR
      CMOT = CMOT * POHFAN * SAAF
      FANLEC = FANLEC * POHLEC
C
C          TOTAL CAPITAL COST OF THE FAN SYSTEM
      TCSTPF = FCST + CMOT + CSR + FANLEC + CFROS
      TCSTF = TCSTPF * NOF
C
C          ANNUAL COST OF THE FAN SYSTEM
C
      ANFCOS=(TCSTF+TOTHP**.7457*PLANC)*FCR+EHR*FCOS/10**.8*TOTHP*
     $.7457*CAPF*8760.
C
C          COST OF PLENUM
C
      CPL = CPM * WPL *(ITOWN * PI/4. * DTOW**2 - NOF * PI/4.*(FAND*3.5)
     $ **2)
      CPL=CPL * POHSTC
C
C          STRUCTURAL AND FOUNDATION COSTS OF THE CIRCULAR TOWER
C
      STRUCC = .2458 * (PI*DTOW**2/4.) * ELENG * ITOWN
     $          * (.00685 * ROOFL + .726)
      STRUCC = STRUCC * POHSTC
      FNDC = .019 * (WHX+WATERW) + .82*(PI/4.)*DTOW**2*ITOWN
      FNDC = FNDC * POHSTC
C
C          ANNUAL FAN, STRUCTURAL AND FOUNDATION COSTS
C
      ANSFPC = (CPL + STRUCC + FNDC) * FCR
      ANSFPF = ANSFPC + ANFCOS
C
C          STORAGE OF DESIGN PARAMETERS FOR THE LEAST COST FAN SYSTEM TO
C          TO BE PRINTED OUT BY THE SUBROUTINE RPTFAN
C
  150 IF (ANSFPF .GT. AFC) GOTO 400
      AFC = ANSFPF
      AFCH = ANFCOS
      AC=TCSTF
      AHP=TOTHP
      ADIA=FANDAP(I,8)
      ABLN=FANDAP(I,9)
      BLDANG=FANDAP(I,10)
      XNFAN=NOF
      NUMTOW = ITOWN
```

```
      CTOWD = DTOW
      AVEL=VEL
      CFPERF=CFMPF
      HPPERF=HPPF
      TOTCF=TOTCFM
      FBCPF = FCST
      FMCPF = CMOT + CSR
      CPLEN=CPL
      CYLRNG = CFROS
      HPAIR=TOTHP
      FROW=TOTHP/1.341
      DPFEL=(VP/(.07495*SPVOL))*5.2022
      DPHX = DPTINW * 5.2021B / 144.
      HUBDIA = SQRT (ADIA**2 - 4.*A/3.14159)
      TCTPF = TCSTPF
      FDCPF = FCST
      FMTRC = CMOT
      ACCTTP= (DPTINW + VP/(.07495*SPVOL)) * 5.2018/144.
      CFANEL = FANLEC
      ADJTP = TP * 5.20218/144.
      ACTBPD = DPHX
      ADJBPD = DPHX * .07495*SPVOL
      ACTVH = DPFEL/144.
      ADJVH = VP * 5.2021B / 144.
      ADJPPF = HPPF * SPVOL * .07405
      THPAIR = HPAIR
      TCTFL = AC
      AFCST = AFCH
      CSRD = CSR
  400 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FRICHO(FAIR,HO,ODL,XW,XD,XDG,GAIR,I)
C
C     THIS VARIATION TO SUBROUTINE FRICHO CALCULATES THE
C     FRICTION FACTOR AND HEAT TRANSFER COEFFICIENT FOR AIR FLOW
C     THROUGH A BANK OF PLASTIC HEAT EXCHANGER TUBES.
C
C     DEFINITION OF I
C             1 - MCADAMS RELATIONSHIPS FOR THE HEAT TRANSFER
C                 COEFFICIENT AND FRICTION FACTOR THROUGH A BANK OF
C                 STAGGERED BARE TUBES
C
C             2 - ZUKAUSKAS RELATIONSHIP FOR HEAT TRANSFER
C                 COEFFICIENTS AND MCADAMS FRICTION FACTOR
C                 RELATIONSHIP FOR A BANK OF STAGGERED TUBES
C
C             3 - ZUKAUSKAS HEAT TRANSFER COEFFICIENT AND MCADAMS
C                 FRICTION FACTOR RELATIONSHIPS FOR IN LINE BARE
C                 TUBES
C
C     DEFINITION OF VARIABLES
C
C     AMU     - VISCOSITY OF AIR (LBM/FT-HR)
C     CP      - SPECIFIC HEAT OF AIR (BTU/LBM DEG F)
C     FAIR    - AIR SIDE FRICTION FACTOR FOR BARE TUBES (DIMENSION-
C               LESS)
C     GAIR    - MASS FLUX OF AIR THROUGH MINIMUM CROSS-SECTIONAL
C               FLOW AREA (LBM/SQ FT HR)
C     HO      - AIR SIDE HEAT TRANSFER COEFFICIENT (BTU/HR SQ FT
C               DEG F)
C     ODL     - OUTSIDE DIAMETER OF THE PLASTIC TUBES (IN)
C     PRANTL  - AIR SIDE PRANDTL NUMBER (DIMENSIONLESS)
C     RATIO   - RATIO OF TRANSVERSE TO LONGITUDINAL PITCH OF THE
C               TUBES
C     REAIR   - AIR SIDE REYNOLDS NUMBER BASED ON THE MINIMUM
C               CROSS-SECTIONAL FLOW AREA AND OUTSIDE DIAMETER
C               OF THE TUBES
C     THCONA  - THERMAL CONDUCTIVITY OF AIR (BTU/HR-FT-DEG F)
C     XD      - LONGITUDINAL PITCH OF TUBES PARALLEL TO AIR FLOW
C     XL      - RATIO OF LONGITUDINAL PITCH TO THE OUTSIDE
C               DIAMETER OF THE TUBES
C     XT      - RATIO OF TRANSVERSE PITCH TO THE OUTSIDE DIAMETER
C               OF THE TUBES
C     XW      - TRANSVERSE PITCH OF TUBES NORMAL TO AIR FLOW
C
C     PROPERTIES OF AIR AT 100 DEGREES F
C
      AMU = 0.04594
      CP = 0.2406
      THCONA = 0.01566
C
C     FLOW CONDITIONS
C
      ODLFT = ODL/12.0
      PRANTL = AMU*CP/THCONA
      REAIR = ODLFT*GAIR/AMU
C
C     TRANSVERSE AND LONGITUDINAL PITCHES
```

```
C
      XT = XW/ODL
      XL = XD/ODL
      RATIO = XT/XL
C
C****     AIR SIDE FRICTION FACTOR - EQUATIONS 6-13A AND B MCADAMS
C                 "HEAT TRANSMISSION" THIRD EDITION
C
C         BRANCH POINT FOR STAGGERED AND INLINE TUBE ARRANGEMENTS
      GO TO (5,5,7)I
C
C         STAGGERED TUBE FRICTION FACTOR
    5 CONTINUE
      FAIR = (0.250 + 0.1175/(XT - 1.0)**1.08)/(REAIR**0.16)
      GO TO 8
C
C         INLINE TUBE FRICTION FACTOR
    7 VALUE = 0.430 + (1.13/XL)
      FAIR = (0.044 + 0.080*XL/(XT - 1.0)**VALUE)/(REAIR**0.15)
C
C****     AIR SIDE HEAT TRANSFER COEFFICIENT MCADAMS AND ZUKAUSKAS"
C         CORRELATIONS
C
C         BRANCH POINT FOR STAGGERED AND INLINE TUBE ARRANGEMENT
    8 GO TO (10,20,60)I
C
C         STAGGERED TUBE ARRANGEMENT, EQUATION 10-11A MCADAMS "HEAT
C         TRANSMISSION" THIRD EDITION
   10 HO = 0.33*(REAIR**0.60)*(PRANTL**0.3333)*THCONA/ODLF
      RETURN
C
C         STAGGERED TUBE ARRANGEMENT, EQUATIONS 38, 40, AND 41 A.
C         ZUKAUSKAS "HEAT TRANSFER FROM TUBES IN CROSSFLOW"
C
   20 IF(REAIR .LT. 10.0) RETURN
      IF(REAIR .GT. 100.0) GO TO 30
C
C         REYNOLDS NUMBER GREATER THAN 10 BUT LESS THAN 100
      HO = 0.90*(REAIR**0.40)*(PRANTL**0.36)*THCONA/ODLF
      RETURN
C
C         REYNOLDS NUMBER GREATER THAN 100 AND LESS THAN 1000
   30 IF(REAIR .GT. 1000) GO TO 40
      IF (RATIO .GT. 2.) GOTO 35
      XC = .3755 + 100.**(-.2*ALOG10(RATIO))
      XM = .5898 + .2*ALOG10(RATIO)
C
C         RATIO OF TRANSVERSE TO LONGITUDINAL PITCH LESS THAN 2
      HO = XC * REAIR**XM * PRANTL**.36 * THCONA  /  ODLF
      RETURN
C
C         RATIO OF TRANSVERSE TO LONGITUDINAL PITCH GREATER THAN 2
   35 HO = .5875 * REAIR**.6478 * PRANTL**.36 * THCONA  /  ODLF
      RETURN
C
C         REYNOLDS NUMBER GREATER THAN 1000 AND LESS THAN 2.00E05
   40 CONTINUE
```

```
      IF(RATIO .GT. 2.00) GO TO 50
C
C           RATIO OF TRANSVERSE TO LONGITUDINAL PITCH LESS THAN 2
      HO = 0.35*(RATIO**0.20)*(REAIR**0.60)*(PRANTL**0.36)*THCONA/ODLF
      RETURN
C
C           RATIO OF TRANSVERSE TO LONGITUDINAL PITCH GREATER THAN 2
   50 HO = 0.40*(REAIR**0.60)*(PRANTL**0.36)*THCONA/ODLF
      RETURN
C
C           INLINE TUBE ARRANGEMENT, EQUATIONS 38, 38, AND 42.  A
C           ZUKAUSKAS "HEAT TRANSFER FROM TUBES IN CROSSFLOW"
C
   60 IF(REAIR .LT. 10) RETURN
      IF(REAIR .GT. 100) GO TO 70
C
C           REYNOLDS NUMBER GREATER THAN 10 AND LESS THAN 100
      HO = 0.90*(REAIR**0.40)*(PRANTL**0.360)*THCONA/ODLF
      RETURN
C
C           REYNOLDS NUMBER GREATER THAN 100 AND LESS THAN 1000
   70 IF(REAIR .GT. 1000.0) GO TO 80
      HO = 0.293*(REAIR**0.618)*(PRANTL**0.360)*THCONA/ODLF
      RETURN
C
C           REYNOLDS NUMBER GREATER THAN 1000 AND LESS THAN 2.00E05
   80 IF(REAIR .GT. 2.00E05) GO TO 90
      HO = 0.270*(REAIR**0.630)*(PRANTL**0.360)*THCONA/ODLF
      RETURN
C
C           REYNOLDS NUMBER GREATER THAN 2.00E05
   90 HO = 0.021*(REAIR**0.84)*(PRANTL**0.36)*THCONA/ODLF
      RETURN
      END
```

```
      SUBROUTINE HEADER(GPMHDR,NBRANCH,BRCHGPM,RED,NN,J,DIA,REDCOST,
     $TEECOST,ELCOST,UPIPCST,VELO,EJCOST,FLGCOST,DESVEL)
C
C          THIS SUBROUTINE DETERMINES DESIGN AND COST INFORMATION FOR
C          THE MAIN CIRCULATION PIPING AND THE QUADRANT PIPING.
C
C          DEFINITION OF VARIABLES
C
C          APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
C          BRCHCST - PORTION OF THE COST OF A TEE ATTRIBUTED TO THE
C                    BRANCH ($1000)
C          BRCHDIA - DIAMETER OF DISTRIBUTION PIPING.  DIAMETER OF
C                    BUNDLE FITTINGS (INCHES)
C          BRCHGPM - FLOW RATE TO CIRCULAR TOWER OR TUBE BUNDLE (GPM)
C          DESVEL  - PIPING SYSTEM WATER DESIGN VELOCITY (FT/SEC)
C          DIA     - PIPE COMPONENT DIAMETER (INCHES)
C          EJCOST  - EXPANSION JOINT COST ($1000)
C          ELCOST  - 90 DEGREE ELBOW COST ($1000)
C          FLGCOST - FLANGE COST ($1000)
C          GPMHDR  - INITIAL FLOW INTO HEADER (GPM)
C          GPMREM  - FLOW IN A HEADER SECTION (GPM)
C          IPRESS  - PIPE COMPONENT DESIGN PRESSURE (PSI)
C          NFL     - UPPER LIMIT FOR NUMBER OF TOWERS OR TUBE BUNDLES
C                    PER QUADRANT
C          NFS     - NUMBER OF POSITIONS IN UNIT COST ARRAYS.  MUST
C                    MATCH NUMBER OF POSITIONS IN DIAM ARRAY
C          NN      - IF=0 THEN MAIN CIRCULATION HEADER IS DESIGNED
C                    IF=1 THEN QUADRANT HEADER IS DESIGNED
C          PIPCST  - BELOW GROUND PIPE COST ($1000/FT)
C          RED     - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
C                    HEADER SECTIONS (INCHES).  IF RED=0 THE PROGRAM
C                    CALCULATES THE REDUCTION
C          REDCOST - REDUCER COST ($1000)
C          REDUCT  - REDUCTION IN DIAMETER BETWEEN ADJACENT HEADER
C                    SECTIONS (INCHES).  ONLY USED WHEN RED=0
C          TEECOST - TEE COST ($1000)
C          UPIPCST - UNIT PIPE COST ($1000/FT)
C          VACST   - VALVE COST ($1000) , VALVES ARE MOTOR OPERATED
C                    BUTTERFLY VALVES
C          VELO    - TRUE VELOCITY IN PIPE, ALWAYS LESS THAN
C                    DESVEL(FT/SEC)
C
      COMMON /CPIPE / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
     $, FLGCST(23)
     $ ,ELCST(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
      COMMON /PRESS/ IPRESS
      DIMENSION VELO(200)
      DIMENSION DIA(200),REDCOST(200),TEECOST(200),UPIPCST(200)
      LOGICAL  CALL 1
      DATA  DIAM/12.,18.,24.,30.,36.,42.,48.,54.,60.,66.,72.,78.,84.,
     $90.,96.,102.,108.,114.,120.,126.,132.,138.,144./
      DATA  FLGCST/.342,.618,.893,1.145,1.398,1.934,2.471,3.218,3.966,
     $5.55,7.134,9.815,12.496,14.725,16.954,20.455,23.956,25.61,27.264,
     $28.918,30.572,32.226,33.88/
      DATA  EJCST/.56,1.11,1.66,2.172,2.685,4.242,5.8,7.242,8.685,
     $10.072,11.46,13.955,16.45,19.845,23.24,26.93,30.62,34.14,37.66,
     $41.18,44.7,48.22,51.74/
```

```
      DATA REDCST/.7,.8,.9,1.3,1.65,2.0,4.65,5.45,6.3,7.1,9.5,11.5,
     $13.5,15.5,17.5,19.3,45.5,60.,73.0,87.0,101.,114.,127./
      DATA TEECST/.882,2.048,3.215,3.843,4.472,5.1,9.9,16.156,22.41,
     $28.661,37.261,42.1,46.944,51.785,65.968,71.,104.2,117.5,131.25,
     $144.,159.,170.,185./
      DATA PIPCST/.115,.15,.185,.225,.26,.295,.42,.465,.51,.555,.665,
     $.71,.75,.795,.94,.99,1.28,1.335,1.39,1.445,1.505,1.555,1.61/
      DATA ADIPCST/.072,.100,.122,.148,.172,.198,.299,.328,.360,.390,
     1.495,.525,.555,.585,.714,.745,1.023,1.070,1.11,1.15,1.19,1.23,
     21.27/
      DATA ELCST/.638,1.34,2.04,2.60,3.15,3.71,8.03,14.2,20.4,26.5,
     134.1,39.4,44.6,49.8,64.9,70.2,102.,116.,129.,143.,157.,171.,185./
      DATA CALL 1 /.TRUE./
C
      DATA NFS/23/, NFL/200/
C
C
C          CALL THE APPROPRIATE SUBROUTINE TO ESTABLISH UNIT COST DATA
C          FOR THE PIPING SYSTEM COMPONENTS.
C
      IF (CALL 1 .AND. IPRESS .EQ.  50) CALL P50
      IF (CALL 1 .AND. IPRESS .EQ.  75) CALL P75
      IF (CALL 1 .AND. IPRESS .EQ. 125) CALL P125
      CALL 1 = .FALSE.
      DO 24 I=1,NFL
      REDCOST(I)=0.
      TEECOST(I)=0.
   24 CONTINUE
      EJCOST=0.
      FLGCOST=0.
C
C          THE INITIAL CONDITION IS TO HAVE THE FLOW REMAINING IN THE
C          HEADER (GPMREM) EQUAL TO THE FLOW THAT ENTERS THE HEADER
C          (GPMHDR).
C
      GPMREM=GPMHDR
      ELCOST=0.
      CONST1=(3.1416/4.)*7.481*60.*DESVEL
      CONST2=(4./3.1416)*144./(60.*7.481)
C
C          IF NN=1 THE QUADRANT HEADERS ARE BEING SPECIFIED.  THE CALC-
C          ULATION OF BRANCH DIAMETER IS BY-PASSED BECAUSE THE BRANCH,
C          IN THIS CASE THE PIPE CONNECTING THE QUADRANT HEADER TO THE
C          BUNDLE HEADER, IS FIXED AT 8 INCHES DIAMETER.  OTHERWISE, THE
C          BRANCH DIAMETER IS THE DIAMETER OF THE DISTRIBUTION PIPING.
C          THIS CALCULATION IS USED TO GET THE INDEX II TO DETERMINE THE
C          BRANCH TEE COST (BRCHCST) BELOW.
C
      IF(NN.EQ.1) GO TO 23
      BRCHDIA=SQRT(BRCHGPM/CONST1)*12.
      IF(BRCHDIA.LT.DIAM(1)) BRCHDIA=DIAM(1)
      DO 10 I=1,NFS
      II = I
      IF(BRCHDIA-DIAM(II)) 11,11,10
   10 CONTINUE
   11 BRCHDIA=DIAM(II)
   23 J=1
```

```
C
C         THE LOOP INCLUDING STATEMENTS 22 TO 21 DESIGNS AND COSTS THE
C         COMPONENTS OF EACH HEADER SECTION.
C
C         COMPUTE THE REQUIRED PIPE DIAMETER FOR HEADER SECTION J BASED
C         ON THE FLOW REMAINING (GPMREM) AND THE DESIGN VELOCITY
C         (DESVEL).  THE DIAMETER ASSIGNED TO HEADER SECTION J IS THE
C         NEXT LARGEST DIAMETER, IN 6 INCH INCREMENTS, FROM THE DIA-
C         METER ARRAY, DIAM, IN SUBROUTINES P50, P75, OR P125.
C
   22 DIA(J)=SQRT(GPMREM/CONST1)*12.
      DO 12 I1= 1,NFS
      I = I1
      IF(DIA(J)-DIAM(I))13,13,12
   12 CONTINUE
   13 DIA(J)=DIAM(I)
C
C         THE MAIN CIRCULATION HEADER HAS AN EXPANSION JOINT AND
C         APPROPRIATE FLANGES AT THE CONDENSER INLET AND OUTLET.
C
      IF(J.EQ.1 .AND. NN.NE.1) EJCOST=EUCST(I)
      IF(J.EQ.1 .AND. NN.NE.1) FLGCOST=3.*FLGCST(I)
C
C         IN THE STATEMENTS THROUGH STATEMENT 17 THE REDUCTION IN
C         HEADER PIPE SIZE IS SPECIFIED.  THE REDUCER COST IS DETER-
C         MINED.  THE INDEXES USED TO DEFINE THE ARRAY POSITIONS FOR
C         OTHER COMPONENT COSTS ARE DETERMINED.
C
C         IF A REDUCER IS COSTED FOR HEADER SECTION J IT IS INCLUDED IN
C         THE COSTS FOR HEADER SECTION J-1.  ITS LARGER DIAMETER WILL
C         BE THAT OF HEADER SECTION J-1.  THE COST OF A REDUCER IS
C         BASED ON ITS LARGER DIAMETER.
C
C         FOR J=1 THIS ROUTINE IS BY-PASSED BECAUSE THE FIRST HEADER
C         WILL NOT HAVE A REDUCER PRECEDING IT.
C
      IF(J.EQ.1) GO TO 15
C
C         THE PROGRAM MAY HAVE A SPECIFIED VALUE OF RED WHICH FIXES THE
C         REDUCTION IN PIPE DIAMETERS BETWEEN HEADER SECTIONS.  RED
C         MUST BE A MULTIPLE OF 6.  IF RED=0 THE ROUTINE CALCULATES A
C         REDUCTION.  FOR EXAMPLE, HEADER SECTION J-1 HAS BEEN ASSIGNED
C         A DIAMETER OF 96 INCHES. IT IS DETERMINED THAT HEADER SECTION
C         J SHOULD BE 84 INCHES.  THE REQUIRED REDUCTION IS 12 INCHES.
C         IF RED=0 THEN A 96 INCH REDUCER IS COSTED AND HEADER SECTION
C         J WILL BE ASSIGNED A DIAMETER OF 84 INCHES.  IF RED=6 INCHES
C         A 96 INCH REDUCER IS COSTED BUT DIAMETER J WOULD BE ASSIGNED
C         A VALUE OF 90 INCHES.  IF RED=12 INCHES THEN A 96 INCH RE-
C         DUCER IS COSTED AND DIAMETER J IS ASSIGNED A VALUE OF 84
C         INCHES.  IF RED=18 INCHES OR MORE THEN NO REDUCER IS SPECI-
C         FIED AND DIAMETER J IS ASSIGNED A VALUE OF 96 INCHES.  LARGER
C         VALUES OF RED RESULT IN PIPE SIZES LARGER THAN REQUIRED BUT
C         FEWER REDUCERS ARE REQUIRED.
C
      IF(RED.NE.0.) GO TO 14
      IF (ABS(DIA(J)-DIA(J-1)).LT.0.1) GO TO 15
C
```

```
C          CALCULATION OF REDUCTION, RED NOT SPECIFIED.
C
      REDUCT=DIA(J-1)-DIA(J)
      M = REDUCT/6. + .01
      IJ = I
      GO TO 16
C
C          RED SPECIFIED, POSSIBLE REASSIGNMENT OF DIAMETER J.
C
   14 IF (DIA(J)-0.1.GT.DIA(J-1)-RED) GO TO 17
      DIA(J)=DIA(J-1)-RED
      M = RED / 6. + .01
      IJ = I + (DIA(J) - DIAM(I)) / 6. + .01
C
C          DETERMINE REDUCER COST.  IT HAS BEEN ASSUMED FROM THE RE-
C          DUCER COST DATA THAT, FOR EXAMPLE, A 96 INCH REDUCER WILL
C          COST THE SAME WHETHER THE REDUCTION IS TO 90, 84, OR 78
C          INCHES.  IF THE TOTAL REDUCTION BETWEEN ADJACENT HEADER
C          SECTIONS EXCEEDS 18 INCHES THEN AN ADDITIONAL REDUCER MUST BE
C          COSTED.  IN THE EXAMPLE, THIS WOULD BE A 78 INCH REDUCER.  IF
C          THE TOTAL REDUCTION EXCEEDS 36 INCHES, SAY 96 TO 54, THEN A
C          96, 78, AND 60 INCH REDUCER WOULD BE COSTED, AND SO ON.
C
   16 K=0
      JJ=M
      IF(JJ + IJ .GT. NFL) J=2*NFL
      IF(J.GT.NFL) RETURN
   18 REDCOST(J-1) = REDCOST(J-1) + REDCST(IJ+JJ)
      K=K+1
      JJ=M-3*K
      IF(JJ.LE.0) GO TO 15
      GO TO 18
   17 DIA(J)=DIA(J-1)
   15 M = (DIA(J) - DIAM(I))/6. + .01
C
C          DETERMINE TEE COSTS.  IF THE LAST HEADER SECTION IS BEING
C          DESIGNED THEN USE AN ELBOW RATHER THAN A TEE.  THE TEE COST
C          IS ASSUMED TO BE .67* THE COST OF A TEE OF THE "RUN" DIAMETER
C          PLUS .33* THE COST OF A TEE OF THE "BRANCH" DIAMETER.  THE 8
C          INCH BRANCH DIAMETER CONNECTING THE QUADRANT HEADER TO THE
C          BUNDLE HEADER IS NOT AN ARRAY VALUE.  BRCHCST IS ASSIGNED A
C          VALUE OF $200.
C
      IF (M + I .GT. NFL) J=2*NFL
      IF (J .GT. NFL) RETURN
      IF (ABS(GPMREM-BRCHGPM).LT.0.01) GO TO 19
      IF(NN .NE. 1) BRCHCST = TEECST(II) * .33
      IF(NN.EQ.1) BRCHCST=.2
      TEECOST(J)=TEECST (I+M)*0.67+BRCHCST
C
C          MAIN CIRCULATION PIPING IS UNDERGROUND.  QUADRANT PIPING IS
C          ABOVE GROUND.  FITTINGS COSTS WERE NOT DEPENDENT ON ABOVE OR
C          BELOW GROUND SPECIFICATION.
C
      GO TO 20
   19 ELCOST=ELCST(I+M)
   20 IF (NN .NE. 1) UPIPCST(J) = PIPCST(I+M)
```

```
C
C          SUBTRACT OUT THE FLOW TO ONE BRANCH FROM THE FLOW IN THE
C          HEADER.  IF NO FLOW REMAINS THEN THE LAST HEADER SECTION HAS
C          BEEN DESIGNED.  THERE ARE FINALLY J SECTIONS IN THE HEADER.
C
      IF(NN.EQ.1) UPIPCST(J)=APIPCST(I+M)
      VELO(J)=(GPMREM/DIA(J)**2)*CONST2
      GPMREM=GPMREM-BRCHGPM
      IF (GPMREM.LE.1.0) GO TO 21
      J=J+1
      IF (J.GT.NFL) RETURN
      GO TO 22
   21 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPSUM
C
C     THIS ROUTINE REPORTS INPUT SUMMARY AND CASE DESCRIPTION
C
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPI, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCF
     $ ,RBF, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBAEG, TW
     $ ,UCS, UWS
     $ ,VAS(6)
     $ ,WEV
     $ ,XDEP, XW, XD
      COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF, FBCPF,
     $VELREC,AFC,ELEV,EHR
      COMMON /TTNC2/ CCM
  126 FORMAT(//79X,"COEFFICIENTS FOR POLYNOMIAL CURVE FIT")
  127 FORMAT(70X,"A0",11X,"A1",11X,"A2",11X,"A3",11X,"A4")
  128 FORMAT(" HEAT RATE FACTOR AS FUNCTION OF BACKPRESSURE (INCHES OF M
     +ERCURY)  ",1P5E13.5//)
  129 FORMAT(T4,"TURBINE RATING BACKPRESSURE",F6.2," INCHES OF MERCURY")
  130 FORMAT(T4,"SITE ELEVATION",F7.0," FEET ABOVE SEA LEVEL")
  202 FORMAT(1H1,T30,"I N P U T    S U M M A R Y    A N D    C A S E
     $D E S C R I P T I O N"//)
  204 FORMAT(T2,3("----------"),T90,2("----------"),"-")
  206 FORMAT(T2,"OPTIONS SELECTED FOR THIS RUN",T90,"STARTING CONDITIONS
     $")
  200 FORMAT(1H0)
  210 FORMAT(T4,"EXCHANGER DEPTH UNCONSTRAINED")
  208 FORMAT(T6,"UPPER LIMIT ON TURBINE TEMP",F6.1," F")
  215 FORMAT(T4,"EXCHANGER DEPTH CONSTRAINED TO ",A4,1X,F5.1," TUBES")
  220 FORMAT(1H+,T30,"TURBINE OUTLET TEMPERATURE, T1",F10.3,"  F")
  225 FORMAT(T4,"EXCHANGER LENGTH UNCONSTRAINED")
  230 FORMAT(T4,"EXCHANGER LENGTH FIXED AT ",F5.0," FEET")
  235 FORMAT(1H+,T89,"CAPACITY RATIO, CWARA",F10.3)
  240 FORMAT(T4,"RUN WITH VELOCITY RECOVERY")
  245 FORMAT(T4,"RUN WITHOUT VELOCITY RECOVERY")
```

```
  250 FORMAT(1H+,T91,"FRONTAL AREA, AFRON",F11.0)
  255 FORMAT(T4,"NTU CALCULATION IS BY ",2A10)
  260 FORMAT(1H+,T82,"WIDTH TO LENGTH RATIO, WLRAT",F10.3)
  265 FORMAT(T8,"TUBE ARRANGEMENT ",A10)
  300 FORMAT(//T51,"UNIT COSTS AND COSTING FACTORS"/T51,30("-")//)
  305 FORMAT(T2,"FUEL  ",F7.3," CENTS/MMBTU"
     $,T30,"POWER PLANT CONSTRUCTION",F11.3," $/KW"
     $,T104,"FIXED CHARGE RATE",F9.3)
  310 FORMAT(T2,"LAND  ",F7.3," $/SQ FT"
     $,T30,"REPLACEMENT POWER",7X,F11.3," MILLS/KWH"
     $,T106,"CAPACITY FACTOR",F9.3)
  315 FORMAT(T2,"MOTORS",F7.3," $ / HP"
     $,T30,"STEAM SUPPLY",T54,F11.3," $/KW TURBINE OUTPUT"
     $,T93,"BASE THERMAL EFFICIENCY",F9.3)
  320 FORMAT(T30,"CAPACITY CHARGE",T54,F11.3," $/MW"
     $,T93,"CONSTRUCTION COST MULTIPLIER",F9.3)
  325 FORMAT(T95,"MAINT COSTS /CAPITAL COSTS",F9.3)
      WRITE(6,202)
      WRITE(6,204)
      WRITE(6,206)
      WRITE(6,204)
      WRITE(6,200)
      WRITE(6,203) TLIM
C
      LOGSYM = ".LE."
      IF(DEEPL.GT.0.0) LOGSYM = ".GE."
      IF(DEEPL.EQ.0.0) WRITE(6,210)
      IF(DEEPL.NE.0.0) WRITE(6,215) LOGSYM, ABS(DEEPL)
C
      WRITE(6,220) VAS(1)
C
      IF(FIXL .EQ. 0.0) WRITE(6,225)
      IF(FIXL .NE. 0.0) WRITE(6,230) FIXL
C
      WRITE(6,235) VAS(3)
C
      IF(VELREC.EQ.0.0) WRITE(6,245)
      IF(VELREC.NE.0.0) WRITE(6,240)
C
      WRITE(6,250) VAS(4)
C
      WRITE(6,255) NTUCAL
      WRITE(6,260) VAS(5)
C
C
      WRITE(6,265) TUBARG
C
      WRITE(6,126)
      WRITE(6,127)
      WRITE(6,128) (TPO(I),I=1,4)
      WRITE(6,129) RBP
      WRITE(6,130) ELEV
C
      WRITE(6,300)
      WRITE(6,305) FCOS,PLANC,FCR
      WRITE(6,310) COSTL,PWCOS,CAPFI
      WRITE(6,315) HPCST,CSSPKW,TEFFI
```

```
115          WRITE(6,320) CAPCHG,CCM
             WRITE(6,325) PER
             RETURN
             END
```

```
      SUBROUTINE HYDLOS(DIA,VEL,VIS,RHO,ID,HDLS)
C
C         SUBROUTINE HYDLOS FOR GIVEN VALUES OF INSIDE DIAMETER,
C         VELOCITY, VISCOSITY, AND DENSITY, DETERMINES THE FRICTION
C         HEAD LOSS PER FEET OF DRAWN TUBING (ID=1), STEEL PIPE (ID=2),
C         OR CAST IRON PIPE (ID=3) USING MOODY FRICTION FACTOR CHART
C         EQUATIONS
C         REFERENCE, KNUDSEN, J.G. AND KATZ, D.L. "FLUID DYNAMICS AND
C         HEAT TRANSFER", MCGRAW-HILL, NEW YORK, 1958, P.175
C
      DIMENSION EP(3)
C
C         INSIDE SURFACE PROTUBERANCES FOR COMMERCIAL TUBING AND PIPE
C
      DATA EP/0.00006,0.0018,0.0102/
C
C         CALCULATE REYNOLDS NUMBER AND DETERMINE IF IN LAMINAR OR
C         TURBULENT REGION
C
      RE=300.*RHO*VEL*DIA/VIS
      IF(RE-2000.)100,101,101
C
C         CALCULATE LAMINAR FLOW FRICTION FACTOR
C
  100 F=16./RE
      GO TO 102
C
C         CALCULATE RECIPROCAL OF RELATIVE ROUGHNESS AND RECIPROCAL OF
C         SQUARE ROOT OF FRICTION FACTOR FOR FULLY TURBULENT FLOW
C
  101 RF=DIA/EP(ID)
      FF=4.*ALOG10(RF)+2.28
C
C         CHECK TO DETERMINE IF TURBULENT FLOW IS FULLY DEVELOPED
C
      CF=RF*FF/RE
      IF(CF-0.01)104,103,103
C
C         DETERMINE RECIPROCAL OF SQUARE ROOT OF FRICTION FACTOR
C         FOR TRANSITION FLOW INITIALLY ASSUMING IT TO BE THE SAME AS
C         FOR FULLY TURBULENT FLOW
C
  103 TRF=FF
  107 TRFC=FF-4.*ALOG10(1.+4.67*RF*TRF/RE)
C
C         IF CALCULATED AND ASSUMED VALUES OF RECIPROCAL OF SQUARE ROOT
C         OF TRANSITION FLOW FRICTION FACTOR DO NOT AGREE WITHIN
C         SPECIFIED LIMITS, ASSUME NEW VALUE EQUAL TO CALCULATED VALUE
C         AND REPEAT CALCULATION
C CALCULATION
C
      IF((ABS(TRFC-TRF)/TRF)-0.001)105,105,106
  106 TRF=TRFC
      GO TO 107
C
C         CALCULATE FULLY DEVELOPED TURBULENT FLOW OR TRANSITION FLOW
C         FRICTION FACTOR
```

```
C
  105  FF=TRF
  104  F=1./FF**2
C
C          DETERMINE FRICTION HEAD LOSS
C
  102  HDLS=74.594*F*VEL**2/DIA
C
       RETURN
       END
```

```
      SUBROUTINE NOVART(TVAL3,VCST)
C
C     SUBROUTINE NOVART CALCULATES THE PERFORMANCE OF THE POWER
C     PLANT AND DRY COOLING TOWER UNDER THE ASSUMPTION THAT THE
C     AIR SIDE HEAT TRANSFER COEFFICIENTS AND AIR VELOCITY THROUGH
C     THE HEAT EXCHANGER TUBES ARE UNCHANGED
C
C     DEFINITION OF VARIABLES
C
C     CAPCHG  - GAS TURBINE CAPITAL COST ($/MW)
C     CAPCST  - COST OF GAS TURBINE ($)
C     CAPF    - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER
C               (PERCENT)
C     CCOS    - COST OF THE DRY COOLING TOWERS ($)
C     CLAND   - COST OF LAND TAKEN UP BY THE DRY COOLING TOWERS ($)
C     CONBAS  - COST OF SURFACE CONDENSER ($)
C     COSM    - COST OF MAINTAINING THE DRY COOLING TOWERS ($)
C     CPIP    - COST OF PIPING AND PUMPING SYSTEMS ($)
C     CSTCH   - COST OF MAKE-UP POWER BY GAS TURBINES AT EACH
C               AMBIENT AIR TEMPERATURE (MILLS/KW-HR)
C     DELFC   - INCREMENTAL FUEL COST FOR STEAM SUPPLY SYSTEM
C               (MILLS/KW HR)
C     EFF     - HEAT EXCHANGER EFFECTIVENESS OF DRY COOLING TOWERS
C               (DIMENSIONLESS)
C     EFFC    - CONDENSER EFFECTIVENESS
C     FCOS    - FUEL COST FOR THE STEAM SUPPLY SYSTEM (MILLS/BTU)
C     FCR     - FIXED CHARGE RATE ON CAPITAL PER YEAR (PERCENT)
C     FPOW    - POWER REQUIREMENTS OF FAN SYSTEM (KW)
C     HRFAC1  - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
C               PRESSURE (DIMENSIONLESS)
C     HRFAC2  - HEAT RATE FACTOR OF STEAM TURBINE AT DESIGN
C               CONDITIONS OF POWER PLANT (DIMENSIONLESS)
C     HRFAC4  - HEAT RATE FACTOR OF STEAM TURBINE AT A PARTICULAR
C               AMBIENT AIR TEMPERATURE (DIMENSIONLESS)
C     P       - BACK PRESSURE OF STEAM TURBINE (IN. HG.)
C     PARCOS  - INCREMENTAL POWER PRODUCTION COST OF THE DRY
C               COOLED POWER PLANT FOR A PARTICULAR AMBIENT AIR
C               TEMPERATURE (MILLS/KW-HR)
C     PGEN    - POWER OUTPUT OF PLANT AT A PARTICULAR AMBIENT AIR
C               TEMPERATURE (MW)
C     PPOW    - POWER REQUIREMENTS OF THE PIPING SYSTEM (KW)
C     PISZ13  - POWER OUTPUT OF STEAM TURBINE AT RATED BACK
C               PRESSURE TO PRODUCE REQUIRED OUTPUT OF PLANT AT
C               DESIGN CONDITIONS (MW)
C     PTOT    - POWER OUTPUT OF PLANT AT SPECIFIED AMBIENT AIR
C               TEMPERATURE (MW)
C     PWCOS   - COST OF FUEL FOR GAS TURBINE (MILLS/KW-HR)
C     QTN1    - THERMAL ENERGY OUTPUT OF STEAM SUPPLY SYSTEM AT
C               RATED BACK PRESSURE OF TURBINE (BTU/HR)
C     QREJCT  - HEAT REJECTED AT A SPECIFIED AMBIENT AIR
C               TEMPERATURE (BTU/HR)
C     RANGE   - TEMPERATURE RANGE OF WATER PASSING THROUGH THE
C               HEAT EXCHANGER (DEG F)
C     SPCO    - INCREMENTAL COST OF PLANT DUE TO SCALE UP OF STEAM
C               SUPPLY SYSTEM AND THE SCALE UP OF THE PLANT TO
C               TAKE INTO ACCOUNT FOR FAN AND PUMP POWER
C               REQUIREMENTS ($)
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C          TA       - AMBIENT AIR TEMPERATURE (DEG F)
C          TEFF     - THERMAL EFFICIENCY OF CONVENTIONAL STEAM TURBINE
C                     AT RATED BACK PRESSURE (DIMENSIONLESS)
C          TEFF1    - THERMAL EFFICIENCY OF STEAM TURBINE AT RATED
C                     BACK PRESSURE (DIMENSIONLESS)
C          TEFF3    - THERMAL EFFICIENCY OF STEAM TURBINE AT POWER
C                     PLANT DESIGN CONDITIONS (DIMENSIONLESS)
C          TEFF4    - THERMAL EFFICIENCY OF STEAM TURBINE ASSOCIEATED
C                     WITH A PARTICULAR AMBIENT AIR TEMPERATURE
C                     (DIMENSIONLESS)
C          TLIM     - LIMIT ON THE TEMPERATURE EXITING THE STEAM
C                     TURBINE (DEG F)
C          TPER     - PERCENT OF TIME AN AMBIENT TEMPERATURE OCCURS
C                     DURING THE YEAR (PERCENT)
C          TPO      - COEFFICIENTS FOR THIRD ORDER CURVE FIT OF STEAM
C                     TURBINE HEAT RATE FACTOR (DIMENSIONLESS)
C          TTDP     - TERMINAL TEMPERATURE DIFFERENCE OF SURFACE
C                     CONDENSER FOR A PARTICULAR AMBIENT AIR TEMPERATURE
C          TVAL3    - THERMAL CAPACITY RATIO OF THE WATER TO THE AIR
C                     PASSING THROUGH THE HEAT EXCHANGER (DIMENSIONLESS)
C          T1       - EXIT TEMPERATURE OF STEAM TURBINE (DEG F)
C          VCST     - TOTAL INCREMENTAL COST OF DRY COOLING (MILLS/KW-HR)
C          W3       - MASS FLOW RATE OF WATER THROUGH THE HEAT EXCHANGER
C                     (LBM/HR)
C          XCOST    - INCREMENTAL COST OF DRY COOLING FOR EACH AMBIENT
C                     AIR TEMPERATURE (MILLS/KW-HR)
C          YFP      - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR
C                     FAN AND PUMP POWER (DIMENSIONLESS)
C
      REAL XCOST(8)
      COMMON /VARVAR/ VTPER(16),VTA(16)
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTJCAL(2), NTA
      COMMON
     $ DDR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
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```
      $ ,VAS(5)
      $ ,WFV
      $ ,XDEPA, XW, XD
       COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
      $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
      $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HT,    HO,    T4,
      $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
      $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
      $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
      $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
      $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
      $,  WTHOR, WTERM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
      $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
       COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
      $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
       DIMENSION VLIST(9)
       DATA NTRIP/0/
       DATA VLIST /"CCOS","SPCD","CLAND","CPIP","CONBAS","COSM"
      $ ,"TPER","PARCOS","VCST"/
C
C          THERMAL EFFICIENCY OF TURBINE AT THE DESIGN POINT OF THE
C          PLANT.
C
       TEFFB=TEFF/HRFAC2
C
C          THERMAL EFFICIENCY OF TURBINE AT THE RATED BACK PRESSURE
C
       TEFF1=TEFF/HRFAC1
       QIN1=3413.E+3 * PSIZ13/TEFF1
       VCST=0.0
C
C          START OF LOOP FOR CALCULATING THE INCREMENTAL COST OF DRY
C          COOLING FOR EACH TEMPERATURE RANGE
C
       DO 300 I=1,NTA
C
C          AMBIENT AIR TEMPERATURE AND PERCENTAGE OF YEAR OVER WHICH
C          TEMPERATURE OCCURS.
C
        TA=VTA(I)
       TPER=VTPER(I)
C
C          ITERATIVE LOOP FOR CALCULATING THE EXIT TEMPERATURE OF THE
C          STEAM TURBINE AS A FUNCTION OF THE AMBIENT AIR TEMPERATURE.
C
C          CALCULATION OF THE THERMAL EFFICIENCY OF STEAM TURBINE FOR
C          THE SPECIFIED EXIT TEMPERATURE OF THE TURBINE
       T1=140.
     1 P=EXP(17.168-9240./(T1+460.))
       HRFAC4=TPO(1) + TPO(2)*P + TPO(3)*P**2 + TPO(4)*P**3
       TEFF4=TEFF/HRFAC4
C
C          TEMPERATURE RANGE OF WATER FLOWING THROUGH THE HEAT EXCHANGER
```

```
      QREJCT=QIN1*(1.-TEFF4)
      RANGE=QREJCT/(W3*(1.+YFP))
C
C          TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND THE
C          STEAM OF THE SURFACE CONDENSER
      TTDP=RANGE/EFFC-RANGE
C
C          EXIT TEMPERATURE OF THE STEAM TURBINE ON PREVIOUS EXTIMATE
      IF(TVAL3.GT.1.) GOTO 2
      T11=RANGE/EFF + TA + TTDP
      GOTO 3
    2 T11=RANGE*TVAL3/EFF + TA + TTDP
C
C          CONVERGENCE CRITERION FOR EXIT TEMPERATURE OF TURBINE
    3 IF(.NOT. FXTEMP .AND. (T11-T1)**2 .LT. .001) GOTO 4
      CVT = ABS( (T11-T1) / T11)
      IF (FXTEMP .AND. CVT .LT. 0.0001) GOTO 4
      T1=T11
      GOTO 1
C
C          TOTAL POWER OUTPUT OF TURBINE AT THE PARTICULAR AMBIENT
C          AIR TEMPERATURE
C
    4 PTOT = QIN1 * TEFF4 / 3413.E+3
C
C          POWER OUTPUT FROM PLANT AT THE PARTICULAR AMBIENT AIR
C          TEMPERATURE
C
      PGEN=PTOT-PPOW/1000.-FPOW/1000.
      TEFFD=TEFF4
      IF(PGEN.GE.PSIZE) GOTO 5
C
C          COST OF FUEL FOR GAS TURBINE MAKE UP POWER
C
      CSTCL=(PSIZE-PGEN)/PSIZE*PWCOS
      TEFFD=TEFF3
      GOTO 6
    5 CSTCL=0.0
C
C          INCREMENTAL COST OF FUEL FOR STEAM SUPPLY SYSTEM DUE TO STEAM
C          TURBINE OPERATING AT OFF DESIGN CONDITIONS (RATED BACK
C          PRESSURE)
C
    6 DELFC=FCOS*3413.E-5 * ((1.+YFP)/TEFFD-1./TEFFD
      IF(I.NE.1) GO TO 10
C
C          TEMPERATURE LIMITATION ON MAXIMUM YEARLY EXIT, TEMPERATURE OF
C          THE STEAM TURBINE
C
      IF (T11 .GT. TLIM) VCST = 10. * T11
      IF (T11 .GT. TLIM) RETURN
C
C          CAPITAL COST OF GAS TURBINE USED FOR MAKE-UP POWER OF STEAM
C          PLANT
C
      IF(PSIZE.LE.PGEN) GO TO 10
      CAPCST=CAPCHG*(PSIZE-PGEN)
```

```
   10 CONTINUE
C
C          COST OF PRODUCING POWER WITH DRY COOLED PLANT AT SPECIFIED
C          AMBIENT AIR TEMPERATURE
C
      PARCOS = (CCOS + SPCD + CLAND + CPIP + CONBAS + CAPCST) * FCR/
     $ (PSIZE * CAPF * 8760.) + COSM + DELFC + CSTCL
      XCOST(I)=TPER*PARCOS
  800 CONTINUE
C
C          SUMMATION OF INCREMENTAL POWER PRODUCTION COSTS
C
      DO 820 I=1,NTA
      VCST=VCST+XCOST(I)
  820 CONTINUE
C
C          DEBUG PRINT OUT STATEMENTS
C
      NDBUG=0
      IF(NDBUG.EQ.0) RETURN
      NTRIP=NTRIP+1
      WRITE(6,902) NTRIP
      WRITE(6,900) CCOS,SPCD,CLAND,CPIP,CONBAS,COSM,TPER,PARCOS,VCST
      WRITE(6,901) VLIST
  900 FORMAT(1H ,9G14.5)
  901 FORMAT(1H ,9(4X,A6,4X))
  902 FORMAT("0NOVART CALL NO.",I10)
      RETURN
      END
```

```
      SUBROUTINE NUNO2P( T1, TD, TTD, CWARA, RANGE, W3, W4, ANTU)
C
C          THIS ROUTINE DETERMINES THE NUMBER OF TRANSFER UNITS
C          FOR A TRUE COUNTER-FLOW HEAT EXCHANGER.
C          THE NTU-EFFECTIVENESS CORRELATION FOR TRUE COUNTER FLOW IS
C          USED.  THERE ARE THREE POSSIBLE CONDITIONS-  CAPACITY RATIO
C          GREATER THAN UNITY, EQUAL TO UNITY, AND LESS THAN UNITY.
C
C          DEFINITION OF VARIABLES
C
C          CMIN     - MINIMUM CAPACITY (BTU/HR DEG F)
C          CWARA    - CAPACITY RATIO OF WATER TO AIR (DIMENSIONLESS)
C          EFF      - HEAT EXCHANGER EFFECTIVENESS (DIMENSIONLESS)
C          ITD      - INITAL TEMPERATURE DIFFERENCE OF HEAT
C                     EXCHANGER (DEG F)
C          RANGE    - TEMPERATURE RANGE OF WATER (DEG F)
C          T1       - STEAM SATURATION TEMPERATURE (DEG F)
C          TD       - AMBIENT DESIGN TEMPERATURE (DEG F)
C          TTD      - CONDENSER TERMINAL TEMPERATURE DIFFERENCE (DEG F)
C
      REAL ITD
    1 FORMAT("0IN S.R. NUNO2P  EFF IS GREATER THAN OR EQUAL TO 1."/
     $ T2,"EFF=",1PE12.6,T20,"T1,TD,TTD,CWARA,RANGE=",
     $ 1P5E15.6)
      ITD = T1 - TTD - TD
      IF(CWARA.GE. 1.0) GOTO 200
      EFF = RANGE / ITD
      IF (EFF.GE. 1.0) GOTO 700
      CMIN = W3
      ZCAP = CWARA
      GOTO 300
C
  200 EFF = CWARA * RANGE / ITD
      IF ( EFF.GE. 1.0) GOTO 700
      CMIN = W4 * 0.24
      ZCAP = 1.0 / CWARA
C
      IF (CWARA .EQ. 1.0) ANTU = EFF/ (1.-EFF)
      IF(CWARA.NE. 1.0) ANTU = (-ALOG((1.-EFF) / (1.-EFF*ZCAP)))/(1.-
     $ ZCAP)
      RETURN
  300 ANTU = (-ALOG( (1.-EFF)/(1.-EFF*ZCAP)) ) / (1.-ZCAP)
      RETURN
  700 WRITE(6,1) EFF, T1, TD, TTD, CWARA, RANGE
      STOP
      END
```

```
      SUBROUTINE NTU1P (CP, E, Y)
C
C          THIS ROUTINE DETERMINES THE NUMBER OF TRANSFER UNITS FOR A
C          ONE-PASS CROSS-FLOW HEAT EXCHANGER.
C          THE TABULATED DATA OF NTU VERSUS EFFECTIVENESS AND CAPACITY
C          RATIO WAS TAKEN FROM "MEAN TEMPERATURE DIFFERENCE IN COUNTER-
C          CROSS-FLOW HEAT EXCHANGERS", RA STEVENS, MS THESIS,
C          SOUTHERN METHODIST UNIVERSITY, 1956.  THE DATA WERE
C          DETERMINED ANALYTICALLY.
C
      DIMENSION VE(16,11), VC(11), VY(15), PCOL(16)
C
      DATA VC / 0.0, .1, .2, .3, .4, .5, .6, .7 ,.8, .9, 1. /
C
      DATA VY /0.0, .25, .5, .85, 1.00, 1.25, 1.5, 1.75, 2.0, 2.5, 3.0,
     $ 3.5, 4., 5., 6., 7. /
C
      DATA (VE( 1,I),I=1,11)   /
     $ 11 * 0.0 /
      DATA (VE( 2,I),I=1,11) /
     $  .2212, .2188, .2164, .2141, .2117, .2095, .2072, .2050, .2028,
     $  .2007, .1985/
      DATA (VE( 3,I),I=1,11) /
     $  .3935, .3860, .3787, .3716, .3646, .3578, .3512, .3448, .3385,
     $  .3323, .3263/
C
      DATA (VE( 4,I),I=1,11) /
     $  .5728, .5574, .5427, .5285, .5147, .5014, .4885, .4760, .4640,
     $  .4523, .4410/
      DATA (VE( 5,I),I=1,11) /
     $  .6321, .6141, .5966, .5797, .5633, .5475, .5323, .5175, .5033,
     $  .4896, .4763/
      DATA (VE( 6,I),I=1,11) /
     $  .7134, .6916, .6702, .6496, .6296, .6103, .5917, .5737, .5563,
     $  .5396, .5243/
C
      DATA (VE( 7,I),I=1,11) /
     $  .7769, .7522, .7281, .7046, .6819, .6598, .6385, .6179, .5980,
     $  .5788, .5603/
      DATA (VE( 8,I),I=1,11) /
     $  .8259, .8000, .7741, .7487, .7239, .6998, .6763, .6536, .6316,
     $  .6104, .5899/
      DATA (VE( 9,I),I=1,11) /
     $  .8647, .8378, .8109, .7843, .7582, .7325, .7075, .6831, .6594,
     $  .6365, .6143/
C
      DATA (VE(10,I),I=1,11) /
     $  .9179, .8920, .8652, .8379, .8104, .7830, .7559, .7291, .7030,
     $  .6774, .6526/
      DATA (VE(11,I),I=1,11) /
     $  .9502, .9270, .9018, .8753, .8479, .8199, .7917, .7635, .7357,
     $  .7082, .6814/
      DATA (VE(12,I),I=1,11) /
     $  .9698, .9501, .9273, .9024, .8758, .8480, .8194, .7904, .7613,
     $  .7325, .7041/
C
      DATA (VE(13,I),I=1,11) /
```

```
     $  .9817, .9654, .9454, .9225, .8971, .8699, .8414, .8120, .7821,
     $  .7522, .7226/
      DATA (VE(14,I),I=1,11) /
     $  .9933, .9830, .9683, .9495, .9273, .9019, .8742, .8447, .8140,
     $  .7826, .7511/
      DATA (VE(15,I),I=1,11) /
     $  .9975, .9914, .9808, .9661, .9470, .9239, .8975, .8685, .8375,
     $  .8052, .7723/
C
      DATA (VE(16,I),I=1,11) /
     $  .9991, .9955, .9883, .9767, .9605, .9397, .9149, .8866, .8557,
     $  .8229, .7889/
C
C
      C = CR
      IF( CR .GT. 1.) C = 1./C
C
C
C     FIND COLUMNS WHICH BOUND C.
C
      KL = 0
      DO 400 K=1,11
       IF(C.LT.VC(K)) GOTO 410
       KL = K
  400 CONTINUE
C
C
C     GENERATE ARRAY PCOL BY INTERPOLATING BETWEEN VE VALUES IN
C     COLUMNS KL AND KL+1
C
  410 IF(KL.GT.0.0 .AND. KL.LT.11) FACTOR=(C-VC(KL+1))/(VC(KL)-VC(KL+1))
      DO 500 I=1,16
      IF(KL.EQ.0) PCOL(I) = VE(I,1)
       IF(KL .EQ. 11) PCOL(I) = VE(I,KL)
      IF(KL.GT.0 .AND. KL .LT. 11)
     $ PCOL(I) = (VE(I,KL) - VE(I,KL+1) ) * FACTOR +VE(I,KL+1)
  500 CONTINUE
C
C
C     FIND THE POSITION OF PCOL VALUES BOUNDING E
C
      IA = 1
      DO 600 I=1,16
       IF(E .LT. PCOL(I) ) GOTO 610
       IA = I
  600 CONTINUE
C
C
C     THE VY VALUES BOUNDING Y ARE VY(IA) AND VY(IA+1)
C
C     INTERPOLATE BETWEEN VY VALUES TO GET Y
C
  610 FACTOR = (E-PCOL(IA))/(PCOL(IA+1)-PCOL(IA) )
      Y = VY(IA) + (VY(IA+1)-VY(IA)) * FACTOR
      RETURN
      END
```

```
      SUBROUTINE NTU2P (CR, E, Y)
C
C          THIS ROUTINE DETERMINES THE NUMBER OF TRANSFER UNITS FOR A
C          TWO-PASS COUNTER-CROSS-FLOW HEAT EXCHANGER WITH THE WATER
C          SIDE MIXED BETWEEN PASSES.
C          THE TABULATED DATA OF NTU VERSUS EFFECTIVENESS AND CAPACITY
C          RATIO WAS TAKEN FROM "MEAN TEMPERATURE DIFFERENCE IN COUNTER-
C          CROSS-FLOW HEAT EXCHANGERS". RA STEVENS, MS THESIS,
C          SOUTHERN METHODIST UNIVERSITY, 1956.  THE DATA WERE
C          DETERMINED ANALYTICALLY.
C
      DIMENSION VE(15,11), VC(11), VY(15), PCOL(15)
      DATA (VE( 1,I), I=1,11) /
     $11 * 0.0 /
      DATA (VE( 2,I), I=1,11) /
     $  .2212, .2189, .2167, .2145, .2122, .2100, .2079, .2058, .2038,
     $  .2017, .1996/
      DATA (VE( 3,I), I=1,11) /
     $  .3935, .3868, .3801, .3736, .3673, .3610, .3549, .3487, .3428,
     $  .3369, .3312/
C
      DATA (VE( 4,I), I=1,11) /
     $  .5034, .4930, .4828, .4728, .4629, .4532, .4437, .4343, .4252,
     $  .4162, .4074/
      DATA (VE( 5,I), I=1,11) /
     $  .6321, .6172, .6024, .5877, .5732, .5590, .5449, .5311, .5176,
     $  .5043, .4914/
      DATA (VE( 6,I), I=1,11) /
     $  .7275, .7095, .6914, .6734, .6554, .6375, .6198, .6023, .5852,
     $  .5683, .5518/
C
      DATA (VE( 7,I), I=1,11) /
     $  .8173, .7975, .7772, .7564, .7353, .7141, .6929, .6717, .6507,
     $  .6300, .6097/
      DATA (VE( 8,I), I=1,11) /
     $  .8647, .8448, .8239, .8022, .7800, .7571, .7340, .7108, .6877,
     $  .6648, .6421/
      DATA (VE( 9,I), I=1,11) /
     $  .9179, .8996, .8794, .8576, .8346, .8104, .7855, .7600, .7343,
     $  .7085, .6828/
C
      DATA (VE(10,I), I=1,11) /
     $  .9502, .9344, .9160, .8954, .8728, .8485, .8227, .7959, .7684,
     $  .7406, .7127/
      DATA (VE(11,I), I=1,11) /
     $  .9698, .9567, .9407, .9225, .9015, .8780, .8523, .8251, .7965,
     $  .7671, .7374/
      DATA (VE(12,I), I=1,11) /
     $  .9817, .9712, .9575, .9406, .9206, .8977, .8721, .8445, .8152,
     $  .7848, .7538/
C
      DATA (VE(13,I), I=1,11) /
     $  .9933, .9870, .9775, .9645, .9477, .9271, .9030, .8758, .8460,
     $  .8142, .7813/
      DATA (VE(14,I), I=1,11) /
     $  .9975, .9939, .9876, .9779, .9642, .9462, .9239, .8976, .8679,
     $  .8355, .8013/
```

```
      DATA (VE(15,I), I=1,11) /
     $  .9991, .9971, .9930, .9858, .9747, .9592, .9388, .9138, .8845,
     $  .8519, .8166/
C
      DATA VY /0.0, .25, .5, .7, 1., 1.3, 1.7, 2., 2.5, 3., 3.5, 4.,
     $ 5., 6., 7. /
C
      DATA VC / 0.0, .1, .2, .3, .4, .5, .6, .7 ,.8, .9, 1. /
C
      C = CP
      IF( CP .GT. 1.) C = 1./C
C
C
C     FIND COLUMNS WHICH BOUND C.
C
      KL = 0
      DO 400 K=1,11
       IF(C.LT.VC(K)) GOTO 410
       KL = K
  400 CONTINUE
C
C
C     GENERATE ARRAY PCOL BY INTERPOLATING BETWEEN VE VALUES IN
C     COLUMNS KL AND KL+1
C
  410 IF(KL.GT.0.0 .AND. KL.LT.11) FACTOR=(C-VC(KL+1))/(VC(KL)-VC(KL+1))
      DO 500 I=1,15
      IF(KL.EQ.0) PCOL(I) = VE(I,1)
       IF(KL .EQ. 11) PCOL(I) = VE(I,KL)
      IF(KL.GT.0 .AND. KL .LT. 11)
     $ PCOL(I) = (VE(I,KL) - VE(I,KL+1) ) * FACTOR +VE(I,KL+1)
  500 CONTINUE
C
C
C     FIND THE POSITION OF PCOL VALUES BOUNDING E
C
      IA = 1
      DO 600 I=1,15
       IF(E .LT. PCOL(I) ) GOTO 610
       IA = I
  600 CONTINUE
C
C
C     THE VY VALUES BOUNDING Y ARE VY(IA) AND VY(IA+1)
C
C     INTERPOLATE BETWEEN VY VALUES TO GET Y
C
  610 FACTOR = (E-PCOL(IA))/(PCOL(IA+1)-PCOL(IA) )
      Y = VY(IA) + (VY(IA+1)-VY(IA)) * FACTOR
      RETURN
      END
```

```
      SUBROUTINE OUT2(RBP,HRFAC1,SSCD,CASSS1,PLANCT1,PLANC1)
C
C     THIS ROUTINE REPORTS STEAM SUPPLY COSTS DUE TO INCREASED HEAT RATE
C     AT RATING BACKPRESSURE.
C
    1 FORMAT(1H0,T3,"STEAM SUPPLY SCALING TO COMPENSATE FOR INCREASED ",
     $ "HEAT RATE AT RATING BACKPRESS RE.  RBP=",F5.2,T97,"IN. HG",
     $ T113,"HRFAC1=",F11.6)
    2 FORMAT(1H0,T5,"STEAM SUPPLY COST DIFFERENTIAL $",T38,F12.0,
     $ T69,"STEAM SUPPLY UNIT COST",F12.0,"  $/KW")
    3 FORMAT(1X,T3,"PLANT COST INCLUDING STEAM SUPPLY $",T38,F12.0,
     $ T53,"PLANT UNIT COST INCLUDING STEAM SUPPLY  ",T91,F12.3,"$/KW")
      WRITE(6,1) RBP,HRFAC1
      WRITE(6,2) SSCD,CASSS1
      WRITE(6,3) PLANCT1,PLANC1
      RETURN
      END
```

```
      SUBROUTINE OUT4(KWHICH)
C
C     WHEN CALLED WITH KWHICH = 1 THIS ROUTINE REPORTS CONDITIONS AFTER
C                                 SCALING PLANT AND STEAM SUPPLY BUT BE-
C                                 FORE SCALING FOR FANS AND PUMPS
C
C     WHEN CALLED WITH KWHICH NOT 1 THE ROUTINE REPORTS CONDITIONS AFTER
C                                   S ALING FOR FANS AND PUMPS
      LOGICAL FXTLNG
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBUF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHBR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSND, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31,  COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
```

```
      $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
      $,   TL01, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
      $,  CLTC1,  CFC1, CPCC1,FITC01,  CSC1,CEPRE1,DEPIP1,  AST1
      $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
      $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
      $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
      $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
      $,   CSD1, WATER1, WSTRC1, CFDUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
      $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
       COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
      $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
       COMMON /DJB/ DI,XDG,SF
       COMMON /FLSW/ EXTLNG
  901 FORMAT(" CONDITIONS AFTER SCALING PLANT AND STEAM SUPPLY  (BEFORE
     *SCALING FOR FANS AND PUMPS)",T33,"HRFAC2=",G15.7)
  906 FORMAT(1X,T88,"PSIZ12=",G15.7," MW")
  911 FORMAT(1X,T88,"PLANC2=",G15.7," $/KW")
  916 FORMAT(1X,T88," SPBP=", G15.9," $")
  917 FORMAT(1X,T81,"BACK PRESSURE=",G15.7," IN. HG")
  918 FORMAT(1X,T79,"SAT TEMPERATURE=",G15.9," DEG F")
  921 FORMAT(1X,T14,"WATER FLOW RATE ", G15.9, " LB MASS / HR")
  926 FORMAT(1X,T14,"AIR   FLOW RATE ", G15.9, " LB MASS / HR")
  931 FORMAT(1X,T14,"     PUMP POWER ", G15.9, " KILOWATTS")
  936 FORMAT(1X,T14,"     FAN  POWER ", G15.9, " KILOWATTS")
  941 FORMAT(1X,T14,"HX SURFACE AREA ", G15.9, " SQ FT")
  946 FORMAT(1X,T14,"   FRONTAL AREA ", G15.9, " SQ FT")
  951 FORMAT(1X,T11,"WIDTH/LENGTH RATIO ", G15.9)
  956 FORMAT(1X,T15,"          WIDTH ",I11,T45," TUBES")
  961 FORMAT(1X,T15,"          WIDTH ",G15.9," FEET")
  962 FORMAT(1X,T9,"NO. CONDENSER TUBES ",G15.9)
  963 FORMAT(1X,T8,"CONDENSER TUBE LENGTH ",G15.9," FT.")
  964 FORMAT(1X,T15,"WATER VELOCITY ",G15.9," FT/SEC")
  965 FORMAT(1X,T7,"CONDENSER HT TRFR AREA ",G15.9," SQ FT TOTAL")
 1001 FORMAT(1X,"SCALING FOR FAN AND PUMP POWER REQUIREMENTS",
     + T80,"SCALING FACTOR ", G15.9)
 1005 FORMAT(1X,T88," PSIZE ",G15.9," MW")
 1006 FORMAT(1X,T88,"PSIZ13 ", G15.9, " MW")
 1011 FORMAT(1X,T88,"PTOTAL ",G15.9, " MW")
 1016 FORMAT(1X,T88,"PLANC3 ", G15.9," $/KW")
 1021 FORMAT(1X,T88,"   SPC ", G15.9," $")
 1026 FORMAT(1X,T88,"  SPCD ",G15.9," $")
 8888 FORMAT(1H0,12(" ** ** ** ")//)
      WRITE(6,8888)
      WLRTP = WIDT1/ELEN1
      IF(KWH.GE.1) GOTO 2000
      WRITE(6,901) HRFAC2
      WRITE(6,906) ZSIZ12
      WRITE(6,911) ZPLNC2
      WRITE(6,916) ZSPBP
      WRITE(6,917) BP2MIN
      WRITE(6,918)VAR(1)
      WRITE(6,921) W31
      WRITE(6,926) W41
      WRITE(6,931) (PPOW1/(1.+YFPMIN))
      WRITE(6,936) (FPOW1/(1.+YFPMIN))
      WRITE(6,941) (AAIR1/(1.+YFPMIN))
      WRITE(6,946) (AFRO1/(1.+YFPMIN))
```

```
      WRITE(6,951) WLRTP/(1.+YFPMIN)
      WRITE(6,956) NW2MIN
      WRITE(6,961) WT2MIN
      WRITE(6,965) AST1
      WRITE(6,962) XNTS1
      WRITE(6,963) TLA1
      WRITE(6,964) VELD1
      RETURN
 2000 CONTINUE
      WRITE(6,1001) (1.+YFPMIN)
      WRITE(6,1005) PSIZE
      WRITE(6,1006) SPS13
      WRITE(6,1011) PT0T1
      WRITE(6,1016) PLNC31
      WRITE(6,1021) SPC1
      WRITE(6,1026) SPCD1
      WRITE(6,921) SW31
      WRITE(6,926) SW41
      WRITE(6,931) PPOW1
      WRITE(6,936) FPOW1
      WRITE(6,941) AAIR1
      WRITE(6,946) AFRO1
      WRITE(6,951)WLRTP
      WRITE(6,956) NW1
      WRITE(6,961) WIDT1
      WRITE(6,965) AST1  * (1. + YFPMIN)
      WRITE(6,962) XNTS1 * (1. + YFPMIN)
      WRITE(6,963) TLA1
      WRITE(6,964) VELD1
      RETURN
      END
```

```
      SUBROUTINE P50
      COMMON /PIP50 / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
     $, FLGCST(23)
     $ ,EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
      COMMON /CPIPE/ X(230)
C
C          THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
C          PIPCRT FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
C          125 PSI.  THIS DATA IS CALLED BY USING A VALUE OF
C          DPRESS= 125  (DPRESS=PIPING DESIGN PRESSURE) ON CARD G1
C          OF THE INPUT.  THUS, ANY COST DATA CAN BE SUBSTITUTED HERE
C          FOR STUDY PURPOSES.
C
C          DEFINITION OF VARIABLES
C
C          APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
C          DIAM    - COMPONENT DIAMETER (INCHES)
C          EJCST   - EXPANSION JOINT COST ($1000)
C          ELCST   - 90 DEGREE ELBOW COST ($1000)
C          EL45    - 45 DEGREE ELBOW COST ($1000)
C          FLGCST  - FLANGE COST ($1000)
C          PIPCST  - BELOW GROUND PIPE COST ($1000/FT)
C          REDCST  - REDUCER COST ($1000)
C          TEECST  - TEE COST ($1000)
C          VACST   - VALVE COST ($1000). VALVES ARE MOTOR OPERATED
C                    BUTTERFLY VALVES
C
C
C                                  50 PSI
C
      DATA APIPCST /
     $              .056,     .074,     .092,     .112,     .132,
     $    .152,     .240,     .265,     .290,     .322,     .353,
     $    .375,     .396,     .423,     .449,     .470,     .490,
     $    .511,     .681,     .727,     .772,     .812,     .852      /
C
      DATA DIAM/
     $              12.   ,   18.   ,   24.   ,   30.   ,   36.   ,
     $  42.   ,   48.   ,   54.   ,   60.   ,   66.   ,   72.   ,
     $  78.   ,   84.   ,   90.   ,   96.   ,  102.   ,  108.   ,
     $ 114.   ,  120.   ,  126.   ,  132.   ,  138.   ,  144.      /
C
      DATA EJCST/
     $              .560,    1.11 ,    1.66 ,    2.17 ,    2.69 ,
     $   4.24 ,    5.80 ,    7.24 ,    8.69 ,   10.1  ,   11.5  ,
     $  14.0  ,   16.5  ,   19.8  ,   23.2  ,   25.9  ,   30.6  ,
     $  34.1  ,   37.7  ,   41.2  ,   44.7  ,   48.2  ,   51.7      /
      DATA ELCST/
     $              .437,     .999,    1.56 ,    2.12 ,    2.68 ,
     $   3.24 ,    7.05 ,   12.0  ,   16.9  ,   20.3  ,   23.6  ,
     $  27.4  ,   31.1  ,   34.9  ,   38.7  ,   43.1  ,   47.4  ,
     $  51.7  ,   74.8  ,   77.9  ,   80.9  ,   88.0  ,   95.1      /
C
      DATA EL45/
     $              .300,     .670,    1.03 ,    1.37 ,    1.71 ,
     $   2.05 ,    4.77 ,    8.94 ,   13.1  ,   15.4  ,   17.6  ,
     $  20.0  ,   22.4  ,   25.0  ,   27.6  ,   30.6  ,   33.6  ,
```

```
      $  35.6  ,   51.9  ,   56.4  ,   60.9  ,   65.0  ,   69.0        /
C
      DATA FLGCST/
      $              .342,     .618,     .893,     1.15 ,    1.40 ,
      $   1.93 ,    2.47 ,    3.22 ,    3.97 ,    5.55 ,    7.13 ,
      $   9.82 ,   12.5  ,   14.7  ,   17.0  ,   20.5  ,   24.0  ,
      $  25.6  ,   27.3  ,   28.9  ,   30.6  ,   32.2  ,   33.9        /
C
      DATA PIPCST/
      $              .096,     .127,     .157,     .189,     .221,
      $    .253,    .363,     .402,     .441,     .472,     .503,
      $    .548,    .593,     .634,     .675,     .697,     .719,
      $    .741,    .963,    1.03 ,    1.09 ,    1.17 ,    1.24        /
C
      DATA REDCST/
      $              .365,     .455,     .545,     .798,    1.05 ,
      $   1.38 ,    1.55 ,    2.91 ,    4.26 ,    4.99 ,    5.71 ,
      $   5.95 ,    8.19 ,    8.37 ,    8.55 ,   12.7  ,   16.8  ,
      $  20.9  ,   35.9  ,   42.9  ,   49.9  ,   56.9  ,   63.8        /
      DATA TEECST/
      $              .494,    1.29 ,    2.09 ,    2.59 ,    3.08 ,
      $   3.57 ,    7.37 ,   12.1  ,   16.8  ,   20.1  ,   23.3  ,
      $  25.1  ,   26.8  ,   31.0  ,   35.2  ,   39.1  ,   43.0  ,
      $  46.9  ,   68.6  ,   74.9  ,   81.2  ,   87.8  ,   94.4        /
C
      DATA VACST/
      $              3.64 ,    6.16 ,    8.67 ,   11.2  ,   13.8  ,
      $  17.4  ,   21.0  ,   27.7  ,   34.3  ,   37.4  ,   40.4  ,
      $  45.0  ,   51.7  ,   58.6  ,   65.6  ,   70.5  ,   75.5  ,
      $  80.5  ,   85.5  ,   90.6  ,   95.6  ,  101.   ,  106.        /
C
      DO 40 I=1,230
      X(I) = APIPCST(I)
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE P75
      COMMON /PIP75 / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
     $, FLGCST(23)
     $ ,EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
      COMMON /CPIPE/ X(230)
C
C          THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
C          PIPCRT FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
C           75 PSI.  THIS DATA IS CALLED BY USING A VALUE OF
C          DPRESS=  75  (DPRESS=PIPING DESIGN PRESSURE) ON CARD G1
C          OF THE INPUT.  THUS, ANY COST DATA CAN BE SUBSTITUTED HERE
C          FOR STUDY PURPOSES.
C
C          DEFINITION OF VARIABLES
C
C          APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
C          DIAM    - COMPONENT DIAMETER (INCHES)
C          EJCST   - EXPANSION JOINT COST ($1000)
C          ELCST   - 90 DEGREE ELBOW COST ($1000)
C          EL45    - 45 DEGREE ELBOW COST ($1000)
C          FLGCST  - FLANGE COST ($1000)
C          PIPCST  - BELOW GROUND PIPE COST ($1000/FT)
C          REDCST  - REDUCER COST ($1000)
C          TEECST  - TEE COST ($1000)
C          VACST   - VALVE COST ($1000), VALVES ARE MOTOR OPERATED
C                    BUTTERFLY VALVES
C
C
C                                  75 PSI
C
      DATA APIPCST/
     $              .056,     .074,     .092,     .112,     .132,
     $    .152,     .240,     .265,     .290,     .322,     .353,
     $    .385,     .471,     .501,     .530,     .576,     .622,
     $    .652,     .681,     .711,     .879,     .922,     .965      /
C
      DATA DIAM/
     $             12.    ,  18.    ,  24.    ,  30.    ,  36.    ,
     $  42.    ,  48.    ,  54.    ,  60.    ,  66.    ,  72.    ,
     $  78.    ,  84.    ,  90.    ,  96.    , 102.    , 108.    ,
     $ 114.    , 120.    , 126.    , 132.    , 138.    , 144.      /
C
      DATA EJCST/
     $              .560,    1.11 ,    1.66 ,    2.17 ,    2.69 ,
     $   4.24 ,    5.80 ,    7.24 ,    8.59 ,   10.1  ,   11.5  ,
     $  14.0  ,   16.5  ,   19.8  ,   23.2  ,   26.9  ,   30.6  ,
     $  34.1  ,   37.7  ,   41.2  ,   44.7  ,   48.2  ,   51.7      /
      DATA ELCST/
     $              .437,    1.00 ,    1.56 ,    2.12 ,    2.68 ,
     $   3.24 ,    7.05 ,   12.0  ,   16.9  ,   20.3  ,   23.6  ,
     $  27.0  ,   39.2  ,   43.9  ,   48.6  ,   53.7  ,   58.7  ,
     $  66.8  ,   74.8  ,   82.9  ,   97.0  ,  106.   ,  114.    /
C
      DATA EL45/
     $              .300,     .665,    1.03 ,    1.37 ,    1.71 ,
     $   2.05 ,    4.77 ,    8.94 ,   13.1  ,   15.4  ,   17.6  ,
     $  19.9  ,   28.8  ,   32.1  ,   35.3  ,   38.9  ,   42.5  ,
```

```
      $  47.2  ,   51.9  ,   56.6  ,   74.3  ,   79.3  ,   84.3        /
C
      DATA FLGCST/
      $                .342,    .618,    .893,   1.15 ,   1.40 ,
      $   1.93 ,   2.47 ,   3.22 ,   3.97 ,   5.55 ,   7.13 ,
      $   9.82 ,  12.5  ,  14.7  ,  17.0  ,  20.5  ,  24.0  ,
      $  25.6  ,  27.3  ,  28.9  ,  30.6  ,  32.2  ,  33.9        /
C
      DATA PIPCST/
      $                .096,    .127,    .157,    .189,    .221,
      $    .253,       .363,    .402,    .441,    .472,    .503,
      $    .534,       .669,    .713,    .757,    .816,    .874,
      $    .919,       .963,   1.08 ,   1.19 ,   1.28 ,   1.36        /
C
      DATA REDCST/
      $                .365,    .455,    .545,    .798,   1.05 ,
      $   1.36 ,   1.55 ,   2.91 ,   4.26 ,   4.99 ,   5.71 ,
      $   5.95 ,  10.9  ,  11.1  ,  11.3  ,  16.3  ,  21.2  ,
      $  28.6  ,  35.9  ,  43.3  ,  62.5  ,  71.2  ,  79.9        /
      DATA TEECST/
      $                .494,   1.29 ,   2.09 ,   2.59 ,   3.08 ,
      $   3.57 ,   7.37 ,  12.1  ,  16.8  ,  20.1  ,  23.3  ,
      $  25.1  ,  38.0  ,  41.5  ,  45.0  ,  49.7  ,  54.3  ,
      $  61.5  ,  68.6  ,  75.8  ,  99.1  ,  107.  ,  115.        /
C
      DATA VACST/
      $                3.64 ,   6.16 ,   8.67 ,  11.2  ,  13.8  ,
      $  17.4  ,  21.0  ,  27.7  ,  34.3  ,  37.4  ,  40.4  ,
      $  45.0  ,  51.7  ,  58.6  ,  65.6  ,  70.5  ,  75.5  ,
      $  80.5  ,  85.5  ,  90.6  ,  95.6  ,  101.  ,  106.        /
C
      DO 40 I=1,230
      X(I) = APIPCST(I)
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE P125
      COMMON /PIP125/ APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
     $, FLGCST(23)
     $ ,EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
      COMMON /CPIPE/ X(230)
C
C          THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
C          PIPCRT FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
C           50 PSI.  THIS DATA IS CALLED BY USING A VALUE OF
C          DPRESS= 50   (DPRESS=PIPING DESIGN PRESSURE) ON CARD G1
C          OF THE INPUT.  THUS, ANY COST DATA CAN BE SUBSTITUTED HERE
C          FOR STUDY PURPOSES.
C
C          DEFINITION OF VARIABLES
C
C          APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
C          DIAM    - COMPONENT DIAMETER (INCHES)
C          EJCST   - EXPANSION JOINT COST ($1000)
C          ELCST   - 90 DEGREE ELBOW COST ($1000)
C          EL45    - 45 DEGREE ELBOW COST ($1000)
C          FLGCST  - FLANGE COST ($1000)
C          PIPCST  - BELOW GROUND PIPE COST ($1000/FT)
C          REDCST  - REDUCER COST ($1000)
C          TEECST  - TEE COST ($1000)
C          VACST   - VALVE COST ($1000); VALVES ARE MOTOR OPERATED
C                    BUTTERFLY VALVES
C
C
C                                  125 PSI
C
      DATA APIPCST/
     $              .056,     .074,     .092,     .110,     .168,
     $    .204,     .240,     .276,     .350,     .386,     .421,
     $    .457,     .555,     .653,     .718,     .787,     .822,
     $    .858,     .893,     .928,    1.11 ,    1.16 ,    1.21      /
C
      DATA DIAM/
     $            12.   ,   18.   ,   24.   ,   30.   ,   36.   ,
     $  42.   ,   48.   ,   54.   ,   60.   ,   66.   ,   72.   ,
     $  78.   ,   84.   ,   90.   ,   96.   ,  102.   ,  108.   ,
     $ 114.   ,  120.   ,  126.   ,  132.   ,  138.   ,  144.      /
C
      DATA EJCST/
     $              .560,    1.11 ,    1.66 ,    2.17 ,    2.69 ,
     $   4.24 ,    5.80 ,    7.24 ,    8.69 ,   10.1  ,   11.5  ,
     $  14.0  ,   16.5  ,   19.8  ,   23.2  ,   26.9  ,   30.6  ,
     $  34.1  ,   37.7  ,   41.2  ,   44.7  ,   48.2  ,   51.7      /
      DATA ELCST/
     $              .437,     .999,    1.56 ,    2.12 ,    3.47 ,
     $   5.26 ,    7.05 ,    8.84 ,   21.5  ,   25.7  ,   29.9  ,
     $  34.1  ,   47.6  ,   62.8  ,   69.4  ,   76.1  ,   82.7  ,
     $  93.9  ,  105.   ,  116.   ,  130.   ,  141.   ,  152.      /
C
      DATA EL45/
     $              .300,     .665,    1.03 ,    1.40 ,    2.33 ,
     $   3.55 ,    4.77 ,    5.99 ,   15.0  ,   18.9  ,   22.7  ,
     $  26.6  ,   35.5  ,   45.7  ,   51.7  ,   56.7  ,   61.7  ,
```

```
      $  65.0  ,   68.3  ,   71.6  ,  102.   ,  109.   ,  116.        /
C
      DATA FLGCST/
      $              .342,     .618,     .893,    1.15 ,    1.40 ,
      $   1.93 ,    2.47 ,    3.22 ,    3.97 ,    5.55 ,    7.13 ,
      $   9.85 ,   12.5  ,   14.7  ,   17.0  ,   20.5  ,   24.0  ,
      $  25.6  ,   27.3  ,   28.9  ,   30.6  ,   32.2  ,   33.9        /
C
      DATA PIPCST/
      $              .096,     .127,     .157,     .188,     .257,
      $    .310,     .363,     .416,     .501,     .537,     .572,
      $    .617,     .753,     .884,     .946,    1.01 ,    1.07 ,
      $   1.13 ,    1.18 ,    1.23 ,    1.43 ,    1.52 ,    1.60        /
C
      DATA REDCST/
      $              .355,     .455,     .545,     .635,    1.55 ,
      $   2.44 ,    3.33 ,    4.22 ,    5.63 ,    6.61 ,    7.58 ,
      $   8.56 ,   13.9  ,   15.9  ,   17.8  ,   24.3  ,   30.8  ,
      $  46.5  ,   62.1  ,   77.7  ,   88.5  ,  101.   ,  113.        /
C
      DATA TEECST/
      $              .494,    1.29 ,    2.09 ,    2.89 ,    4.22 ,
      $    5.86 ,    7.37 ,    5.95 ,   21.9  ,   26.0  ,   30.1  ,
      $   34.2  ,   47.0  ,   59.8  ,   66.2  ,   72.7  ,   79.1  ,
      $   89.4  ,   99.7  ,  110.   ,  136.   ,  147.   ,  157.        /
C
      DATA VACST/
      $              3.64 ,    6.16 ,    8.67 ,   11.2  ,   13.8  ,
      $   17.4  ,   21.0  ,   27.7  ,   34.3  ,   37.4  ,   40.4  ,
      $   45.0  ,   51.7  ,   58.6  ,   65.6  ,   70.5  ,   75.5  ,
      $   80.5  ,   85.5  ,   90.6  ,   95.6  ,  101.   ,  106.        /
C
      DO 40 I=1,230
      X(I) = APIPCST(I)
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PIPCRT (TS, W3, TTD, TR, TOWERD, DELHX, DELCON, DIST,
     $                   DESVEL, REDUCE, DREDUCE, BUNWIDT, TUBDEP,
     $                   TRANPIT, COST, NCTOW, PDP, EPDP, HPWAT,
     $                   RHO, CDANG, POHCIR, POHLEC, EFFP)
C
C     THIS SUBROUTINE DESIGNS AND COSTS THE PIPING SYSTEM. THE PIP-
C     ING SYSTEM INCLUDES ALL THE PIPE, VALVES, PUMPS AND FITTINGS
C     BETWEEN THE CONDENSER AND THE HEAT EXCHANGER.  PIPE DIAMETER
C     IS DETERMINED FROM THE WATER FLOW RATE AND THE DESIGN
C     VELOCITY.  VALVE AND FITTING SIZES CORRESPOND TO THE PIPE
C     SIZES WITH THE SAME FLOW RATE.  THE PUMPS ARE SIZED
C     ACCORDING TO TOTAL FLOW RATE AND TOTAL DYNAMIC HEAD.
C
C     THE SUPPLY AND RETURN PIPING DESIGNS ARE IDENTICAL ALTHOUGH
C     DIFFERENCES IN WATER PROPERTIES ARE ACCOUNTED FOR IN THE HEAD
C     LOSS AND PRESSURE DROP.  COSTS FOR SUBSYSTEMS OF THE PIPING
C     ARE MULTIPLIED BY A FACTOR OF TWO TO ACCOUNT FOR BOTH THE
C     SUPPLY AND RETURN PIPING.  THE PUMP STATION IS PROVIDED IN
C     THE RETURN PIPING ONLY.  THE COST AND PRESSURE DROP OF THE
C     RETURN PIPING ACCOUNTS FOR THE LENGTH OF THE PUMP STATION
C     WHICH IS ASSUMED TO BE 50 FEET.
C
C     DEFINITION OF VARIABLES
C
C     BUNGPM  - WATER FLOW RATE TO EACH TUBE BUNDLE (GPM)
C     BUNWIDT - TUBE BUNDLE WIDTH (FT)
C     COST    - TOTAL COST OF WATER CIRCULATION PIPING SYSTEM
C               ($1000)
C     CPGP    - PIPING COST PER TOWER GROUP ($1000)
C     CPTOW   - PIPING COST PER TOWER ($1000)
C     CTOW    - NUMBER OF CIRCULAR TOWERS
C     DELCON  - PRESSURE DROP IN CONDENSER (PSF)
C     DELFIT  - PRESSURE DROP IN BUNDLE FITTINGS (PSF)
C     DELHX   - PRESSURE DROP IN HEAT EXCHANGER (PSF)
C     DELPUMP - PRESSURE DROP IN PUMP STATION PIPING (PSF)
C     DELRET  - PRESSURE DROP IN WATER CIRCULATION PIPING, RETURN
C               SYSTEM (PSF)
C     DELSUP  - PRESSURE DROP IN WATER CIRCULATION PIPING,
C               SUPPLY SYSTEM (PSF)
C     DELSURE - TOTAL PRESSURE DROP IN WATER CIRCULATION PIPING
C               (PSF)
C     DELTD   - PRESSURE DROP IN TOWER PIPING (PSF)
C     DESVEL  - PIPING SYSTEM WATER DESIGN VELOCITY (FT/SEC)
C     DIAD    - DIAMETER OF DISTRIBUTION PIPING (INCHES)
C     DIAH    - DIAMETER OF PIPE COMPONENTS FOR MAIN CIRCULATION
C               HEADER (INCHES)
C     DIAQ    - DIAMETER OF PIPE COMPONENTS OF QUADRANT
C               HEADER (INCHES)
C     DIAT    - DIAMETER OF TOWER PIPING (INCHES)
C     DIST    - DISTANCE FROM CONDENSER OUTLET TO BOUNDARY OF
C               TOWER GROUP (FT)
C     DSGTM   - DISTANCE FROM ELECTRIC SWITCH GEAR TO PUMP MOTOR
C               (FT)
C
C     DYNHEAD - DYNAMIC HEAD SEEN BY PUMPS (FT OF WATER)
C     EFFP    - PUMP EFFICIENCY (DECIMAL FRACTION)
C     EJCST   - EXPANSION JOINT COST ($1000)
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C          ELCST   - 90 DEGREE ELBOW COST ($1000)
C          EL45    - 45 DEGREE ELBOW COST ($1000)
C          EQLEN   - EQUIVALENT LENGTH (FT)
C          EQLEND  - EQUIVALENT LENGTH OF DISTRIBUTION PIPING (FT)
C          EQLENT  - EQUIVALENT LENGTH OF TOWER PIPING (FT)
C          EQLFIT  - EQUIVALENT LENGTH OF BUNDLE FITTINGS (FT)
C          EQLPUMP - EQUIVALENT LENGTH OF PIPE IN PUMP STATION (FT)
C          FLGCST  - FLANGE COST ($1000)
C          FRG     - FLOW TO COMPLETE TOWER GROUPS (LBM/HR)
C          GRCST   - COST OF PIPING FOR MAIN CIRCULATION HEADERS ($1000)
C          GRGPM   - FLOW RATE TO COMPLETE TOWER GROUPS (GPM)
C          GRMCIRC - FLOW RATE TO EACH CIRCULAR TOWER (GPM)
C          GRMMAX  - MAXIMUM FLOW RATE THAT CAN BE TRANSPORTED THROUGH
C                    LARGEST DIAMETER PIPE AVAILABLE AT THE GIVEN DESIGN
C                    VELOCITY (GPM)
C          GRMTOT  - TOTAL WATER FLOW RATE (GPM)
C          HEAD    - HEAD LOSS (FT OF WATER/100 FT OF EQUIVALENT LENGTH)
C          HEAD1,2 - HEAD LOSS FOR EQLEND, SUPPLY (1) AND RETURN(2),
C                    (FT/100 FT)
C          HEAT1,2 - HEAD LOSS FOR EQLENT, SUPPLY (1) AND RETURN (2),
C                    (FT/100 FT)
C          HEDR    - LENGTH OF MAIN CIRCULATION HEADER SECTIONS (FT)
C          HRPPMP  - HORSE POWER PER PUMP (HP)
C          HRWAT   - REQUIRED PUMP HORSE POWER (HP)
C          IPRESS  - PIPING COMPONENT DESIGN PRESSURE (PSI)
C          NBUNPQD - TUBE BUNDLES PER QUADRANT
C          NCTOW   - CTOW
C          NFL     - UPPER LIMIT FOR NUMBER OF TOWERS OR TUBE BUNDLES
C                    PER QUADRANT
C          NFS     - NUMBER OF POSITIONS IN UNIT COST ARRAYS
C          NPMP    - TOTAL NUMBER OF PUMPS
C          NPX     - NUMBER OF PUMPS SERVING EXTRA TOWER GROUP
C          NTOWGPS - NUMBER OF COMPLETE TOWER GROUPS
C          NTOWPGP - NUMBER OF TOWERS PER GROUP
C          NTUBPBU - NUMBER OF TUBES PER BUNDLE
C          PDIA    - DIAMETER OF PUMP STATION PIPING COMPONENTS (INCHES)
C          PDP     - PRESSURE DROP IN PIPING SYSTEM (PSF)
C          PIPCOST - COST OF STRAIGHT PIPE FOR ONE HEADER SECTION OF
C                    MAIN CIRCULATION PIPING ($1000)
C          PISCOS  - TOTAL PIPING SYSTEM COST ($1000)
C          PMELEC  - PUMP MOTOR ELECTRIC COST ($)
C          PDHCIR  - INDIRECT COST FACTOR FOR CIRCULATION PIPING
C          PDHLEC  - INDIRECT COST FACTOR FOR ELECTRICAL REQUIREMENTS
C          PROP    - WATER PROPERTIES ARRAY
C          PSTACST - COST OF PUMP STATION FOR COMPLETE TOWER GROUP-
C                    PIPING AND PUMPS ($1000)
C          PUFITS  - COST OF PIPING COMPONENTS IN PUMP STATION OF
C                    COMPLETE TOWER GROUP ($1000)
C          PUMPCST - PUMP COSTS FOR COMPLETE TOWER GROUP ($1000)
C          QDELR,S,SR - PRESSURE DROP IN QUADRANT HEADER RETURN (R),
C                    SUPPLY (S), SUPPLY AND RETURN (SR) (PSF)
C          QELCST  - COST OF ELBOW ON LAST QUADRANT HEADER SECTION
C                    ($1000)
C          QHDCST  - TOTAL COST OF QUADRANT HEADER PIPING COMPONENTS
C                    ($1000)
C          QHEDR   - LENGTH OF SECTION OF QUADRANT HEADER (FT)
C          QPIPCST - COST OF STRAIGHT PIPE FOR ONE QUADRANT HEADER
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C                 SECTION ($1000)
C         QRDCST  - QUADRANT REDUCER COST ($1000)
C         QREDUCE - VALUE OF ALLOWABLE REDUCTION IN PIPE DIAMETER
C                   BETWEEN ADJACENT QUADRANT HEADER SECTIONS.  CAN BE
C                   ZERO OR MULTIPLE OF SIX (INCHES)
C         QTECST  - QUADRANT TEE COST ($1000)
C         QTPCST  - PIPE COMPONENTS COST FOR ONE QUADRANT
C                   HEADER ($1000)
C         QUADGPM - FLOW RATE TO ONE QUADRANT (GPM)
C         REDCOST - REDUCER COST ($1000)
C         REDUCE  - VALUE OF ALLOWABLE REDUCTION IN PIPE DIAMETER
C                   BETWEEN ADJACENT HEADER SECTIONS OF MAIN CIRCULA-
C                   TION PIPING.  CAN BE ZERO OR MULTIPLE OF SIX
C                   (INCHES)
C         RHO,1,2 - DENSITY OF WATER AVERAGE, SUPPLY (1), RETURN (2)
C                   (LBM/CU FT)
C         TDCST   - DISTRIBUTION AND TOWER PIPING COSTS ($1000)
C         TF      - WATER TEMPERATURE LEAVING CONDENSER (DEG F)
C         TEECOST - TEE COST ($1000)
C         TGPCST  - TOTAL COST OF MAIN CIRCULATION HEADERS ($1000)
C         TH2O    - WATER TEMPERATURE (DEG F)
C         TI      - WATER TEMPERATURE ENTERING CONDENSER (DEG F)
C         TOWDIA  - TOWER DIAMETER (FT)
C         TPCST   - TOTAL COST OF PUMP STATIONS ($1000)
C         TQDCST  - TOTAL COST OF QUADRANT HEADERS ($1000)
C         TR      - TEMPERATURE RANGE OF WATER (DEG F)
C         TRANPIT - TRANSVERSE TUBE PITCH (INCHES)
C         TRTRMA, - TERMS IN PUMP ELECTRIC CHARGES DETERMINED BY
C         TRMB,     EMPIRICAL COST CORRELATIONS
C         TRMC
C         TS      - STEAM SATURATION TEMPERATURE (DEG F)
C         TTD     - CONDENSER TERMINAL TEMPERATURE DIFFERENCE (DEG F)
C         TTDCST  - TOTAL COST OF TOWER DISTRIBUTION PIPING ($1000)
C         TUBDEP  - HEAT EXCHANGER TUBE ROWS IN DIRECTION OF AIR FLOW
C         UNIPCST - UNIT COST OF STRAIGHT PIPE ($/FT)
C         VACST   - VALVE COST ($1000)
C         VEL0    - ACTUAL WATER VELOCITY (FT/SEC)
C         VELOCIT - ACTUAL VELOCITY IN BUNDLE FITTINGS OR PUMP STATION
C                   PIPING (FT/SEC)
C         VELOD   - ACTUAL VELOCITY IN DISTRIBUTION PIPING (FT/SEC)
C         VELOT   - ACTUAL VELOCITY IN TOWER PIPING (FT/SEC)
C         VIS,1,2 - WATER VISCOSITY AVERAGE, SUPPLY(1),RETURN(2),
C                   (LBM/FT HR)
C         VM      - PUMP MOTOR VOLTAGE (VOLTS)
C         VS      - PUMP SYSTEM VOLTAGE (VOLTS)
C         W3      - CIRCULATION WATER FLOW RATE (LBM/HR)
C         XTOW    - CTOW
C
C         VARIABLES APPLYING TO EXTRA TOWER GROUP WITH COUNTERPARTS
C         FOR COMPLETE TOWER GROUPS
C
C         EDELPMP - DELPUMP
C         EDELSR  - DELSURE
C         EDYNHD  - DYNHEAD
C         EFJCST  - EJCST
C         EFLGCST - FLGCST
C         EGPCST  - GPCST
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C          EPDIA   - PDIA
C          EPDP    - PDP
C          EPMPCST - PUMPCST
C          EPCST   - PSTACST
C          EPUFITS - PUFITS
C          EXCST   - CPGP
C          EXFLO   - FPG
C          EXGPM   - GPGPM
C          NEXTOW  - NTOWPGP
C
      DIMENSION VELO(200), UPIPCST(200)
      COMMON /CPIPE / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
     $, FLGCST(23)
     $ ,ELMS(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
      COMMON /PRESS/ IPRESS
      COMMON /PH2O/ TH2O(16), PROP(15,2)
      LOGICAL CALL 1
      COMMON /RPRT1/
     $  RUNGPM
     $ ,DYNHEAD ,DIAD ,DIAT ,DIAH(200) ,DIAQ(200)
     $ ,EPSCST ,EGPCST ,EPMPCST ,EPUFITS ,EDYNHD ,EXGPM ,EJCOST ,ELCOST
     $ ,FLGCST
     $ ,GPMCTRC ,GPGPM ,GPCST
     $ ,HEDR(200)
     $ ,JSAVE
     $ ,LSAVE
     $ ,NTUBRBU ,NBUNPRD ,NTOWGPS ,NTOWPGP ,NEXTOW
     $ ,PSTACST ,PUFITS ,PUMPCST ,PIPCOST(200) ,PISCOS
     $ ,QHDCST ,QUADGPM ,QPIPCST(200) ,QHEDR(200) ,QTECST(200)
     $ ,QRDCST(200), QELCST
     $ ,REDCOST(200), RPTPL
     $ ,TEECOST(200) ,TPCST ,TDCST ,TTDCST ,TGPCST ,TOWDIA ,TRDCST
     $ ,XTOW
      COMMON /PME/ PMELEC
      DATA CALL 1 /.TRUE./
      DATA DSGTM /100./
      DATA NFS /23/ , NFL /200/
C
C
C          CALL THE APPROPRIATE SUBROUTINE TO ESTABLISH UNIT COST DATA
C          FOR THE PIPING SYSTEM COMPONENTS.
C
      IF (CALL 1  .AND. IPRESS .EQ.  50) CALL P50
      IF (CALL 1  .AND. IPRESS .EQ.  75) CALL P75
      IF (CALL 1  .AND. IPRESS .EQ. 125) CALL P125
      CALL 1 = .FALSE.
      XTOW = NCTOW
      CTOW = NCTOW
      TOWDIA = TOWERD
      DO 1 I=1,NFL
    1 REDCOST(I)=0.
      TE=TS-TTD
C
C          USE WATER TEMPERATURE TO GET WATER PROPERTIES.
C
      TI=TE-TR
      VISI=TLU(TE,TH2O,PROP(1,2),15)
```

```
      RHO1=TLU(TE,TH2O,PROP,16)
      VIS2=TLU(TI,TH2O,PROP(1,2),16)
      RHO2=TLU(TI,TH2O,PROP,16)
      RHO=(RHO1+RHO2)/2.
      VIS=(VIS1+VIS2)/2.
      GPMTOT = W3/(60.*RHO/7.481)
      NTUBPBU=12.*BUNWIDT*TUBDEP/TRANPIT
      CONST1=(3.1416/4.)*7.481*60.*DESVEL
      CONST2=(4./3.1416)*144./(60.*7.481)
      GPMCIRC=GPMTOT/CTOW
      GPMMAX = (DIAM(NFS)**2/144.) * CONST1
      NTOWPGP=GPMMAX/GPMCIRC
C
C           IF THE FLOW TO ONE TOWER EXCEEDS THE FLOW THAT CAN BE
C           TRANSPORTED THROUGH THE LARGEST DIAMETER PIPE THEN REJECT
C           THIS DESIGN CONDITION.
C
C           A TOWER GROUP CONSISTS OF ALL THE TOWERS SUPPLIED BY A SINGLE
C           MAIN CIRCULATION PIPING HEADER.  THE NUMBER OF TOWERS PER
C           GROUP (NTOWPGP) CANNOT EXCEED THE MAXIMUM FLOW AVAILABLE IN
C           THE LARGEST PIPE DIAMETER DIVIDED BY THE FLOW PER TOWER
C           (GPMCIRC).
C
      IF( NTOWPGP .LT. 1) COST = 1.E+40
      IF(NTOWPGP .LT. 1) WRITE(6,6767)
 6767 FORMAT("0IN PIPING ROUTINE NUMBER OF TOWERS PER GROUP =0 WAS
     $ REJECTED")
      IF( NTOWPGP .LT. 1) RETURN
      IF(NTOWPGP.GT.CTOW) NTOWPGP=CTOW  +1.E-40
      NTOWGPS=CTOW/NTOWPGP
C
C           IF THE NUMBER OF CIRCULAR TOWERS EXCEEDS THE NUMBER OF TOWERS
C           PER GROUP AND IS NOT AN EVEN MULTIPLE OF THE NUMBER OF TOWERS
C           PER GROUP (E.G.-NCTOW=12, NTOWPGP=5) THEN A SEPARATE MAIN
C           CIRCULATION HEADER AND PUMP STATION IS DESIGNED FOR THE
C           NUMBER OF EXTRA TOWERS (NEXTOW, IN THIS CASE NEXTOW=2) AND
C           THE TOTAL FLOW TO THOSE EXTRA TOWERS (EXGPM).  THIS SO
C           CALLED "EXTRA TOWER GROUP" WILL BE DIFFERENT FROM THE MAIN
C           TOWER GROUPS ONLY WITH RESPECT TO THE NUMBER OF TOWERS IN
C           THE GROUP AND THE SIZE OF MAIN CIRCULATION PIPING.  ALL THE
C           PIPING ASSOCIATED WITH THE TOWER PIPING AND QUADRANT PIPING
C           IS UNAFFECTED BY THE EXTRA TOWER PROBLEM.  THE LENGTH OF
C           THE MAIN CIRCULATION HEADER SECTIONS IS ALSO UNAFFECTED.
C           SINCE THERE IS LESS TOTAL FLOW TO THE EXTRA GROUP THE PIPE
C           DIAMETER OF THE EXTRA GROUP MAIN CIRCULATION HEADER IS
C           SMALLER AND THE PUMP STATION REQUIREMENTS ARE REDUCED.
C
      NEXTOW=CTOW-NTOWPGP*NTOWGPS
      EXGPM=NEXTOW*GPMCIRC
      GPGPM=NTOWPGP*GPMCIRC
      QUADGPM=GPMCIRC/4.
      NBUNPQD = (TOWDIA*3.14159)/(4. * BUNWIDT * COANG) +1.
      BUNGPM=QUADGPM/NBUNPQD
C
C           SIZE THE DISTRIBUTION PIPING.
C
      DIAD=SQRT(GPMCIRC/CONST1)*12.
```

```
      DO 10 NT = 1,NFS
      ID = NT
      IF(DIAD-DIAM(ID))11,11,10
   10 CONTINUE
C
C          SIZE THE TOWER PIPING.
C
   11 DIAD=DIAM(ID)
      DIAT=SQRT(QUADGPM/CONST1)*12.
      DO 12 NT = 1,NFS
      IT = NT
      IF(DIAT-DIAM(IT))13,13,12
   12 CONTINUE
   13 DIAT=DIAM(IT)
C
C          DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE DISTRIBUTION
C          AND TOWER PIPING.     THIS INCLUDES THE PIPING FROM THE MAIN
C          CIRCULATION HEADER TO THE QUADRANT HEADER.
C
      EQLEND=.2*TOWDIA+200.*DIAD/12.
      VELOD=(GPMCIRC/DIAD**2)*CONST2
      EQLENT=TOWDIA+60.*DIAT/12.
      VELOT=(QUADGPM/DIAT**2)*CONST2
      CALL HYDLOS(DIAD,VELOD,VIS1,RHO1,2,HEAD1)
      CALL HYDLOS(DIAD,VELOD,VIS2,RHO2,2,HEAD2)
      CALL HYDLOS(DIAT,VELOT,VIS1,RHO1,2,HEAT1)
      CALL HYDLOS(DIAT,VELOT,VIS2,RHO2,2,HEAT2)
      DELTD=(EQLEND*(HEAD1*RHO1+HEAD2*RHO2)+EQLENT*(HEAT1*RHO1+HEAT2*
     $RHO2))/100.
C
C          DETERMINE THE COST OF THE DISTRIBUTION AND TOWER PIPING.
C
C          THE DISTRIBUTION AND TOWER PIPING COST (TDCST) INCLUDES THE
C          LENGTH OF PIPE (.2*TOWDIA) CONNECTING THE MAIN CIRCULATION
C          HEADER TO THE TOWER DISTRIBUTION HEADER AND THE PIPE
C          CONNECTING THE TOWER DISTRIBUTION HEADER TO THE QUADRANT
C          HEADERS (ASSUMED TO TOTAL 3.25*TOWDIA).  THE TOWER DISTRIBU-
C          TION HEADER IS COSTED AS FOUR PIPE TEES.  THE TEE IS COSTED
C          AS .67 TIMES THE COST OF A TEE OF THE "RUN" DIAMETER PLUS
C          .33 TIMES THE COST OF A TEE OF THE "BRANCH" DIAMETER.
C
      TDCST=.2*TOWDIA*PIPCST(ID)+4.*(.67*TEECST(ID)+.33*TEECST(IT))
     $+3.25*TOWDIA*PIPCST(IT)+10.*ELCST(IT)+2.*EL45(IT)+4.*VACST(IT)
     $+8.*FLGCST(IT)
      TDCST=2.*TDCST
C
C          DESIGN AND COST THE QUADRANT PIPING.
C
      CALL HEADER(QUADGPM,NBUNPQD,BUNGPM,QREDUCE,1,L,DIAQ,QRDCST,QTECST,
     $QELCST,UPIPCST,VELO,QEJCST,QFLGCST,DESVEL)
      LSAVE = L
      QDELS=0.
      QDELP=0.
      QTPCST=0.
      IF(L.GT.NFL) COST = 1.E+40
      IF(L.GT.NFL) RETURN
      DO 20 KK=1,L
```

```
      I = KK
      IF(I.GT.1) GO TO 21
      QHEDR(I)=0.
C
C          THE LENGTH OF STRAIGHT PIPE FOR QUADRANT HEADER SECTION I
C          ACCOUNTS FOR THE LENGTH OF THE TEE AS BEING 1.75 TIMES THE
C          DIAMETER OF THE TEE.  NO ALLOWANCE IS MADE FOR REDUCER
C          LENGTH.
C
      GO TO 22
C
C          DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE QUADRANT
C          PIPING.
C
   21 QHEDR(I) = BUNWIDT * CDANG * DIAQ(I) * 1.75 / 12.
   22 EQLEN=QHEDR(I)+20.*DIAQ(I)/12.
      CALL HYDLOS(DIAQ(I),VELO(I),VIS1,RHO1,2,HEAD1)
      CALL HYDLOS(DIAQ(I),VELO(I),VIS2,RHO2,2,HEAD2)
      QDELS=QDELS+HEAD1*RHO1*EQLEN/100.
      QDELR=QDELR+HEAD2*RHO2*EQLEN/100.
      QPIPCST(I)=QHEDR(I)*UPIPCST(I)
      IF(I.LT.L)QTPCST=QTPCST+QPIPCST(I)+QRDCST(I)+QTECST(I)
      IF(I.EQ.L)QTPCST=QTPCST+QPIPCST(I)+QRDCST(I)+QELCST
   20 CONTINUE
C
C          THE FITTINGS AND PIPE CONNECTING THE QUADRANT HEADER TO
C          THE BUNDLE HEADER ARE GIVEN A DIAMETER OF 8 INCHES AND
C          ESTIMATED TO COST $1.75 X 10**3 TOTAL FOR EACH TUBE BUNDLE.
C
      QDELSR=(QDELS+QDELR)/2.
      QHDCST=QTPCST*2.+1.75*NBUNPQD
C
C          DESIGN AND COST THE MAIN CIRCULATION PIPING FOR THE
C          EXTRA TOWER GROUP.
C
C          VARIABLES DEFINING CONDITIONS IN THE EXTRA TOWER GROUP ARE
C          GENERALLY RESET TO A ZERO VALUE EACH TIME PIPCRT IS CALLED SO
C          THAT STORED VALUES FROM A PREVIOUS CALCULATION WILL NOT BE
C          INCORRECTLY INCLUDED.  IF THERE ARE NO EXTRA TOWERS
C          SPECIFIED THEN BY-PASS THIS SET OF CALCULATIONS.
C
C
      EDELSR=0.
      EPDIA=0.
      EGPCST=0.
      EEJCST=0.
      EFLGCST=0.
      IF(NEXTOW.EQ.0) GO TO 35
      CALL HEADER(EXGPM,NEXTOW,GPMCIRC,REDUCE,0,JEX,DIAH,REDCOST,TEECOST
     $,ELCOST,UPIPCST,VELO,EEJCST,EFLGCST,DESVEL)
      DELSUP=0.
      DELRET=0.
      EGPCST=0.
      IF(JEX.GT.NFL) COST = 1.E+40
      IF(JEX.GT.NFL) RETURN
C
C          THE HEADER SECTION FROM THE CONDENSER TO THE FIRST TOWER
```

```
C          IS HEADER SECTION 1.  THEN, ALL EVEN NUMBER HEADER SECTIONS
C          ARE GIVEN ZERO LENGTH BECAUSE TOWERS ARE MATCHED ON OPPOSITE
C          SIDES OF THE MAIN CIRCULATION HEADER.
C
      DO 30 I2=1,JEX
      I = I2
      IF(I.EQ.1) GO TO 31
      IF(MOD(I,2).EQ.0) HEDR(I)=0.
      IF(MOD(I,2).NE.0) HEDR(I)=1.5*TOWDIA
C
C          DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE MAIN CIRC-
C          ULATION PIPING TO THE EXTRA TOWER GROUP.
C
      GO TO 32
   31 HEDR(I)=DIST+.5*TOWDIA
   32 EQLEN=HEDR(I)+20.*DIAH(I)/12.
      CALL HYDLOS(DIAH(I),VELO(I),VIS1,RHO1,2,HEAD1)
      CALL HYDLOS(DIAH(I),VELO(I),VIS2,RHO2,2,HEAD2)
      DELSUP=DELSUP+HEAD1*RHO1*EQLEN/100.
      IF(I.GT.1) GO TO 33
      DELRET=DELRET+HEAD2*RHO2*(EQLEN-50.)/100.
      GO TO 34
   33 DELRET=DELRET+HEAD2*RHO2*EQLEN/100.
   34 PIPCOST(I)=UPIPCST(I)*HEDR(I)
      IF(I.LT.JEX)EGPCST=EGPCST+PIPCOST(I)+REDCOST(I)+TEECOST(I)
      IF(I.EQ.JEX)EGPCST=EGPCST+PIPCOST(I)+REDCOST(I)+ELCOST
   30 CONTINUE
      EDELSR=DELSUP+DELRET
      EPDIA=.7*DIAH(1)
      EGPCST=EGPCST*2.-50.*UPIPCST(1)+(EEJCST+EFLGCST)*2
   35 CONTINUE
C
C          DESIGN AND COST THE MAIN CIRCULATION PIPING FOR THE COMPLETE
C          TOWER GROUPS.  COMMENTS IN THE ABOVE SECTION ON EXTRA GROUP
C          PIPING DESIGN APPLY HERE IDENTICALLY.
C
      CALL HEADER(GPGPM,NTOWPGP,GPMCIRC,REDUCE,0,J,DIAH,REDCOST,TEECOST,
     SELCOST,UPIPCST,VELO,EJCOST,FLGCOST,DESVEL)
      JSAVE = J
      DELSUP=0.
      DELRET=0.
      GPCST=0.
      IF(J.GT.NFL) COST = 1.E+40
      IF(J.GT.NFL) RETURN
      DO 40 I3=1,J
      I = I3
      IF(I.EQ.1) GO TO 41
      IF(MOD(I,2).EQ.0) HEDR(I)=0.
      IF(MOD(I,2).NE.0) HEDR(I)=1.5*TOWDIA
      GO TO 42
   41 HEDR(I)=DIST+.5*TOWDIA
   42 EQLEN=HEDR(I)+20.*DIAH(I)/12.
      CALL HYDLOS(DIAH(I),VELO(I),VIS1,RHO1,2,HEAD1)
      CALL HYDLOS(DIAH(I),VELO(I),VIS2,RHO2,2,HEAD2)
      DELSUP=DELSUP+HEAD1*RHO1*EQLEN/100.
      IF(I.GT.1) GO TO 43
      DELRET=DELRET+HEAD2*RHO2*(EQLEN-50.)/100.
```

```
      GO TO 44
   43 DELRET=DELRET+HEAD2*RHO2*EQLEN/100.
   44 PIPCOST(I)=UPIPCST(I)*HEDR(I)
      IF(I.LT.J)GPCST=GPCST+PIPCOST(I)+REDCOST(I)+TEECOST(I)
      IF(I.EQ.J)GPCST=GPCST+PIPCOST(I)+REDCOST(I)+ELCOST
C
C        DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE BUNDLE
C        FITTINGS CONNECTING THE QUADRANT HEADER TO THE TUBE BUNDLE
C        HEADER.
C
   40 CONTINUE
      DELSURF=DELSUP+DELRET
      GPCST=GPCST*2.-50.*UPIPCST(1)+(EJCOST+FLGCOST)*2
C
C
C
      EQLFIT=350.
C
C        DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE PIPING FOR
C        THE PUMP STATION SERVING THE COMPLETE TOWER GROUP.
C
      VELOCIT=(BUNGPM/8.**2)*CONST2
      CALL HYDLOS(8.,VELOCIT,VIS,RHO,2,HEAD)
      DELFIT=HEAD*RHO*EQLFIT/100.
      EQLPUMP=200.
      PDIA=.7*DIAH(1)
C
C        SUM THE PRESSURE DROPS AND DYNAMIC HEAD TO GET THE PUMP STA-
C        TION COSTS.  THE EQUATIONS FOR PUMP COSTS AND PUMP FITTINGS
C        COSTS WERE EXTRAPOLATIONS OF AVAILABLE COST DATA.
C        TWO PUMPS SERVE EACH TOWER GROUP.  NO AUXILIARY PUMP
C        CAPACITY IS PROVIDED.
C
      VELOCIT=(GPGPM/PDIA**2)*CONST2
      CALL HYDLOS(PDIA,VELOCIT,VIS2,RHO2,2,HEAD)
      DELPUMP=HEAD*RHO2*EQLPUMP/100.
      PDP=DELSURF+QDELSR+DELFIT+DELPUMP+DELTD
      DYNHEAD=(PDP+DELHX+DELCON)/RHO
      PUMPCST=(.0129*DYNHEAD+1.065)*GPGPM/1000.
C
C        TOTAL COST OF PIPE, FITTINGS, AND PUMPS PER COMPLETE TOWER
C        GROUP.
C
      PUFITS=(2.5*GPGPM/1000.)*7./DESVEL
C
C        DESIGN AND COST THE PUMP STATION SERVING THE EXTRA TOWER
C        GROUP.  THE METHOD IS IDETICAL TO THAT FOR THE COMPLETE
C        TOWER GROUP.
C
      PSTACST=PUMPCST+PUFITS
      CPTOW=OHDCST*4.+TDCST
      CPGP=CPTOW*NTOWPGP+GPCST+PSTACST
      EDELPMP=0.
      EPDP=0.
      EDYNHD=0.
      EPMPCST=0.
      EPUFITS=0.
```

```
      EPSCST=0.
      EXCST=0.
      IF(NEXTOW.EQ.0) GO TO 50
      VELOCIT=(EXGPM/EPDIA**2)*CONST2
      CALL HYDLOS(EPDIA,VELOCIT,VIS2,RHO2,2,HEAD)
      EDEL_PMP=HEAD*RHO2*EQLPUMP/100.
      EPDP=EDELSR+QDELSR+DELFIT+EDELPMP+DELTD
      EDYNHD=(EPDP+DELHX+DELCON)/RHO
      EPMPCST=(0.0129*EDYNHD+1.065)*EXGPM/1000.
      EPUFITS=(2.5*EXGPM/1000.)*7./DESVEL
C
C           DETERMINE TOTAL COSTS.
C
      EPSCST=EPMPCST+EPUFITS
      EXCST=CPTOW*NEXTOW+EGPCST+EPSCST
   50 CONTINUE
      COST=CPGP*NTOWGPS          +EXCST
      COST = COST * POHCIR
      TTDCST=TDCST*CTOW
      TGPCST=GPCST*NTOWGPS+EGPCST
      TPCST=PSTACST*NTOWGPS+EPSCST
      FPG = GPGPM * (60.0*RHO/7.481) * NTOWGPS
      EXFLO =EXGPM *  (60.*RHO/7.481)
      HPWAT = (FPG *(PDP + DELHX + DELCON) +
     $         EXFLO*(EPDP+ DELHX + DELCON)) / (62.*3600.*550.)
C
C           COMPUTE PUMP MOTOR ELECTRIC COSTS.
C
      NPX = 0
      IF (NEXTOW .GT. 0) NPX = 2
      NPMP = 2 * NTOWGPS + NPX
      HPPPMP = HPWAT/(NPMP*EFFP)
      IF(HPPPMP .LT. 251.) TRMA = 112500./NPMP + 7.88 * HPPPMP
     $                     + (116.-.159*HPPPMP)*HPPPMP
      IF(HPPPMP .GE. 251. .AND. HPPPMP .LE. 4000.) TRMA = 112500./NPMP
     $                     + 7.88*HPPPMP + 870./SQRT(HPPPMP)*HPPPMP
      IF(HPPPMP .GT. 2000.) TRMA = 112500./NPMP + 7.88 * HPPPMP
      VS = 7200.
      IF (HPPPMP .LT. 2000.) VS = 13900.
      VM = 6000.
      IF(HPPPMP .LT. 2000.) VM = 2300.
      IF (HPPPMP .LT. 251) VM = 480.
      TRMB = (DIST/2. - 1000.)*(37. + .47*HPPPMP*NPMP/SQRT(VS)
     $ + .5 *NPMP) / NPMP
      TRMC = (100. + 1.1 * HPPPMP) + (DSSTM -250.) / SQRT(VM)
      PMELEC = (TRMA + TRMB + TRMC) * POHLEC
      COST = COST + PMELEC/1000. * NPMP
      PISCOS = COST
      RPTPL = PMELEC/1000. * NPMP
      RETURN
      END
```

```
      SUBROUTINE ROOT(TFIX,RFIX,TTD,TD,CWARL)
C
C          GIVEN THE EFFECTIVENESS THIS ROUTINE CALCULATES THE
C          CAPACITY RATIO LIMIT FOR THE HEAT EXCHANGER USING A
C          SINGLE PASS CROSSFLOW CORRELATION
C
C          DEFINITION OF VARIABLES
C
C          CWARA    - THERMAL CAPACITY RATIO OF WATER TO AIR FLOWING
C                     THROUGH THE HEAT EXCHANGER (DIMENSIONLESS)
C          EFF      - EFFECTIVENESS OF HEAT EXCHANGER (DIMENSIONLESS)
C          RFIX     - TEMPERATURE RANGE OF WATER FLOWING THROUGH THE
C                     HEAT EXCHANGER (DEG F)
C          TD       - HEAT EXCHANGER AMBIENT AIR DESIGN TEMPERATURE
C                     (DEG F)
C          TFIX     - EXIT TEMPERATURE OF THE TURBINE AT WHICH THE
C                     SYSTEM IS TO BE DESIGNED FOR (DEG F)
C          TTD      - TERMINAL TEMPERATURE DIFFERENCE OF THE SURFACE
C                     CONDENSER (DEG F)
C
      EFF = RFIX/(TFIX - TTD - TD)
      CWARA = (1.00 - EFF)/EFF
C
C          NEWTON-RAPHSON ROOT FINDING ROUTINE
C
   10 FUNC = CWARA*EFF - (1.0 - EXP(-CWARA))
      DFDC = EFF - EXP(-CWARA)
      CWARA = CWARA - FUNC/DFDC
      IF(ABS(FUNC) .GT. 0.01) GO TO 10
      CWARL = CWARA
      RETURN
      END
```

```
      SUBROUTINE RPRT1(DESVEL, PF)
C
C     THIS ROUTINE PRINTS PIPING COST REPORT
C
      COMMON /KPRT1/
     $  BUNGR1
     $ ,DYNHD1 ,DIAD1 ,DIAT1 ,DIAH1(200), DIAQ1(200)
     $ ,EPSCR1 ,EGPCS1 ,EPMPC1 ,EPUFI1 ,EDYNH1 ,EXGPM1 ,EUCOS1 ,ELCOS1
     $ ,FLGCR1
     $ ,GPMCT1 ,GPGPM1 ,GPCST1
     $ ,HEDR1(200)
     $ ,JSAVI
     $ ,LSAVI
     $ ,NTUBR1 ,NBUNP1 ,NTOWG1 ,NTOWP1 ,NEXTO1
     $ ,PSTAC1 ,PUFIT1 ,PUMPC1 ,PIPCOS1(200), PISCO1
     $ ,QHDCS1 ,QUADG1 ,QPIPC1(200) ,QHEDR1(200) ,QTECSI(200)
     $ ,QPDCS1(200) ,QELCS1
     $ ,REDCR1(200), RPTPL1
     $ ,TEECR1(200) ,TPCS1 ,TDCS1 ,TTDCS1 ,TGPCSI ,TOWDI1 ,TQDCSI
     $ ,XTOWI
      COMMON /PRESS/ IPRESS
  180 FORMAT(T31,16("-")//T36,"PIPING",T55,I3," PSI DESIGN PRESSURE"
     $ //T31,16("-"))
  200 FORMAT(//25X,"CIRCULATION PIPING TO EACH TOWER GROUP"//52X,"COST I
     $N 10**3 DOLLARS FOR"/40X,50("-")/12X,"HEADER   DIAMETER   LENGTH
     $   PIPE       TEES    REDUCERS EXPANSION  FLANGES"/12X,"SECTION  (I
     $NCHES)   (FEET)",33X,"JOINT(1)     (3)"//)
  203 FORMAT(1H ,14X,I2,1X,7F10.0)
  204 FORMAT(//10X,"CIRCULAR TOWERS",I6,14X,"TOWER GROUPS",I4X,I6,/10X,
     $"TOWERS PER GROUP",I5,14X,"TOWERS IN INCOMPLETE GROUP",I6)
 1204 FORMAT(//10X,
     $"COST OF CIRCULATION PIPING FOR EACH TOWER GROUP   $",F5.0," *10**
     $3"/10X,"COST OF CIRCULATION PIPING FOR INCOMPLETE GROUP   $",F5.0,
     $" *10**3"///47X,"TOTAL COST OF CIRCULATION PIPING  $",F5.0," *10**
     $3"////)
  205 FORMAT(/25X,"QUADRANT PIPING"//42X,"COST IN 10**3 DOLLARS FOR"/40X
     $,"-----------------------------"/12X,"HEADER   DIAMETER   LENGTH
     $    PIPE       TEES    REDUCERS"/12X,"SECTION  (INCHES)   (FEET)"/)
  208 FORMAT(//10X,"TUBES PER BUNDLE",I10,/10X,"BUNDLES PER QUADRANT",I6
     $,/10X,"COST OF HEADERS PER QUADRANT  $",F5.0," *10**3"///49X,"TOTA
     $L COST OF QUADRANT HEADERS  $",F5.0," *10**3"////)
  209 FORMAT(/25X,"TOWER PIPING"//10X,"TOWER DIAMETER",23X,F5.0," FEET"/
     $10X,                          "DIAMETER OF PIPE FROM CIRCULATION
     $"/10X,"HEADER TO TOWER DISTRIBUTION HEADER",F7.0," INCHES"/10X,"DI
     $AMETER OF TOWER DISTRIBUTION PIPE",F7.0," INCHES"//10X,"COST OF DI
     $STRIBUTION PIPING PER TOWER  $",F5.0," *10**3"///40X,"TOTAL COST O
     $F TOWER DISTRIBUTION PIPING  $",F5.0," *10**3"////)
  211 FORMAT(/25X,"PUMP STATION"//10X,"DESIGN VELOCITY",15X,F3.0," FPS"/
     $                          10X,"FLOW PER BUNDLE",10X,F8.0," GPM"/
     $10X,"FLOW PER QUADRANT",8X,F9.0," GPM"/10X,"FLOW PER TOWER",11X,
     $F8.0," GPM"/10X,"FLOW PER TOWER GROUP      ",F8.0," GPM"/10X,
     $"FLOW TO INCOMPLETE GROUP ",F8.0," GPM"//)
  212 FORMAT(10X,"FOR EACH TOWER GROUP",20X,"FOR INCOMPLETE TOWER GROUP"
     $/12X,"DYNAMIC HEAD",9X,F5.0," FEET",9X,"DYNAMIC HEAD",9X,F5.0,
     $" FEET"/12X,"PUMP COST",11X,"$",F5.0," *10**3",7X,"PUMP COST",11X,
     $"$",F5.0," *10**3"/12X,"PUMP FITTINGS COST  $",F5.0," *10**3",7X,
     $"PUMP FITTINGS COST  $",F5.0," *10**3"/12X,"PUMP STATION COST   $"
```

```
      $,F5.0," *10**3",7X,"PUMP STATION COST   $",F5.0," *10**3")
 2120 FORMAT(//T58,"PUMP ELECTRICAL COSTS $",F6.0," *10**3"///)
 2125 FORMAT(T58,"COST OF PUMP STATIONS  $",F5.0," *10**3"/////,
      $       ,T54,"TOTAL PIPING SYSTEM COSTS $",F6.0," *10**3"///)
  213 FORMAT(1H1)
  214 FORMAT(1H ,13X,I2,1X,7F10.1)
      WRITE(6,213)
      WRITE(6,180) IPRESS
      WRITE(6,204) IFIX(XTOW1*1.E-30),NTOWG1,NTOWP1,NEXTO1
      WRITE(6,200)
      DO 201 I = 1, JSAV1
      IF(I.GT.1) GO TO 202
      WRITE(6,203) I,DIAH1(I), HEDR1(I), PIPCOS1(I)*PF, TEECO1(I)*PF,
     $ REDCO1(I)*PF, EJCOS1*PF, FLGCO1*PF
      GO TO 201
  202 IF (I .EQ. JSAV1) GOTO 210
      WRITE(6,203) I, DIAH1(I), HEDR1(I), PIPCOS1(I)*PF, TEECO1(I)*PF,
     $ REDCO1(I)*PF
      GO TO 201
  210 WRITE(6,203) I, DIAH1(I), HEDR1(I), PIPCOS1(I)*PF, ELCOS1*PF,
     $REDCO1(I)*PF
  201 CONTINUE
      WRITE(6,1204) GPCST1*PF, EGPCS1*PF, TGPCS1*PF
      WRITE(6,209) TOWDI1, DIAD1, DIAT1, TDCS1*PF, TTDCS1*PF
      WRITE(6,205)
      DO 206  I = 1, LSAV1
      IF (I.EQ.LSAV1) GOTO 207
      WRITE(6,214) I,DIAQ1(I), QHEDR1(I), QPIPC1(I)*PF, QTECS1(I)*PF
     $ ,QRDCS1(I)*PF
      GO TO 206
  207 WRITE(6,214) I, DIAQ1(I), QHEDR1(I), QPIPC1(I)*PF, QELCS1*PF,
     $ QRDCS1(I)*PF
  206 CONTINUE
      WRITE(6,211) DESVEL, BUNGP1, QUADG1, GPMCI1, GPGPM1, EXGPM1
      WRITE(6,212) DYNHD1, EDYNH1, PUMPC1*PF, EPMPC1*PF, PUFIT1*PF,
     $ EPUFI1*PF, PSTAC1*PF, EPSCS1*PF
      WRITE(6,2120) RPTPL1
      WRITE(6,2125) TPCS1*PF, PISCO1
      RETURN
      END
```

```
      SUBROUTINE RPRT2 (EFFC, TUBEM, TUBEM2)
C
C     THIS ROUTINE REPORTS CONDENSER DESIGN AND COSTS
C
      COMMON /KPRT2/  UCON   ,TI     ,TE     ,TDLM   ,XNP
     $ ,VELD, DELPWC,ARPS,TLA,XNTS,XNS,TS
      COMMON /KPRT3/  TUBCST,SHLCST,FETCST,CHX
 6100 FORMAT(
     C T40,20("-")/T41,"C O N D E N S E R"/T40,20("-"))
 6105 FORMAT(
     L T08,"--- DESIGN CONDITIONS ---"
     R,T72,"--- DESIGN OPERATING CONDITIONS ---"//)
 6110 FORMAT(
     L T15,"STEAM TEMPERATURE",F6.1," F"
     R,T60,"OVERALL HEAT TRANSFER COEFFICIENT ",F9.2," BTU/HR SQ FT DEG
     RF")
 6115 FORMAT(
     L T10,"INLET WATER TEMPERATURE",F6.1," F"
     R,T60,"AVERAGE WATER VELOCITY THRU COND ",F8.1," FT/SEC")
 6120 FORMAT(
     L T11,"EXIT WATER TEMPERATURE",F6.1," F"
     R,T65,"PRESSURE DROP THRU CONDENSER ",F8.1," LB/SQ FT")
 6125 FORMAT(
     L T02,"LOG MEAN TEMPERATURE DIFFERENCE",F6.1," F"
     R,T70,"CONDENSER EFFECTIVENESS ",F9.3)
 6130 FORMAT(
     L/T06,"--- CONDENSER DESCRIPTION ---"
     R,T79,"--- CONDENSER COSTS ---"//)
 6135 FORMAT(
     L T17,"NUMBER OF SHELLS",I6,
     R T75,"TUBING MATERIAL $",F14.2,2X("'",2A10,"")")
 6140 FORMAT(
     L T05,"HEAT TRANSFER AREA PER SHELL",G11.5," SQ FT"
     R T85,"SHELLS $",F14.2)
 6145 FORMAT(
     L T07,"NUMBER OF PASSES PER SHELL",I6,
     R T77,"FIELD ERECTION $",F14.2)
 6150 FORMAT(
     L T22,"TUBE LENGTH",I6,T45,"FEET")
 6155 FORMAT(
     L T08,"NUMBER OF TUBES PER SHELL",I6
     R,T68,"TOTAL COST OF CONDENSER $",F14.0)
C
      WRITE(6,6100)
      WRITE(6,6105)
      WRITE(6,6110) TS,UCON
      WRITE(6,6115) TI,VELD
      WRITE(6,6120) TE,DELPWC
      WRITE(6,6125) TDLM,EFFC
      WRITE(6,6130)
      WRITE(6,6135) (IFIX(XNS)),TUBCST,TUBEM,TUBEM2
      WRITE(6,6140) ARPS,SHLCST
      WRITE(6,6145) (IFIX(XNP)),FETCST
      WRITE(6,6150) (IFIX(TLA))
      WRITE(6,6155) (IFIX(XNTS)),(TUBCST+SHLCST+FETCST)
      RETURN
      END
```

```
      SUBROUTINE RPTFAN
C
C     THIS ROUTINE REPORTS FAN DESCRIPTION AND COSTS
C
      COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPFI, FBCPFI,
     $VELREC,AFC,ELEV,EHR
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CBU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPI, DESVEL, DANGLE
     $ ,EFF
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HX, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
C
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W3I, COSMI,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWATI,   HII,   HD1,   T41,
     $   REWA1,    NW1,ZPLNC2,ZSIZI2, ZSPBP,  SW41,  SW3I,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCDI, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBAI, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIPI,  AST1
     $,CAPCSI,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WITU1,  AD11,  ABL1
     $,  WTHR1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCFI,EFFINI, ANTU1
     $, AIRFE1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSP1, WATER1, WSTRC1, CFOUN1, HUBOI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      REAL MOTOR(4,3), DRIVE(3,2), PITCH(3,2), RECOVY(5,2)
C
      DATA ((MOTOR(I,K),I=1,4), K=1,3)/
     *    "TOTALLY EN","CLOSED SQU","IRREL CAGE"," MOTOR    ",
     *    "EXPLOSION ","PROOF SQUI","RREL CAGE ","MOTOR     ",
     *    "TWO SPEED ","SQUIRREL C","AGE       ","          "/
      DATA ((DRIVE(I,K),I=1,3),K=1,2)/
```

```
     *     "SPIRAL BEV","EL GEAR DR","IVE        ",
     *     "V-BELT DRI","VE         ","          "/
      DATA ((PITCH(I,K),I=1,3),K=1,2)/
     *     "MANUAL PIT","CH BLADES ","           ",
     *     "AUTO-VARIA","BLE PITCH ","BLADES     "/
      DATA ((RECOVY(I,K), I=1,5),K=1,2)/
     *     "FANS NOT E","QUIPPED WI","TH VELOCIT","Y RECOVERY",
     *     " DIFFUSERS",
     *     "FANS EQUIP","PED WITH V","ELOCITY RE","COVERY DIF",
     *     "FUSERS    "/
C
 1000 FORMAT(1H )
 1005 FORMAT(1H1)
 1010 FORMAT(T52,"F A N S")
 1020 FORMAT(T51,"---------")
 1030 FORMAT(T16,"--- DRIVE SYSTEM ---",T82,"--- FAN GEOMETRY ---")
 1040 FORMAT(T84,"BLADE DIAMETER ",F6.2," FEET")
 1050 FORMAT(T87,"BLADE ANGLE ",F6.2," DEGREES")
 1060 FORMAT(T78,"NUMBER OF BLADES/FAN ",F6.2)
 1070 FORMAT(T84,"NUMBER OF FANS ",F6.0)
 1080 FORMAT(T17,"--- FAN COSTS ---",T78,"--- DESIGN CONDITIONS ---")
C
 1085 FORMAT (T100,"(ACTUAL)",T122,"(ADJUSTED)")
 1090 FORMAT(T73,"VOLUMETRIC FLOW RATE/FAN ",F12.0," CU FT/MIN")
 1100 FORMAT(T16,"BLADE AND HUB COST/FAN $",F10.0,T71,
     *     "TOTAL VOLUMETRIC FLOW RATE ",F12.0," CU FT/MIN")
 1120 FORMAT(T24,"MOTOR COST/FAN $",F10.0,T70,
     *     "TOTAL AIR PRESSURE DROP OF H.X. ",F8.5," PSI",T120,F8.5)
 1130 FORMAT(T10,"SPEED REDUCER DRIVE COST/FAN $",F10.0,T69,
     *     "PRESSURE DROP ACROSS H.X. BUNDLE ",F8.5," PSI",T120,F8.5)
 1140 FORMAT(T24,"STACK COST/FAN $",F10.0,T72,
     *     "NON-RECOVERABLE VELOCITY HEAD ",F8.5," PSI",T120,F8.5)
 1145 FORMAT(T19,"ELECTRICAL COST/FAN $",F10.0
     $ ,T83,"HORSEPOWER/FAN",F13.0," HP",T116,F12.0)
 1150 FORMAT(T79,
     *"FAN POWER REQUIREMENTS ",F8.0," HP")
 1190 FORMAT(T2,"*** ANNUAL OPERATIONAL COSTS $",F10.0)
 1200 FORMAT(T37,5A10)
 1210 FORMAT(
     R T85,"HUB DIAMETER ",F6.2," FEET")
      WRITE(6,1005)
      WRITE(6,1000)
      WRITE(6,1000)
      WRITE(6,1020)
      WRITE(6,1010)
      WRITE(6,1020)
      WRITE(6,1000)
      IF(VELREC.EQ.0)  WRITE(6,1200) (RECOVY(I,1),I=1,5)
      IF(VELREC.EQ.1)  WRITE(6,1200) (RECOVY(I,2),I=1,5)
      WRITE(6,1000)
      WRITE(6,1030)
      WRITE(6,1000)
      WRITE(6,1210) HUBDI1
      WRITE(6,1040) ADI1
      WRITE(6,1050) BLDAN1
      WRITE(6,1060) ABL1
      WRITE(6,1070) XNFAN1
```

```
      WRITE(6,1000)
      WRITE(6,1000)
      WRITE(6,1080)
      WRITE(6,1000)
      WRITE(6,1085)
      WRITE(6,1090) CFMPF1
      WRITE(6,1100) FDCPF1, TOTCF1
      WRITE(6,1120) FMTRC1, ACTTP1, ADJTP1
      WRITE(6,1130) CSR1,ACTBP1, ADJBP1
      WRITE(6,1140) CYLRN1, ACTVH1, ADJVH1
      WRITE(6,1145) CFANE1, HPPF1, ADJPP1
      WRITE(6,1150) THPAI1
      WRITE(6,1190) AFCST1
      RETURN
      END
```

```
      SUBROUTINE RPTHXC(APON)
C
C     THIS ROUTINE REPORTS HEAT EXCHANGER DESIGN, OPERATING CONDITIONS
C     AND COST
C
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RAP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBAOG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSMI,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOWI,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HII,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP, SW41,  SW3I,
     $    SPC1, PTOT1,PLNC21, AFRO1, AAIR1,YFPMIN, SPCDI, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBAI, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CAI,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCD1,  CSC1,CEPRE1,DEPIPI,  AST1
     $,CAPCSI,XNFAN1,RLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHO1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFINI, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACITP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
C
      COMMON /TIME/ XNS, TTD, TLA, XNTS, ARPS
      COMMON /HXD/ AI,ATOT
      COMMON /ESCAL/ BSECF
 6390 FORMAT(
     R T71,"WT OF WATER ",F14.0," LB")
 6400 FORMAT(
     R T71,"WT OF TUBES",F14.0," LB")
 6410 FORMAT(
```

```
      L T8,"ALPHA", G14.8
      R,T71,"WT OF FRAME ",F14.0," LB")
 6420 FORMAT(
      L T8,"SIGMA", G14.8
      R,T71,"WT OF HEADER",F14.0," LB")
 6422 FORMAT(
      R T71,"WT OF STRUCT",F14.0," LB")
 6424 FORMAT(
      L T71,"   ROOF LOAD",F14.0," LB"
      R,T106,"(",F8.2," LB/SQ FT)")
 6430 FORMAT(
      L T3,"FITCO/ATOT", G14.8
      $)
 6440 FORMAT (1H0,2A10,T15,"NTU EFFECTIVENESS CORRELATION USED")
 6500 FORMAT(1H0)
 6505 FORMAT(T35,30("-"))
 6510 FORMAT(T36,"H E A T    E X C H A N G E R")
 6512 FORMAT(1H+,T90,F5.1," FANS",T110,F4.1," PASS")
 6515 FORMAT(
      L T2,"   WATER FLOW RATE",I11," LBM/HR"
      R,T71,"          COOLING SURFACE $",F10.0)
 6520 FORMAT(
      L T2,"     AIR FLOW RATE",I11," LBM/HR"
      R,T71,"         HEADER AND NOZZLE $",F10.0)
 6525 FORMAT(
      L T2,"    TUBES IN DEPTH",F11.2," TUBES   (",F7.1," FT DEEP)"
      R,T70,"            BUNDLE ASSEMBLY $",F10.0)
 6526 FORMAT(
      R  T70,"                BUNDLE FRAME $",F10.0)
 6527 FORMAT(
      R  T70,"          SEALING ELASTOMER $",F10.0)
 6530 FORMAT(
      L T2,"TUBES ACROSS FRONT",I11," TUBES   (",F7.1," FT WIDE)"
      R,T71,"                     PLENUM $",F10.0)
 6532 FORMAT(1X
      R, T71,"                    LOUVERS $",F10.0)
 6533 FORMAT (1X
      R, T71,"              HAIL SCREENS $",F10.0)
 6535 FORMAT(
      L T2,"             LENGTH",F11.0," FEET"
      R,T71,"                 STRUCTURE $",F10.0)
 6537 FORMAT(
      R T71,"                 FOUNDATION $",F10.0)
 6540 FORMAT(
      L T2,"      FRONTAL AREA",I11," SQ FEET"
      R ,T71," HEAT XCHR SHIP AND ERECT $",F10.0)
 6541 FORMAT(T8,"SURFACE AREA",I11," SQ FT")
 6555 FORMAT(T70,11("-"),2X,11("-"))
 6560 FORMAT(T73,"AIR",T87,"WATER")
 6565 FORMAT(T70,25("-"))
 6570 FORMAT(T50,"REYNOLDS NUMBER"
      $ ,2(1PE13.5,E14.5,3X))
 6575 FORMAT(T48,"VELOCITY (FT/SEC)"
      $ ,2(1PE13.5,E14.5,3X))
 6580 FORMAT(T34,"PRESSURE DROP (LBS FORCE/SQ IN)"
      $ ,2(1PE13.5,E14.5,3X))
 6581 FORMAT(T44,"INLET TEMPERATURE (F)",1PE13.5,E14.5)
```

```
 6582 FORMAT(T45,"EXIT TEMPERATURE (F)",1PE13.5,E14.5)
 6583 FORMAT(T56,"RANGE (F)",1PE13.5,E14.5)
 6584 FORMAT(T60,"CWARA",7X,1PE13.5)
 6585 FORMAT(T29,"HEAT TRFR COEFF (BTU/HR SQ FT DEG F)"
     $ ,2(1PE13.5,E14.5,3X))
 6586 FORMAT(T52,"NTU",7X,1PE13.5)
 6587 FORMAT(T50,"FRICTION FACTOR"
     $ ,2(1PE13.5,E14.5,3X))
 6595 FORMAT(T35,"OVERALL U (BTU/HR SQ FT DEG F)"
     $ ,7X,1PE13.5,E14.5)
 6600 FORMAT(T52,"EFFECTIVENESS"
     $ ,T76,F7.4)
 6610 FORMAT(T51,"FIN EFFICIENCY"
     $ ,T76,F7.4)
C
      WRITE(6,6500)
      WRITE(6,6505)
      WRITE(6,6510)
      WRITE(6,6512) XNFAN1, HANP
      WRITE(6,6505)
      WRITE(6,6500)
      WRITE(6,6565)
      WRITE(6,6560)
      WRITE(6,6555)
      WRITE(6,6570) REAI1, REWA1
      WRITE(6,6575) VAIR1, VWAT1
      WRITE(6,6580) DEPA1/144., DPWT1/144.
      WRITE(6,6585) HO1, HI1
      WRITE(6,6587) AIRFF1, WATFF1
      WRITE(6,6581) TD, VAR(1)-TTD
      WRITE(6,6582) T41, VAR(1)-VAR(2)-TTD
      WRITE(6,6583) T41-TD, VAR(2)
      WRITE(6,6584) VAR(3)
      WRITE(6,6586) ANTU1
      WRITE(6,6595) U1
      WRITE(6,6600) EFF1
      WRITE(6,6610) EFFIN1
      WRITE(6,6500)
      WRITE(6,6390) WATER1
      WRITE(6,6400) WTTU1
      WRITE(6,6410) ALPHA, WTFR1
      WRITE(6,6420) SIGMA, WTHD1
      WRITE(6,6422) WSTRC1
      WRITE(6,6424) AFRON*ROOFL, ROOFL1
      WRITE(6,6430) FITCO1/ATOT
      WRITE(6,6440) NTUCAL
      WRITE(6,6500)
C
      WRITE(6,6515) IFIX(SW31), CS1
      WRITE(6,6520) IFIX(SW41),CH1
      WRITE(6,6525) Z1, Z1*XD/12., CBA1
      WRITE(6,6526) CHF1
      WRITE(6,6527) CSE1
      WRITE(6,6530) HW1, WIDT1, CPLEN1
      WRITE(6,6532) CSTLV1
      WRITE(6,6533) CSTHS1
      WRITE(6,6535) ELEN1, STRUC1
```

```
      WRITE(6,6537) CFOUN1
      WRITE(6,6540) IFIX(AFRON), (BSECF-1.)*(CA1 + CH1 + CS1)
      WRITE(6,6541) IFIX(AAIR1)
      RETURN
      END
```

```
      SUBROUTINE RPTHXD
C
C     THIS ROUTINE REPORTS HEAT EXCHANGER DESCRIPTION AND UNIT COST DATA
C
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSIL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CRJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONC
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAG(5)
     $ ,WEV
     $ ,XDEPA, XW, XD
      COMMON /HEADEX/    CHH,    CN,    CHM,    CMW,    CRJ,    CWJ,    CST
     $ ,    CMO,    CSR,    CSM, PITCHF,    CPM, PRESS,HEDMAT,HEDTYP, NPASS
     $ ,    WB
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,    W31, COSM1,   EFF1
     $,   CLAM1, REAI1,     Z1,HRFA2S,    W41,     U1, PPOW1,
     $    FPOW1, DELFC1, WIDT1, ELEN1, VAIR1, VWAT1,    HI1,    HO1,    T41,
     $    REWA1,    NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $   BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,    TLA1, UCON1, FMCS1, FBAC1, EFFC1,    CH1,    CA1,    CS1
     $,   CLTC1,   CFC1, CPCC1,FITCO1,   CSC1,CEPRE1,DEPIP1,   AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,    WH1, WTTU1,   AD1I1,   ABL1
     $,   WTHO1, WTFR1,STRUC1,CFMPF1, HSPF1,TOTCF1,EFFIN1, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FOCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,    CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,    CSE1,    CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /TINE/ XNS, TTD, TLA, XNTS, ARPS
      COMMON /SURFEX/   ODL,GAGLIN,   NTUB,TUBMAT,FINTYP,FINMAT,    CFB
     $ ,APLATE, COATC, ZINCC, CASTC,    SS,EPREPC,XTUBMA,XHEDTY,XFINTY
      COMMON /DJB/     DI,    XDG,     SF
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,   CLAMD, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
```

```
      $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
      $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
      $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
      $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
      $,CAPCST, XNFAN,BLDANG, CPLEN, CPFELL,   WHX, WTTUB,  ADIA,  ABLN
      $,  WTHOR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
      $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
 6600 FORMAT(1H1)
 6601 FORMAT(1H )
 6602 FORMAT (1H+,T10," N O N - D E L T A   H E A T   E X C H A N G E
      $ R   D E S C R I P T I O N",T5,F5.1," DEGREES  ")
 6603 FORMAT(
      L T22,"SUPPORT SPACING ",F7.3,T47,"FEET"
      R ,T57,"SEAL PLATE THKNS",F11.3," INCH")
 6605 FORMAT(
      L T8,"TUBE PITCH NORMAL TO AIR FLOW ",F7.3,T47,"INCH"
      R ,T55,"SEAL PLATE DENSITY",F11.3," LB/CU IN.")
 6610 FORMAT(
      L T2,"TUBE PITCH IN DIRECTION OF AIR FLOW ",F7.3,T47,"INCH"
      R ,T58,"ELASTOMER THKNS",F11.3," INCH")
 6615 FORMAT(
      LT18,"TUBE DIAGONAL PITCH ",F7.3,T47,"INCH"
      R ,T56,"ELASTOMER DENSITY",F11.3," LB/CU IN.")
 6620 FORMAT(
      LT23,"LINER MATERIAL ",2A10
      R )
 6625 FORMAT(
      L T11,"LINER THERMAL CONDUCTIVITY",F7.3
      R )
 6630 FORMAT(
      LT8,"LINER TUBING OUTSIDE DIAMETER " ,F7.4,T47,"INCH"
      R,T62,"HEADER TYPE ",2A10)
 6635 FORMAT(1H+
      LT38,"--- U N I T   C O S T S ---")
 6640 FORMAT(
      R T58,"HEADER MATERIAL (",1A10,") $",F8.3,"/LB")
 6645 FORMAT(
      R T58,"ROLLED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
 6650 FORMAT(
      R T58,"WELDED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
 6655 FORMAT(
      LT10,"SPACER CASTING $",G10.4,"/EA"
      R,T55,"TUBE AND PLUG HOLE PREPARATION  $",F8.3,"/HOLE")
 6660 FORMAT(
      LT9,"END PREPARATION $",G10.4,"/TUBE"
      R,T66,"NOZZEL AND ATTACHING  $",F8.3,"/HOLE")
 6662 FORMAT(
      L  T14,"SEAL PLATE $",G10.4,"/LB"
      R,T67,"BOLTED HEADER JOINT  $", F8.3,"/FT")
 6665 FORMAT(
      L  T14,"FRAME COST $",G10.4,"/LB"
      RT58,"HEADER MACHINING AND WELDING  $",F8.3,"/FT")
 6670 FORMAT(
```

```
                LT09,"LINER TUBING    $",G11.5,"/FT",
                RT70,"STRUCTURAL STEEL  $",F8.3,"/LB")
         6695 FORMAT(
                LT28,"TUBE SPACERS  $",G11.5,"/FT"
                R)
      C
         6617 FORMAT(
                L T27,"LINER GAGE ",F5.1
                R)
         6710 FORMAT(
                LT9,"LINER TUBING INSIDE DIAMETER ",F7.4,T47,"INCH"
                R,T60,"HEADER LENGTH",F11.3," FEET")
                 WRITE(6,6600)
                 DO 20 I=1,3
              20 IF (DANGLE .LT. 1.E-30) WRITE(6,6602)
                 IF (DANGLE.GT.0.0) WRITE(6,6602) DANGLE
                 WRITE(6,6601)
                 WRITE(6,6603) SS, TSEALP
                 WRITE(6,6605) XW, ROESEL
                 WRITE(6,6610) XD, TELAST
                 WRITE(6,6615) XDG, ROEELA
                 WRITE(6,6617) GAGLIN
                 WRITE(6,6620) TUBMAT,XTUBMA
                 WRITE(6,6625) CONL
                 WRITE(6,6630) ODL,HEDTYP,XHEDTY
                 WRITE(6,6710) DI, WB
                 WRITE(6,6601)
                 WRITE(6,6601)
      C
                 DO 30 I=1,3
              30  WRITE(6,6635)
                 WRITE(6,6601)
                 WRITE(6,6640) HEDMAT,CHM
                 WRITE(6,6645) CRJ
                 WRITE(6,6650) CWJ
                 WRITE(6,6655) CASTC,CHH
                 WRITE(6,6660) EPREPC,CN
                 WRITE(6,6662) CSEALP, CBJ
                 WRITE(6,6665) CFS, CMW
                 WRITE(6,6670) CLTC1, CST
                 WRITE(6,6695) CSC1
      C
                 RETURN
                 END
```

```
      SUBROUTINE SCALP (RANGE, CWARA, AFRON, WLRAT, TCWFCS, ITOWN)
C
C     SUBROUTINE SCALP SCALES THE PLANT AND DRY COOLING TOWER
C     DESIGNS AND COSTS LINEARLY UPWARD OR DOWNWARD TO ACCOUNT
C     FOR THE FOLLOWING FACTORS-
C           1. THE DESIGN TEMPERATURE OF THE POWER PLANT DOES
C              NOT CORRESPOND TO THE RATED BACK PRESSURE OF THE
C              STEAM TURBINE.
C           2. PART OF THE TOTAL POWER OUTPUT OF THE PLANT IS
C              USED IN SUPPLYING POWER TO THE FAN AND PUMPING
C              SYSTEMS.
C     THE FOLLOWING ARE POINTS ON THE HEAT RATE FACTOR CURVE WHICH
C     ARE USED IN DESCRIBING THE SCALING OF THE PLANT AND DRY COOL-
C     ING TOWERS.  AT EACH OF THESE POINTS THE HEAT RATE FACTOR,
C     PLANT SIZE AND PLANT COSTS ARE DETERMINED.
C
C     POINT 0 - CONVENTIONAL TURBINE OPERATING AT RATED BACK
C               PRESSURE
C     POINT 1 - STEAM TURBINE OPERATING AT RATED BACK PRESSURE
C     POINT 2 - STEAM TURBINE OPERATING AT SYSTEM DESIGN EXIT
C               TEMPERATURE WITH OUTPUT OF TURBINE GENERATOR EQUAL
C               TO THE DESIGN POWER OUTPUT
C     POINT 3 - STEAM TURBINE OPERATING AT SYSTEM DESIGN EXIT
C               TEMPERATURE WITH THE POWER OUTPUT OF PLANT EQUAL
C               TO THE DESIGN POWER OUTPUT
C     THE DIFFERENCE BETWEEN POINT TWO AND THREE IS THE PLANT HAS
C     BEEN SCALED UP TO ACCOUNT FOR THE POWER CONSUMPTION OF THE
C     FANS AND PUMPS.  BETWEEN POINT ONE AND TWO THE POWER PLANT
C     HAS BEEN SCALED UP OR DOWN TO ACCOUNT FOR AN INCREASE OR
C     DECREASE IN THE HEAT RATE FACTOR.
C
C     DEFINITION OF VARIABLES
C
C     AAIR    - AIR SIDE HEAT TRANSFER AREA OF HEAT EXCHANGER
C               (SQ FT)
C     ADIA    - FAN BLADE DIAMETER (FT)
C     AFRON   - FRONTAL AREA OF THE HEAT EXCHANGER NORMAL TO AIR
C               FLOW (SQ FT)
C     ATUBC   - HEAT EXCHANGER TUBE COST ($)
C     BSECF   - BUNDLE SCHIPPING AND ERECTION COST FACTOR (DIMEN-
C               SIONLESS)
C     CA      - BUNDLE ASSEMBLY COST ($)
C     CAPF    - PERCENT OF TIME PLANT IS GENERATING POWER DURING
C               THE YEAR (PERCENT)
C     CCOS    - TOTAL COST OF THE DRY COOLING TOWER ($)
C     CFANEL  - COST OF THE ELECTRICAL WIRING FOR THE FAN SYSTEM
C               ($)
C     CFOUND  - COST OF THE FOUNDATION FOR THE DRY COOLING TOWERS
C               ($)
C     CH      - BUNDLE COSTS FOR THE HEAT EXCHANGER ($)
C     CHAILS  - COST OF HAIL SCREENS PER UNIT AREA ($/SQ FT)
C     CLAND   - COST OF LAND COVERED BY THE DRY COOLING TOWERS ($)
C     CLUVR   - COST OF LOUVERS PER UNIT AREA ($/SQ FT)
C     CONBAS  - COST OF THE SURFACE CONDENSER ($)
C     COSM    - INCREMENTAL MAINTENANCE COSTS OF DRY COOLING ($)
C     CPIP    - COST OF THE PIPING SYSTEM ($)
C     CPLEN   - COST OF THE PLENUM ON TOP OF THE COOLING TOWERS ($)
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C        CPM      - COST OF PLENUM MATERIAL PER POUND ($/LBM)
C        CS       - COOLING SURFACE COST ($)
C        CSE      - COST OF HEADER SEALANT FOR CONNECTING PLASTIC TUBES
C                   TO THE HEADER ($)
C        CSTHS    - COST OF THE HAIL SCREENS FOR THE ENTIRE FRONTAL
C                   AREA OF THE HEAT EXCHANGER ($)
C        CSTLVR   - COST OF THE LOUVERS FOR CONTROLLING THE AIR FLOW
C                   TO THE HEAT EXCHANGERS ($)
C        CWARA    - RATIO OF HEAT CAPACITY OF THE WATER TO THE AIR
C                   (DIMENSIONLESS)
C        CYLRNG   - COST OF THE FAN RING AND THE VELOCITY RECOVERY
C                   STACK IF THEY ARE USED ($/FAN)
C        DELFC    - INCREMENTAL FUEL COST FOR THE SCALED UP PLANT
C                   (MILLS/KW HR)
C        ELENG    - LENGTH OF HEAT EXCHANGER TUBES (FT)
C        FBACC    - COST OF FAN BLADES AFTER SCALING UP THE NUMBER OF
C                   FANS ($)
C        FBCPF    - COST OF FAN BLADES PER FAN ($/FAN)
C        FCBZ     - FUEL COST FOR THE BASE PLANT WITH A ZERO COST ONCE
C                   THROUGH COOLING SYSTEM (MILLS/HW HR)
C        FCB3     - FUEL COST FOR THE SCALED UP PLANT (MILLS /KW HR)
C        FCOS     - COST OF FUEL FOR POWER PLANT (CENTS/BTU)
C        FCR      - FIXED CHARGE RATE FOR CAPITAL PER YEAR (PERCENT/YR)
C        FIXL     - THE FIXED LENGTH OF HEAT EXCHANGER TUBES SPECIFIED
C                   BY THE INPUT TO THE CODE (FT)
C        FMCPF    - FAN MOTOR COST PER FAN ($/FNA)
C        FMCST    - TOTAL FAN MOTOR COST FOR THE FAN SYSTEM AFTER
C                   SCALE UP ($)
C        FPOW     - POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
C        HPAIR    - HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
C        HPWAT    - HORSEPOWER REQUIREMENTS OF THE WATER PUMPING
C                   SYSTEM (HP)
C        HRFAC1   - HEAT RATE FACTOR AT POINT ON (DIMENSIONLESS)
C        HRFAC2   - HEAT RATE FACTOR AT POINT TWO (DIMENSIONLESS)
C        HRFR21   - RATIO OF HRFAC2 TO HRFAC1 USED FOR SCALING UP
C                   PLANT TO DESING CONDITIONS (DIMENSIONLESS)
C        HSLVA    - SURFACE AREA COVERED BY HAIL SCREENS OR LOUVERS
C                   (SQ FT)
C        ITOWN    - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C        KCONV    - INTERNAL VARIABLE FOR SPECIFYING THAT THE SET OF
C                   INPUT VARIABLES LEAD TO UNREASONABLE VALUES
C                   (DIMENSIONLESS)
C        KGA      - VARIABLE FOR SPECIFYING GAGE OF TUBES USED IN THE
C                   CONDENSER (DIMENSIONLESS)
C        LD       - VARIABLE FOR SPECIFYING THE DIAMETER OF THE
C                   CONDENSER TUBING (DIMENSIONLESS)
C        NEGV     - STOPS THE PROGRAM IF THE SCALED UP FRONTAL AREA,
C                   MASS FLOW OF AIR AND SPECIFIC VOLUME OF AIR IS LESS
C                   THAN ZERO (DIMENSIONLESS).
C        NUMTOW   - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C        NW       - NUMBER OF HEAT EXCHANGER TUBES IN WIDTH
C                   (DIMENSIONLESS)
C        PER      - PERCENTAGE OF TOTAL CAPITAL COSTS OF DRY COOLING
C                   TOWER ALLOWED FOR MAINTENANCE COST (PERCENT)
C        PLANC    - BASE PLANT COSTS ($/KW)
C        PLANC1   - PLANT COSTS AT POINT ONE ($/KW)
C        PLANC2   - PLANT COST AT POINT TWO ($/KW)
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C          PLANC3  - PLANT COSTS AT POINT THREE
C          PMELEC  - COST OF ELECTRICAL WIRING FOR WATER PUMPING SYSTEM
C                    ($)
C          POHCND  - INDIRECT COSTS FOR SURFACE CONDENSER AS A PERCENT-
C                    AGE OF BASE COSTS (PERCENT)
C          POHSCL  - INDIRECT COSTS FOR AHIL SCREENS AND LOUVERS
C                    AS A PERCENTAGE OF BASE COSTS (PERCENT)
C          POHSTC  - ININDIRECT COSTS FOR THE STRUCTURES AND FOUNDATION
C                    FO THE CIRCULAR TOWER AS A PERCENTAGE OF BASE
C                    COSTS (PERCENT)
C          POOW    - POWER REQUIREMENTS OF THE WATER PUMPING SYSTEM (KW)
C          PSIZE   - SPECIFIED POWER OUTPUT OF THE PLANT AND MAKE UP
C                    SYSTEM TO THE POWER GRID (MW)
C          PSIZ12  - POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK
C                    PRESSURE FOR A POWER OUTPUT OF THE TURBINE OF
C                    PSIZE AT DESIGN CONDITIONS (MW)
C          PSIZ13  - POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK
C                    PRESSURE FOR A POWER OUTPUT OF THE PLANT OF PIZSE
C                    AT DESIGN CONDITIONS (MW)
C          PTOTAL  - TOTAL POWER OUTPUT OF THE TURBINE AT DESIGN
C                    CONDITIONS (MW)
C          RANGE   - TEMPERATURE DIFFERENCE OF THE WATER ENTERING
C                    AND LEAVING THE HEAT EXCHANGER (DEG F)
C          ROOFL   - ROOF LOAD DESIGN CONDITIONS FOR STRUCTURAL COSTS OF
C                    CIRCULAR TOWERS (LBF/SQ FT)
C          SAFRON  - SCALED UP FRONTAL AREA OF THE HEAT EXCHANGER
C                    NORMAL TO AIR FLOW (SQ FT)
C          SPBP    - INCREMENTAL PLANT COST BETWEEN PLANT DESIGNED AT
C                    RATED CONDITIONS (POINT 1) AND AT DESIGN CONDITIONS
C                    (POINT 2) ($)
C          SPC     - COST OF PLANT AT DESIGN CONDITIONS (POINT 3)
C          SPCD    - INCREMENTAL COST OF PLANT USING DRY COOLING TOWERS
C                    AT DESING CONDITIONS (POINT 3) OVER PLANT AT RATED
C                    CONDITIONS (POINT 1) ($)
C          STRUCC  - STRUCTURAL COST OF THE CIRCULAR TOWERS ($)
C          SWLRAT  - SCALED UP WIDTH TO LENGTH RATIO OF THE HEAT
C                    EXCHANGER (DIMENSIONLESS)
C          SW3     - SCALED UP MASS FLOW RATE OF WATER THROUGH THE
C                    HEAT EXCHANGER (LBM/HR)
C          SW4     - SCALED UP MASS FLOW RATE OF AIR THROUGH THE HEAT
C                    EXCHANGER (LBM/HR)
C          TCWFCS  - TOTAL COST OF THE PIPING SYSTEM (K$)
C          TD      - DESIGN TEMPERATURE OF THE DRY COOLING TOWER (DEG F)
C          TEFF    - RATED BACK PRESSURE EFFICIENCY OF THE STEAM
C                    TURBINE (PERCENT)
C          TLA     - LENGTH OF CONDENSER TUBING (FT)
C          TA      - EXIT TEMPERATURE OF THE AIR FROM THE HEAT EXCHANGER
C                    (DEG F)
C          VA      - SPECIFIC VOLUME FO THE AIR (CU FT/LBM)
C          WATERW  - WEIGHT OF WATER IN THE HEAT EXCHANGER BUNDLES (LBM)
C          WHX     - TOTAL WERIGHT OF THE HEAT EXCHANGER EXCLUDING
C                    WATER (LBM)
C          WIDTH   - TOTAL HEAT EXCHANGER WIDTH (FT)
C          WLRAT   - RATIO OF THE WIDTH TO THE LENGTH OF THE HEAT
C                    EXCHANGER (DIMENSIONLESS)
C          WPL     - WEIGHT OF THE PLENUM PER UNIT AREA (LBF/SQ FT)
C          WSTRUCT - TOTAL WEIGHT OF THE COOLING TOWER STRUCTURES (LBF)
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C          WTFRM   - TOTAL WEIGHT OF THE HEAT EXCHANGER FRAM (LBG)
C          WTHDR   - TOTAL WEIGHT OF THE HEAT EXCHANGER HEADERS (LBF)
C          WTTUB   - TOTAL WEIGHT OF THE HEAT EXCHANGER TUBES (LBF)
C          W3      - MASS FLOW RATE OF THE WATER THROUGH THE HEAT
C          W4      - MASS FLOW RATE OF THE AIR THROUGH THE HEAT
C                    EXCHANGER (LBM/HR)
C          XNFAN   - NUMBER OF FANS IN THE FAN SYSTEM (DIMENSIONLESS)
C          XNS     - NUMBER OF SHELLS IN THE SURFACE CONDENSER
C                    (DIMENSIONLESS)
C          XNTS    - NUMBER OF CONDENSER TUBES PER SHELL (DIMENSIONLESS)
C          XW      - TRANSVERS PITCH BETWEEN ADJACENT TUBES IN THE SAME
C                    TUBE ROW OF THE HEAT EXCHANGER FROM CENTERLINE TO
C                    CENTERLINE (IN)
C          YFPPI   - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR PUMP
C                    AND FAN POWER
C
      LOGICAL FXTLNG
      LOGICAL NEGV
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,THEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPD(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TUBARG, TW
     $ ,UCS, UWS
     $ ,VAS(8)
     $ ,WEV
     $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAMD, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   RENAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,    NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHDR, WTFRM,STRJCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
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     $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFAC5,   W41,    U1, PFOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   W1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CB1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIREF1, WATEF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSE1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /LACALL/ SRN
      COMMON /ESCAL/ BSECF
      COMMON /TINE/ XNS,TTD,TLA,XNTS,ARPS
      COMMON/TUBE/KGA,FGA(7),LD,ESA(5),TID(7,6),FTF(7,6)
      COMMON /PLCOST/ WPL
      COMMON /FLSW/ FXTLNG
      COMMON /PME/ PMELEC
      COMMON /HEADEX/ CHH,CN,CHM,CMW,CRU,CWU,CST,CMO,CSR,CSM,PITCHF,CPM,
     1PRESS,HEDMAT,HEDTYP,NPASS,WB
      COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF, FBCPF,
     $VELREC,AFC,ELEV,EHR
      DATA NFGV/.FALSE./
  901 FORMAT(1X,A10,"T1,RANGE,CWARA,AFRON,WLRAT",5314.4)
      NAMELIST /DBNL/ AFRON, VA, W4, TD, T4, CWARA, RANGE
      XTOW = ITOWN
C
C          SCALING FACTOR FROM POINT 1 TO POINT 2 TO ACCOUNT FOR CHANGE
C          IN HEAT RATE FACTOR
C
      HRFR21=HRFAC2/HRFAC1
C
C          POWER OUTPUT OF TURBINE AT RATED BACK PRESSURE(POINT 1) WHICH
C          GIVES REQUIRED POWER OUTPUT PSIZE AT THE DESIGN
C          BACK PRESSURE (POINT 2)
C
      PSIZ12=PSIZE*HRFR21
C
C          PLANT COSTS AT DESIGN CONDITIONS (POINT 2) WHICH INCLUDE
C          STEAM SUPPLY AND BACK PRESSURE SCALING TO POINT 2
C
      PLANC2=PLANC1 * HRFR21
C
C          INCREMENTAL COST OF SCALING UP PLANT DUE TO INCREASED HEAT
C          RATE FACTOR
C
      SPBP=(PLANC2-PLANC)*PSIZE*1.E+3
C
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C          SCALING FACTOR FOR SCALING PLANT SIZE TO MEET PUMP AND FAN
C          POWER REQUIREMENTS
C
      IF(PSIZE*1000.-PPOW-FPOW.LE.0.0) KCONV=1
      IF(KCONV.EQ.1) RETURN
      YFP=(PSIZE*1.E+3)/(PSIZE*1.E+3-PPOW-FPOW)-1.0
C
C          POWER OUTPUT OF THE TURBINE GENERATOR AT THE RATED
C          BACK PRESSURE (POINT 1) WHICH MEETS THE POWER REQUIREMENTS OF
C          THE FANS AND PUMPS (POINT 3) AND THE POWER OUTPUT OF THE
C          PLANT AT THE DESIGN BACK PRESSURE (POINT 2)
C
      PSIZ13=(1.+YFP)*PSIZ12
C
C          TOTAL POWER OUTPUT OF THE PLANT AT POINT 3
C
      PTOTAL = PSIZE * (1.+YFP)
C
C          PLANT COST AT POINT 3 EXCLUDING THE DRY COOLING TOWER COST
C
      PLANC3=PLANC2*(1.+YFP)
      SPC=PLANC3*PSIZE*1.E+3
C
C          INCREMENTAL COST OF PLANT DUE TO DRY COOLING TOWERS
C
      SPCD= (PLANC3-PLANC) * PSIZE * 1.E+3
C
C          SCALING UP THE DRY COOLING TOWER DIMENSIONS AND THE COSTS
C          ASSOCIATED WITH IT
C
C          INDEPENDENT PARAMETERS OF THE DRY COOLING TOWER
C
      YFPP1=YFP + 1.
      SW3=W3*YFPP1
      SW4=W4*YFPP1
      SAFRON=AFRON*YFPP1
      SWLRAT=WLRAT * YFPP1
C
C          SURFACE CONDENSER DIMENSIONS AND COSTS
C
      ISUR = 1
      CALL SURCON(ISUR, KGA, LD, TLA, XNTS, ARPS, XNS, CONBAS, CONMAT
     $            ,POHCND)
      XNTS = XNTS*YFPP1
      CONBAS = CONBAS*YFPP1
C
C          SCALE THE NUMBER OF TUBES IN WIDTH AND THE WIDTH OF THE
C          HEAT EXCHANGER
C
      IF(FXTLNG)   WIDTH=SAFRON/FIXL
      IF(.NOT.FXTLNG)  WIDTH=SQRT(SWLRAT*SAFRON)
      TOWLEN = WIDTH / (XTOW*2.)
      NW=WIDTH/XW*12.
C
C          CHECK ON THE EXIT TEMPERATURE OF THE AIR LEAVING THE HEAT
C          EXCHANGER
C
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      T4=CWABA*RANGE+TD
      VA=53.35*(TD+460.)/(15.*144.)
      IF(SAFRON.LT.0.0) NEGV=.TRUE.
      IF(VA.LT.0.0) NEGV=.TRUE.
      IF(SW4.LT.0.0) NEGV=.TRUE.
      IF(NEGV) WRITE(6,DRNL)
      IF(NEGV) STOP
   41 CONTINUE
C
C          FAN AND PUMP POWER
C
      FPOW=FPOW * YFPP1
      PPOW=PPOW * YFPP1
      HPWAT=HPWAT * YFPP1
      HPAIR= HPAIR * YFPP1
      XNFAN=XNFAN*YFPP1
C
C          THE NUMBER OF FANS AND THE MOTOR, BLADE, AND ELECTRICAL
C          WIRING COSTS OF THE FAN SYSTEM
C
      FMCST=XNFAN*FMCPF
      FBACC=FBCPF*XNFAN
      CFANEL = CFANEL * YFPP1
C
C          ELECTRICAL WIRING COST OF THE PIPING SYSTEM
C
      PMELEC = PMELEC * YFPP1
C
C          DIMENSIONS AND WEIGHT OF THE HEAT EXCHANGER
C
      ATUBC = (CA + CH + CS + CSE) * BSECF
      ATUBC = ATUBC*YFPP1
      AAIR=AAIR * YFPP1
      WHX=WHX*YFPP1
      WTTUB=WTTUB*YFPP1
      WTHDR=WTHDR*YFPP1
      WTERM=WTERM*YFPP1
      WATERW = WATERW * YFPP1
C
C          INCREASED FUEL COST OF THE PLANT
C
C          FUEL COST, FOR THE BASE PLANT WITH A CONVENTIONAL TURBINE
C          OPERATING AT RATED BACK PRESSURE
      FCBZ= FCOS * 3413.E-5 / TEFF
C
C          INCREASED FUEL COST FOR THE SCALED UP PLANT
      FCB3 = FCOS * 3413.E-5*(HRFAC2/TEFF) * (1.+YFP)
      DELFC= FCB3-FCBZ
C
C          LAND AND PIPING COSTS
C
      CLAND = COSTL*SAFRON
      CPIPI = TCWFCS * YFPP1 * 1000.
C
C          PLENUM SIZE AND COSTS
C
      CTOWD = CTOWD * YFPP1
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```
      CPLEN = CPM * WPL * (ITOWN * 3.14159/4. * CTOWD**2
     $ - XNFAN * 3.14159/4. * (ADIA+3.5)**2)
      CPLEN = CPLEN * POHSTC
C
C           STRUCTURE AND FOUNDATION COSTS
C
      CALL STRUCT(CTOWD, WHX, WATERW, ROOFL, STRUCC, CFOUND, WSTRCT,
     $            NUMTOW, ELENG, POHSTC)
      CFOUND = POHSTC * CFOUND
C
C           LOUVER AND HAIL SCREEN COSTS
C
      HSLVA = CTOWD * NUMTOW * 3.14159 * ELENG
      CSTLVR = CLUVR * HSLVA * POHSCL
      CSTHS = CHAILS * HSLVA * POHSCL
C
C           TOTAL COST OF DRY COOLING TOWER
C
      CCOS = FBACC + ATURC + FMCST + CPLEN + STRUCC + CFOUND
     $ + CSTLVR + CSTHS + CFANEL*XNFAN/YFPP1 + CYLRNG*XNFAN
C
      COSM = PER * (CCOS + CPIP + CONBAS) / (PSIZE*CAPF*8760.)
C
C           ANNUAL INCREMENTAL COST DUE TO MAINTENANCE OF DRY COOLING
C           TOWERS
C
C
C           INCREMENTAL COST OF DRY COOLING TOWER
C
      OLDCST = (CCOS+SPCD+CLAND+CPIP+CONBAS)*FCR/(PSIZE*CAPF*8760.)
     $   + COSM + DELFC
      RETURN
      END
```

```
      SUBROUTINE SERCH
C
C     THIS ROUTINE SEEKS MINIMUM BY SINGLE VARIABLE SEARCH METHOD
C
      LOGICAL FXTLNG
      COMMON /LACALL/ SRN
      DIMENSION C(5)
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHDR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIRFF,  WATFF,  XNMOD,  TCTPF, FDCPF, FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH, ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WID1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1, AFCST1
     $,   CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CRU, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCN
```

```
      $ ,QREJ, QREDUCE
      $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
      $ ,SAAF, SIGMA, SPAMAT(2)
      $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
      $ ,TJBARG, TW
      $ ,UWS, UWS
      $ ,VWS(5)
      $ ,WFV
      $ ,XDEPA, XW, XD
      COMMON /FLSW/ FXTLNG
      COMMON /TINE/ XNS,TTD,TLA,XNTS,ARPS
      CWARL = 0.0
      IF(FXTEMP) CALL ROOT(TFIX,RFIX,TTD,TD,CWARL)
      IF(FXTEMP .AND. VAR(3) .GT. 0.90*CWARL) VAR(3) = 0.90*CWARL
      DO 50 IVAL=1,5
   50 VAL(IVAL)=VAR(IVAL)
      SRN="/SERCH-1/ "
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),1)
      CALL STORE
      C(1)=5.
      C(2)=1.
      C(3)=1.
      C(4)=CAF
      C(5)=50.
      IB=1
      IF(FXTLNG) IB=2
      DO 8 I=IB,5
      M=6-I
      K=3
      DO 9 IK=1,5
    9 VAL(IK)=VAR(IK)
      KC=0
    1 J=0
    2 VAL(M)=VAR(M)+C(M)
      IF(FXTEMP) VAL(1) = TFIX
      IF (FXTEMP) VAL(2) = RFIX
      IF(FXTEMP .AND. VAL(3) .GT. 0.90*CWARL) GO TO 7
      IF(M.GT.3) GO TO 10
      IF(VAL(1) .GT. TLIM) GO TO 4
      H = VAL(3)*VAL(2)/(VAL(1)-TTD-TD)
   16 IF(H.GE.1.) GO TO 4
      IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 4
   10 SRN="/SERCH-2/ "
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
      IF(KCONV.EQ.1) GO TO 4
C     IF(DELPA.LT.XDEPA) GO TO 3
      IF(DELPA.LE.XDEPA) GO TO 3
      IF(TCOS.GE.TCOS1) GO TO 4
      J=1
      CALL STORE
      GO TO 2
    3 IF(K.EQ.1) KC=1
    4 IF(J.EQ.1) GO TO 7
    5 VAL(M)=VAR(M)-C(M)
      IF(FXTEMP) VAL(1) =TFIX
      IF(FXTEMP) VAL(2) = RFIX
      IF(VAL(M).LE.0.0) GO TO 7
```

```
                H = VAL(3)*VAL(2)/(VAL(1)-TTD-TD)
             18 IF(H.GE.1.) GO TO 7
                IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 7
                SPN=''/SERCH-3/ ''
                CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
                IF(KCONV.EQ.1) GO TO 7
          C     IF(DELPA.LT.XDEPA) GO TO 6
                IF(DELPA.LE.XDEPA) GO TO 6
                IF(TCOS.GE.TCOS1) GO TO 7
                CALL STORE
                KC=0
                GO TO 5
              6 IF(KC.EQ.1) KC=1
              7 IF(KC.EQ.1) CALL CHNGE(M)
                K=K-1
                IF(K.EQ.0) GO TO 8
                C(M)=C(M)/5.
                GO TO 1
              8 CONTINUE
                RETURN
                END
```

```
      SUBROUTINE SETUP(TSTAR,TEND,NUCASE)
C
C                    I N P U T   D E S C R I P T I O N
C
C                   FOR BNW1 PLASTIC CIRCULAR TOWER
C***********           D E C E M B E R  1 0   1 9 7 6          ***********
C*** *** ***
C                   IN THE DESCRIPTIONS BELOW THE SYMBOL (DF) MEANS
C                   DECIMAL FRACTION
C
C ---- -------- ------ -------- - ------------------------------------
C                                T
C                                Y
C CARD                   NAME  OF P
C TYPE COLUMNS  FORMAT   VARIABLE E        DESCRIPTION AND (UNITS)
C ---- -------- ------ -------- - ------------------------------------
C
C  A1    1-80   (8A10)   DESCR(I) R  COMMENTS OR CASE DESCRIPTION TO BE
C                                    PRINTED AT TOP OF FIRST OUTPUT PAGE.
C                                    ANY NUMBER OF TYPE A1 CARDS MAY BE
C                                    USED BUT A BLANK A1 CARD IS NOT
C                                    ALLOWED.
C
C
C*********
C*********
C
C  A2    1-80   BLANK IN ALL COLUMNS.  ONE TYPE A2 CARD ONLY
C
C*********
C*********
C
C  B1    1-10   (E10.0,  TSTAR    R  LOWEST DESIGN TEMPERATURE TO USE
C                                    (DEGREES F)
C
C       11-20   E10.0,  TEND     R  HIGHEST DESIGN TEMPERATURE TO USE
C                                    (DEGREES F)
C
C       21-30   E10.0,  VAS(1)   R  INITIAL VALUE FOR TURBINE OUTLET
C                                    TEMPERATURE (DEGREES F)
C
C       31-40   E10.0,  VAS(3)   R  INITIAL VALUE FOR CWARA, RATIO OF
C                                    MCP WATER / MCP AIR  (DF)
C
C       41-50   E10.0,  VAS(4)   R  INITIAL VALUE FOR APRON, AIR SIDE
C                                    FRONTAL AREA (SQ FT)
C
C       51-60   E10.0,  VAS(5)   R  INITIAL VALUE FOR WLRAT, RATIO OF
C                                    HEAT EXCHANGER WIDTH/LENGTH  (DF)
C
C       61-70   E10.0,  FIXL     R  LENGTH OF HEAT EXCHANGER (FT).
C                                    IF THE ABSOLUTE VALUE OF FIXL=0.
C                                    THEN THE PROGRAM WILL CALCULATE
C                                    THE LENGTH.
C
C       71-80   E10.0)  DEEPL    R  LIMITING VALUE FOR NUMBER OF TUBES
C                                    (NUMBER OF TUBES)
```

```
C                                          IF THE ABSOLUTE VALUE OF DEEPL = 0.0
C                                          THEN THE PROGRAM WILL COMPUTE THE
C                                          DEPTH WITH NO CONSTRAINTS
C
C                                          +DEEPL IMPLIES CONSTRAINT OF GREATER
C                                            THAN OR EQUAL TO DEEPL
C
C                                          -DEEPL IMPLIES CONSTRAINT OF LESS
C                                           THAN OR EQUAL TO DEEPL.
C.........
C.........
C
C  C1     1-40  (8F5.0,  TA(I)     R  TEMPERATURES REPRESENTATIVE OF
C                                     TPER(I) FRACTION OF YEAR (DEGREES F)
C                                     C A U T I O N  -  HIGHEST TA
C                                                       MUST BE FIRST
C
C        41-80   8F5.0)  TPER(I)    R  FRACTION OF YEAR OVER WHICH TEMPERA-
C                                     TURE TA(I) IS TYPICAL. (DF)
C
C.........
C
C  C2     1-40  (8F5.0,  TA(I)     R  CONTINUATION OF TA(I) FOR I= 9 TO 16
C
C        41-80   8F5.0)  TPER(I)    R  CONTINUATION OF TPER(I)
C        NOTE - A TYPE C2 CARD IS REQUIRED EVEN IF BLANK.
C.........
C.........
C  D1     4-10  (E10.0,  PSIZE     R  BASE PLANT SIZE (MEGAWATTS)
C
C        11-20   E10.0,  TEFF      R  BASE THERMAL EFFICIENCY (DF)
C
C        21-30   E10.0,  CAPF      R  CAPACITY FACTOR (DF)
C
C        31-40   E10.0,  FCR       R  FIXED CHARGE RATE (DF)
C
C        41-50   E10.0,  PER       R  RATIO MAINTENANCE COST TO CAPITAL
C                                     COST (DF)
C
C        51-60   E10.0,  CCM       R  CONSTRUCTION COST MULTIPLIER (DF)
C
C        61-70   E10.0,  ELEV      R  SITE ELEVATION ABOVE SEA LEVEL (FT)
C
C        71-80   E10.0)  ROOFL     R  ROOF LOAD (LB/SQ FT)
C
C.........
C.........
C
C  E1     1-10  (E10.0,  FCOS      R  FUEL COST (CENTS/MMBTU)
C
C        11-20   E10.0,  PWCOS     R  REPLACEMENT POWER COST (MILLS/KWH)
C
C        21-30   E10.0,  PLANC     R  POWER PLANT CONSTRUCTION COST ($/KW)
C
C        31-40   E10.0,  COSTL     R  COST OF LAND ($/SQ FT)
C
```

```
C        41-50   E10.0,  CSSPKW   R  COST OF STEAM SUPPLY ($/KW)
C
C        51-60   E10.0,  CAPCHG   R  CAPACITY CHARGE ($/MEGAWATT)
C
C        61-70   E10.0)  HPCST    R  COST OF ELECTRIC MOTORS ($/HP)
C
C.........
C
C
C                                        INDIRECT COST FACTORS FOR
C  E2     1-10  (E10.0,  POHBAF   R  BUNDLE ASSEMBLE AND FRAME
C
C        11-20   E10.0,  POHFAN   R  FANS
C
C        21-30   E10.0   POHLEC   R  ELECTRICAL
C
C        31-40   E10.0   POHCIR   R  CIRCULATION PIPING
C
C        41-50   E10.0   POHCND   R  CONDENSER
C
C        51-60   E10.0,  POHSTC   R  STRUCTURE
C
C        61-70  E10.0)  POHSCL    R  SCREENS AND LOUVERS
C
C.........
C.........
C  F1     1-10  (F10.0,  RBP      R  TURBINE RATING BACK PRESSURE (INCHES
C                                     OF MERCURY)
C
C        11-70   4F15.8) TPO(I)   R  COEFFICIENTS FOR THIRD ORDER POLY-
C                                     NOMIAL FOR HEAT RATE AS A FUNCTION
C                                     OF TURBINE BACK PRESSURE.
C
C.........
C.........
C
C  G1     1-10  (E10.0,  EFFP     R  EFFICIENCY OF PUMPS (DF)
C
C        11-20   E10.0)  DPRESS   R  PIPING DESIGN PRESSURE (PSI)
C                                     MAY BE
C                                            50.
C                                            70.
C                                           125.
C
C
C.........
C.........
C
C  H1     1-10  (E10.0,  VELREC   R  CONTROL VARIABLE.
C                                    =1 FOR VELOCITY RECOVERY
C                                    =0  FOR NO VELOCITY RECOVERY
C
C        11-20   E10.0,  XDEPA    R  MINIMUM AIR SIDE PRESSURE DROP THRU
C                                     HEAT EXCHANGER (LB FORCE/SQ FT)
C
C        21-30   E10.0,  TLIM     R  MAXIMUM STEAM TEMPERATURE FOR THE
C                                     TURBINE (DEGREES F).
```

```
C                                                ASSUMED 180 IF FIELD IS BLANK OR 0.
C
C        31-40    E10.0,   TOWMIN    R   THE MINIMUM ALLOWABLE NUMBER OF
C                                           TOWERS PER GROUP.
C                                           ASSUMED 1 IF NOT SPECIFIED
C
C        41-50    E10.0,   PFACT     R   PACKING FACTOR, RATIO OF CIRCULAR
C                                           TOWER ROOF AREA TO FAN SWEPT AREA
C                                           (DF)
C
C        51-60    E10.0,   TFIX      R   FIXED TURBINE OUTLET TEMPERATURE (F)
C                                           ENTRY IS IGNORED IF BLANK OR ZERO
C
C        61-70    E10.0,   RFIX      R   FIXED RANGE (F). ENTRY IS IGNORED
C                                           IF BLANK OR ZERO
C
C        71-80    E10.0)   TOWMAX    R   MAXIMUM ALLOWABLE NUMBER OF TOWERS.
C                                           ASSUMED 9999 IF BLANK OR ZERO
C
C
C.........
C.........
C
C  H2    1-10     E10.0    GBEFF     R   FAN GEARBOX EFFICIENCY
C
C.........
C.........
C
C  I1    1-10     (E10.0,  CPM       R   PLENUM COST ($/LB)
C
C        11-20    E10.0,   WPL       R   WEIGHT OF PLENUM MATERIAL (LB/SQ FT)
C
C        21-30    E10.0,   CLUVR     R   COST OF LOUVERS ($/SQ FT)
C
C        31-40    E10.0,   CHAILS    R   COST OF HAIL SCREENS ($/SQ FT)
C
C        41-50    E10.0,   UCS       R   UNIT COST OF STACK $/LB
C
C        51-60    E10.0,   UWS       R   UNIT WT OF STACK LB/CU FT
C
C        61-70    E10.0,   CVM       R   FAN RING MATERIAL UNIT COST $/LB
C
C        71-80    E10.0)   WFM       R   UNIT WT OF STRAIGHT CYLINDER LB/SQ FT
C
C
C.........
C.........
C
C  J1    1-20     (2A10,   NTUCAL    I   CONTROL VARIABLE FOR SPECIFYING THE
C                                           METHOD TO BE USED TO CALCULATE NTU.
C                                           NTUCAL MUST BEGIN IN COLUMN 1.
C                                                        CROSS FLOW
C                                                        COUNTER FLOW
C                                                        TABLE
C
```

```
C                                          CROSS FLOW  OR  COUNTER FLOW CAUSES
C                                          CALCULATION OF NTU BY EQUATIONS.
C                                          TABLE  CAUSES TABLE LOOKUP OF NTU.
C
C        21-30    F10.0,   HXNP      R   NUMBER OF PASSES THRU HEAT EXCHANGER
C
C        31-40    F10.0,   WB        R   HEADER LENGTH  (FEET)
C
C        41-50    F10.0,   NTUB      R   NUMBER OF TUBES THRU PLATE FINS
C
C        51-60    F10.0)   SS        R   SUPPORT SPACING (FT)
C
C.........
C.........
C
C  J2    1-10   (E10.0,   DESVEL     R   DESIGN WATER VELOCITY FOR PIPING
C                                          (FT/SEC)
C
C        11-20    E10.0,   REDUCE    R   MINIMUM STEP CHANGE IN PIPE DIAMETER
C                                          FOR TOWER PIPING (INCHES)
C                                          MAY BE 6, 12, OR 18
C
C        21-30    E10.0,   QREDUCE   R   MINIMUM STEP CHANGE IN PIPE DIAMETER
C                                          FOR QUADRANT HEADERING. (INCHES)
C                                          MAY BE 6, 12, OR 18
C
C        31-40    E10.0)   DIST      R   DISTANCE FROM TOWER TO CONDENSER
C                                          ROOM (FT)
C
C.........
C.........
C
C  K1    1-10   (F10.0,   XW        R   TUBE TRANSVERSE PITCH (NORMAL TO AIR
C                                          FLOW)  (INCHES)
C
C        11-20    F10.0,   XD        R   TUBE PITCH IN DIRECTION OF AIR FLOW
C                                          (INCHES)
C
C        21-30    F10.0,   XDG       R   TUBE DIAGONAL PITCH (INCHES)
C
C        31-40    A10,     TUBARG    R TUBE ARRANGEMENT, MUST BEGIN IN
C                                          COLUMN 1.    MAY BE-
C                                                          STAGGERED
C                                                          INLINE
C
C                                          ASSUMED TO BE STAGGERED IF OMITTED
C
C        41-50    A10,     HCCALC    R   CONTROL VARIABLE TO SELECT METHOD
C                                          TO BE USED IN CALCULATING FRICTION
C                                          FACTOR AND HEAT TRANSFER COEFFICIENT
C                                          FOR AIR FLOWING ACROSS STAGGERED
C                                          TUBES.    MAY BE 1 OR 2
C                                          (ASSUMED 2 IF BLANK)
C
C                                          HCCALC=1 SPECIFIES MCADAMS RELATIONS-
C                                                   SHIP FOR HEAT TRFR AND FOR
C                                                   FRICTION FACTOR
```

```
C                                          HCCALC=2 SPECIFIES MCADAMS RELATIONSHIP FOR FRICTION FACTOR
C                                                   AND ZUKAUSKAS RELATIONSHIP
C                                                   FOR HEAT TRANSFER COEFF.
C                                          HCCALC IS IGNORED IF TUBARG = INLINE
C        51-60   F10.0)  DANGLE    R  BASE ANGLE FOR DELTA HEAT EXCHANGER
C                                       (DEGREES)
C.........
C.........
C  L1    1-10   (F10.0,  ODL       R  HX LINER OUTSIDE DIAMETER (INCHES)
C        11-20   F10.0,  DI        R  HX LINER INSIDE DIAMETER (INCHES)
C        21-30   F10.0,  GAGLIN    R  GAGE OF HX LINER TUBE (MAY BE
C                                       22.  20.  19.  18.  17.  16.  15.
C                                       14.5 14.  13.  12.  11.  10.     )
C        31-50   2A10,   TUBMAT,   R  LINER MATERIAL MUST BEGIN IN COL 31
C                        XTUBMA   R
C                                       MAY BE -
C                                                POLYETHYLENE
C                                                POLYPROPYLENE
C                                                POLYVINYLCHLORIDE
C        51-60   F10.0)  CONL      R  THERMAL CONDUCTIVITY OF LINER MATERIAL (BTU/(HR SQFT DEG F/ FT) )
C.........
C.........
C  M1    1-20   (2A10,   SPAMAT    R  SPACER MATERIAL MUST BEGIN IN CARD
C                                       COLUMN 1.   MAY BE
C                                                POLYVINYLCHLORIDE
C                                                POLYCARBONATE
C        21-30   F10.0,  CSEALP    R  SEAL PLATE COST ($/LB)
C        31-40   F10.0,  TSEALP    R  SEAL PLATE THICKNESS (IN)
C        41-50   F10.0,  CELAST    R  ELASTOMER COST ($/LB)
C        51-60   F10.0,  TELAST    R  ELASTOMER LAYER THICKNESS (IN)
C        61-70   F10.0,  ROESEL    R  SEAL PLATE DENSITY (LB/CU IN)
C        71-80   F10.0,  ROEELA    R  ELASTOMER DENSITY (LB/CU IN)
C.........
C.........
C  N1    1-10   (E10.0,  CASTC     R  FIXED CASTING COST FOR SPACERS
```

```
C                                                    ($/SPACER)
C
C        11-20    E10.0,   EPREPC   R  END PREPARATION COST ($/TUBE)
C
C        21-30    E10.0)   CFS      R  FRAME UNIT COST ($/LB)
C
C.........
C.........
C
C  P1    1-20    (2A10,   HEDTYP,   R  HEADER TYPE.  MUST START IN COLUMN 1.
C                         XHEDTY    R
C                                      MAY BE -
C                                                WELD REMOVABLE
C                                                WELD PLUG
C                                                FORM REMOVABLE
C                                                FORM PLUG
C
C        21-30    F10.0,   HEDMAT   R  HEADER MATERIAL. MUST START IN
C                                      COLUMN 21. MAY BE -
C                                                          ALUMINUM
C                                                          STEEL
C
C        31-40    F10.0)   TW       R  THICKNESS OF HEADER MATERIAL, INCHES
C
C.........
C.........
C
C  Q1    1-10    (E10.0,   CRJ      R  COST OF ROLLED JOINT, TUBE TO HEADER
C                                      ($/TUBE)
C
C        11-20    E10.0,   CWJ      R  COST OF WELDED JOINT, TUBE TO HEADER
C                                      ($/TUBE)
C
C        21-30    E10.0,   CHH      R  TUBE AND PLUG HOLE PREPARATION COST
C                                      ($/HOLE)
C
C        31-40    E10.0,   CN       R  NOZZEL AND ATTACHING COST ($/HOLE)
C
C        41-50    E10.0,   CMW      R  COST OF HEADER MACHINING AND WELDING
C                                      ($/FT)
C
C        51-60    E10.0,   CST      R  STRUCTURAL STEEL COST  ($/LB)
C
C        61-70    E10.0)   CBJ      R  COST OF BOLTED HEADER JOINT ($/FT)
C
C.........
C.........
C
C  R1    1-10    (E10.0,   XNS      R  NUMBER OF CONDENSER SHELLS
C
C        11-20    E10.0,   VELN     R  NOMINAL DESIGN VELOCITY THRU CONDEN-
C                                      SER TUBES (FT/SEC)
C
C        21-30    E10.0,   ODC      R  CONDENSER TUBE O.D. (INCHES)
C
C        31-40    E10.0,   GA       R  CONDENSER TUBE WALL GAGE.  MAY BE
C                                      12.  14.  16.  18.  20.  22.  24.
```

```
C
C        41-50   E10.0,   FC       R  CLEANLINESS FACTOR (DF)
C
C        51-60   E10.0,   TTD      R  TERMINAL TEMPERATURE DIFFERENCE
C                                     (DEGREES F)
C
C        61-80   2A10)    CONMAT,  R                 CONDENSER TUBING MATERI-
C                         CONMA2   R                 AL. MUST START IN
C                                                    COLUMN 61. MAY BE -
C
C                                                      ADMIRALTY
C                                                      CU-10 NI
C                                                    304 S/S WELDED
C
C
C.........
C.........
C
C  S1    1-5    (I5,     LFB      I  LFB AND LFE SPECIFY FIRST AND LAST
C        6-10    I5,     LFE      I  POSITION TO BE CONSIDERED IN THE
C                                     TABLE OF FANS.  DEFAULT VALUES ARE
C                                     LFB=1 AND LFE=153
C
C                                     --------      -----      -----
C                                     DIAMETER       IFAN       LFAN
C                                     --------      -----      -----
C                                        24.          1         27
C                                        26.         28         54
C                                        28.         55         88
C                                        30.         89        111
C                                        40.        112        135
C                                        50.        136        153
C
C        11-15   I5       MXEXT    I  THE MAXIMUM ALLOWABLE NUMBER OF
C                                     CALLS TO SUBROUTINE XTEND FOR ANY
C                                     ONE DESIGN TEMPERATURE.
C
C                                     DEFAULT VALUE IS 10
C
C.........
C.........
C
C  U1    2-72  NAMELIST INPUT CARD.     NAMELIST NAME IS "READIN"
C              AT LEAST 1 TYPE U1 CARD IS REQUIRED.
C              IN ITS SIMPLEST FORM THE U1 CARD IS
C                                                  $READIN NUCASE=0 $END
C              BEGINNING IN CARD COLUMN 2.
C
C              VARIABLES IN NAMELIST "READIN" ARE-
C
C              DANGLE,  DESVEL,  DIST,    DI,      FIXL,    LFB,
C              LFE,     NUCASE,  ODL,     PFACT,   QREDUCE, REDUCE,
C              RFIX,    TFIX,    TLIM,    TOWMAX,  TOWMIN,  VELREC,
C              XD,      XDG,     XW
C
C              AFTER THE INITIAL CASE IS DESCRIBED WITH CARD TYPES A1-U1
C              THEN ANY NUMBER OF TYPE U1 CARDS MAY BE USED TO REDEFINE
```

```
C                ANY OF THE VARIABLES IN THE NAMELIST FOR ADDITIONAL CASES
C
C                NUCASE   IS A CONTROL VARIABLE TO SPECIFY HOW THE DATA
C                         FOR THE NEXT CASE ARE TO BE READ.
C
C                NUCASE = 0        SPECIFIES THAT THE DATA FOR THE NEXT
C                                  CASE ARE TO BE READ FROM A COMPLETE SET
C                                  OF A1 THRU U1 CARDS
C
C                NUCASE = 1        SPECIFIES THAT DATA FOR THE NEXT CASE
C                                  ARE TO BE READ FROM NAMELIST CARDS
C
      REAL NTUB
      DIMENSION TOD(6),TGA(7)
      COMMON/DUB/DI,XDG,SF
      COMMON /INDIS/ DIST
      COMMON /HEADEX/ CHH,CN,CHM,CMW,CRJ,CWJ,CST,CMO,CSR,CSM,PITCHF,CPM,
     1PRESS,HEDMAT,HEDTYP,NPASS,WB
      COMMON /SURFEX/ DDL,GAGLIN,NTUB,TUBMAT,FINTYP,FINMAT,CFB,APLATE,
     $COATC,TINCC,CASTC,SS,EPREPC,XTUBMA,XHEDTY,XFINTY
      COMMON/FLSW/ FXTLNG
      COMMON /TINE/ XNS,TTD,TLA,XNTS,ARPS
      COMMON/TINE2/CCM
      COMMON/TUBE/KGA,FGA(7),LO,ESA(5),TID(7,6),FTF(7,6)
      COMMON/OHTC/FC,CU(5),VELN
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  B2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
     $,CAPCST,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  AD11,  ABL1
     $,  WTHO1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSP1, WATER1, WSTRC1, CFDUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/ HREAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /FNLOOP/ LFB, LFE
      COMMON  /PLCOST/ WPL
      LOGICAL FXTLNG
      DIMENSION DEGCR(3)
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXDP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
```

```
      $ ,JCONS
      $ ,KCONV, KALEXT
      $ ,MXEXT
      $ ,NTUCAL(2), NTA
       COMMON
      $ ODRI
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT
      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
      $ ,QREJ, QREDUCE
      $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
      $ ,SAAF, SIGMA, SPAMAT(2)
      $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
      $ ,TJBAEG, TW
      $ ,UCS, UWS
      $ ,VAS(5)
      $ ,WFV
      $ ,XDEPA, XW, XD
       COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
      $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
      $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
      $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
      $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
      $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
      $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
      $,CAMCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
      $,  WTHER, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,   ANTU
      $,  AIREF,  WATEF,  XMMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSBD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
       COMMON /VARVAR/  TPER(16), TA(15)
        COMMON/INLT/TIN(15),FTIN(15)
        COMMON/PH20/TH20(16),PROP(16,2)
        COMMON/CFHL/VELT(15),TELT(15),WBLT(15,2)
       COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF, FBCPF,
      $VELREC,AFC,ELEV,EHR
       COMMON /PRESS/ IPRESS
       NAMELIST/READIN/VELREC,TLIM,TFIX,RFIX,TOWMIN,TOWMAX,DESVEL,REDUCE,
      $   QREDUCE,DIST,XW,XD,XDG,DANGLE,ODL,DI,FIXLL,LFB,LFE,NUCASE,PFACT
       DATA BLANK/"          "/
C
C          SURFACE CONDENSER TUBE O.D. AND TUBE GAGE ARRAYS
C
        DATA TOD/0.625,0.750,0.875,1.000,1.125,1.250/
        DATA TGA/12.,14.,16.,18.,20.,22.,24./
C
C          EXTERNAL SURFACE AREA (SQ FT) OF CONDENSER TUBE PER LINEAR
C          FOOT AS A FUNCTION OF TUBE O.D.
C
        DATA ESA/0.1636,0.1963,0.2291,0.2618,0.2944,0.3271/
C
C          TUBE WALL GAGE CORRECTION FACTOR FOR OVERALL HEAT TRANSFER
C          COEFFICIENT FOR ADMIRALTY METAL, ARSENICAL COPPER OR
C          ALUMINUM TUBES FOR SURFACE CONDENSERS
C
        DATA FGA/0.87,0.92,0.96,1.00,1.02,1.04,1.06/
```

```
C
C          CONDENSER TUBE I.D. AND GPM PER FPS VELOCITY THROUGH TUBE AS
C          A FUNCTION OF TUBE GAGE AND TUBE O.D.
C
      DATA TID/0.407,0.459,0.495,0.527,0.555,0.569,0.581,
     $         0.532,0.584,0.620,0.652,0.680,0.694,0.706,
     $         0.657,0.709,0.745,0.777,0.805,0.819,0.831,
     $         0.782,0.834,0.870,0.902,0.930,0.944,0.956,
     $         0.907,0.959,0.995,1.027,1.055,1.069,1.081,
     $         1.032,1.084,1.120,1.152,1.180,1.194,1.206/
      DATA TTF/0.406,0.516,0.600,0.680,0.754,0.793,0.826,
     $         0.693,0.835,0.941,1.041,1.132,1.179,1.220,
     $         1.057,1.231,1.359,1.473,1.586,1.642,1.690,
     $         1.497,1.703,1.853,1.992,2.117,2.182,2.137,
     $         2.014,2.251,2.424,2.582,2.725,2.797,2.861,
     $         2.607,2.877,3.071,3.249,3.409,3.490,3.560/
C
C          CONDENSER INLET TEMPERATURE ARRAY INLET TEMPERATURE
C          CORRECTION FACTOR FOR OVERALL HEAT TRANSFER COEFFICIENT FOR
C          SURFACE CONDENSERS
C
      DATA TIN/30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,
     $         90.,95.,100./
      DATA FTIN/0.545,0.613,0.679,0.743,0.805,0.863,0.917,0.962,
     $         1.000,1.025,1.042,1.050,1.074,1.088,1.100/
C
C          VELOCITY CONSTANT FOR OVERALL HEAT TRANSFER COEFFICIENT AS A
C          FUNCTION OF TUBE O.D.
C
      DATA CU/257.,267.,263.,263.,259.,259./
C
C          WATER TEMPERATURE ARRAY AND WATER DENSITY AND VISCOSITY AS A
C          FUNCTION OF TEMPERATURE
C
      DATA TH20/32.,40.,50.,60.,70.,80.,90.,100.,110.,120.,130.,
     $         140.,150.,160.,170.,180./
      DATA RROP/62.42,62.42,62.38,62.34,62.27,62.17,62.11,61.99,
     $         61.84,61.73,61.54,61.39,61.20,61.01,60.79,60.57,
     $         4.33,3.75,3.17,2.71,2.37,2.08,1.85,1.65,1.49,
     $         1.36,1.24,1.14,1.04,0.97,0.90,0.84/
C
C
C          CONDENSER TUBE VELOCITY ARRAY AND TUBE END LOSS PER PASS AND
C          WATERBOX LOSS FOR SINGLE AND TWO PASS CONDENSERS AS A
C          FUNCTION OF VELOCITY
C
      DATA VELT/1.,1.5,2.,2.5,3.,3.5,4.,4.5,5.,5.5,6.,6.5,7.,7.5,8./
      DATA TELT/.005,.035,.060,.110,.160,.220,.280,.360,.450,.540,
     $ .643,.752,.873,1.002,1.146/
      DATA WELT/.02,.035,.070 ,.110,.170,.220,.305,.395,.488,.605,.723,
     $ .850,.987,1.136,1.293,
     $ .04,.06,.09,.14,.20,.28,.37,.47,.58,.71,.841,
     $ .988,1.149,1.314,1.487/
   89 FORMAT("0INPUT ERROR.  THE SUM OF THE TPER(I) SHOULD BE 1.0000")
 6000 FORMAT(1H1///T05,"BNWL DRY COOLING TOWER COST MODEL -- ",
     $" PLASTIC TUBE, CIRCULAR TOWER VERSION."
     $ ,T80,"THIS RUN MADE ",A10,5X,A10)
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```
 5001 FORMAT(8A10)
 6001 FORMAT(T21,8A10)
 5002 FORMAT(8E10.0)
 6002 FORMAT(/1X,8G15.8)
 5003 FORMAT(16F5.0)
 6003 FORMAT (/1X8F8.1,8F8.4)
 5004 FORMAT(F10.0,4F15.8)
 6004 FORMAT(/1X,F10.2,4G15.8)
 5005 FORMAT(2A10,6F10.0)
 6005 FORMAT(/1X,2A10,1X,6G15.8)
 5006 FORMAT(3F10.0,2A10,F10.0)
 6006 FORMAT(/1X,3F10.5,1X,2A10,F10.5)
 5007 FORMAT (3A10,5F10.0)
 6007 FORMAT (/1X,2A10,1X,A10,5G15.8)
 5008 FORMAT(8I5)
 6008 FORMAT(/1X,8I6)
 5009 FORMAT(6E10.0,2A10)
 6009 FORMAT(/1X,6G15.8,5X,2A10)
 7060 FORMAT(T6,"TSTAR",T21,"TEND",T35,"VAS(1)",T51,"VAS(3)"
     $ ,T56,"VAS(4)",T81,"VAS(5)",T96,"FIXL",T111,"DEEPL")
 7090 FORMAT( 4X,"TA(1)",3X"TA(2)",3X"TA(3)",3X"TA(4)",3X"TA(5)"
     $,3X"TA(6)",3X"TA(7)",3X"TA(8)",1X"TPER(1)",1X"TPER(2)",1X"TPER(3)"
     $ ,1X"TPER(4)",1X"TPER(5)","TPER(6)",1X"TPER(7)",1X"TPER(8)")
 7120 FORMAT( 4X"TA(9)",2X"TA(10)",2X"TA(11)",2X"TA(12)",2X"TA(13)"
     $2X"TA(14)",2X"TA(15)",2X"TA(16)",1X"TPER(9) TPER(10)TPER(11)TPER(1
     $2TPER(13)TPER(14)TPER(15)TPER(16)")
 7150 FORMAT(T5,"PSIZE",T23,"TEFF",T38,"CAPF",T54,"FCR",T69,"PER"
     $ ,T94,"CCM",T96,"ELEV",T108,"ROOFL")
 7180 FORMAT(T5,"FCOS",T23,"PWCOS",T38,"PLANC",T52,"COSTL",T67,"CSSPKW"
     $ ,T82,"CAPCHG",T97,"HPCST")
 7185 FORMAT (T5,"POHBAF",T20,"POHFAN",T35,"POHLEC",T50,"POHCIR",
     $ T65,"POHCND",T80,"POHSTC",T95,"POHSCL")
 7210 FORMAT(T5,"RBP",T17,"TPO(1)",9X"TPO(2)",9X"TPO(3)",9X"TPO(4)")
 7240 FORMAT(T5,"EFFP",T20,"DPRESS")
 7270 FORMAT(T4,"VELREC",T20,"XDEPA",T35,"TLIM",T50,"TOWMIN",T65,"PFACT"
     $ ,T75,"TFIX",T90,"RFIX",T105,"TOWMAX")
 7300 FORMAT(T5,"CPM",T20,"WPL",T35,"CLUVR",T50,"CHAILS",T65,"UCS",T80
     $ ,"JWS",T95,"CVM",T110,"WFV")
 7330 FORMAT(T5,"NTUCAL",T24,"HXNP",T44,"WB",T58,"NTUB",T75,"SS"
     $ )
 7335 FORMAT(T5,"DESVEL",T21,"REDUCE",T35,"QREDUCE",T50,"DIST")
 7360 FORMAT(T6,"XW",T18,"XD",T28,"XDG",T35,"TUBARG HCALC",T53
     $ ,"DANGLE")
 7390 FORMAT(5X"ODL",12X"DI",03X"GAGLIN",9X"TUBMA",13X"CONL")
 7400 FORMAT(T5,"SPAMAT",T28,"CSEALP",T43,"TSEALP",T58,"CELAST"
     $ ,T73,"TELAST",T88,"ROESEL",T103,"ROEELA")
 7450 FORMAT(5X,"CASTC",10X,"EPREPC",10X,"CFS")
 7480 FORMAT (T4,"HEDTYP", T24,"HEDMAT",T36,"TW")
 7510 FORMAT(5X,"CRJ",12X,"CWJ",12X,"CHH",12X,"CN",12X,"CMW",12X,"CST",
     $ 12X,"CBJ")
 7540 FORMAT(5X"XNS",12X"VELN",11X"ODC",12X"GA",13X"FC",13X"TTD"
     $ ,15X"CONMAT")
 7570 FORMAT(T4, "LFB", T11, "LFE", T15, "MXEXT")
 7280 FORMAT(5X,"GBEFF")
C
      DO 18 I=1,5
   18 VAR(I) = 0.0
```

```
      TCOS = 0.0
C
      EXTLNG=.FALSE.
      EXTEMP = .FALSE.
      CALL DATE(DOY)
      CALL TIME(HEURE)
      WRITE(6,6000) DOY,HEURE
      IF(NUCASE.GT. 0) GO TO 110
C
CARDS A1 - A2
   30 READ(5,5001) DESCR
      DO 35 I=1,8
       IF(DESCR(I).NE.BLANK) GOTO 37
   35 CONTINUE
      GOTO 40
   37 WRITE(6,6001) DESCR
      GOTO 30
   40 CONTINUE
C
CARD B1
       READ(5,5002) TSTAR, TEND, VAS(1), VAS(3), VAS(4), VAS(5)
     $ ,FIXL, DEEPL
      WRITE(6,6002) TSTAR,TEND, VAS(1), VAS(3), VAS(4), VAS(5)
     $ ,FIXL, DEEPL
      WRITE(6,7060)
C
CARD C1
       READ(5,5003) (TA(I),I=1,8) , (TPER(I),I=1,8)
      WRITE(6,6003) (TA(I),I=1,8) , (TPER(I),I=1,8)
      WRITE(6,7090)
C
CARD C2
       READ(5,5003) (TA(I),I=9,16) , (TPER(I),I=9,16)
      WRITE(6,6003) (TA(I),I=9,16) , (TPER(I),I=9,16)
      WRITE(6,7120)
C
CARD D1
       READ(5,5002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
      WRITE(6,6002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
      WRITE(6,7150)
C
CARD E1
       READ(5,5002) FCOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
      WRITE(6,6002) FCOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
      WRITE(6,7180)
C
CARD E2
       READ(5,5002) POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC
     $              ,POHSCL
      WRITE(6,6002) POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC
     $              ,POHSCL
      WRITE(6,7185)
C
CARD F1
       READ(5,5004) RBP, (TPO(I),I=1,4)
      WRITE(6,6004) RBP, (TPO(I),I=1,4)
      WRITE(6,7210)
```

```
C
CARD G1
      READ(5,5002) EFFP, DPRESS
      WRITE(6,6002) EFFP, DPRESS
      DPRESS = DPRESS + 1.E-30
      IPRESS = DPRESS
      WRITE(6,7240)
C
CARD H1
      READ(5,5002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX, RFIX
     $             ,TOWMAX
      WRITE(6,6002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX, RFIX
     $             ,TOWMAX
      ITMIN = TOWMIN + 1.E-30
      IF (ITMIN .LT. 1) ITMIN = 1
      ITMAX = TOWMAX + 1.E-30
      IF (ITMAX .LT. 1) ITMAX = 9999
      IF (ITMAX .LT. ITMIN) STOP"TOWMAX IS LESS THAN TOWMIN"
      IF(TLIM .LT.1.) TLIM = 180.
      IF( TFIX.GT.0.0 .AND. RFIX.GT.0.0) FXTEMP = .TRUE.
      WRITE(6,7270)
      IF (VAS(1) .LE. 0.0) VAS(1) = TSTAR + (TLIM-TA(1))-5.
C
CARD H2
      READ(5,5002) GBEFF
      WRITE(6,6002) GBEFF
      WRITE(6,7280)
C
CARD I1
      READ(5,5002) CPM, WPL, CLUVR, CHAILS, UCS, UWS, CVM, WFV
      WRITE(6,6002) CPM, WPL, CLUVR, CHAILS, UCS, UWS, CVM, WFV
      WRITE(6,7300)
C
CARD J1
      READ(5,5005) NTUCAL, HXNP, WB, NTUB, SS
      WRITE(6,6005) NTUCAL, HXNP, WB, NTUB, SS
      WRITE(6,7330)
C
CARD J2
      READ(5,5002) DESVEL, REDUCE, QREDUCE, DIST
      WRITE(6,6002) DESVEL, REDUCE, QREDUCE, DIST
      WRITE(6,7335)
C
CARD K1
      READ(5,5006) XW, XD, XDG, TUBARG, HCCALC, DANGLE
      IF(TUBARG .EQ. " ") TUBARG = "STAGGERED "
      IF(HCCALC .EQ. " ") HCCALC = "2         "
      IF(TUBARG .EQ."STAGGERED " .AND. HCCALC .EQ."1          ")IHEAT=1
      IF(TUBARG .EQ."STAGGERED " .AND. HCCALC .EQ."2          ")IHEAT=2
      IF(TUBARG .EQ."INLINE    ") IHEAT =3
      WRITE(6,6006) XW, XD, XDG, TUBARG, HCCALC, DANGLE
      WRITE(6,7360)
C     CONVERT DEGREES TO RADIANS
      COANG = COS(DANGLE * 3.14159 / 180.)
 9990 FORMAT("0IHEAT=",I3)
      WRITE(6,9990) IHEAT
C
```

```
      CARD L1
            READ(5,5006) ODL, DI, GAGLIN, TUBMAT, XTUBMA, CONLI
            WRITE(6,6006) ODL, DI, GAGLIN, TUBMAT, XTUBMA, CONLI
            WRITE(6,7390)
      C
      CARD M1
            READ(5,5005) SPAMAT,CSEALP,TSEALP,CELAST,TELAST,ROESEL,ROEELA
            WRITE(6,6005) SPAMAT,CSEALP,TSEALP,CELAST,TELAST,ROESEL,ROEELA
            WRITE(6,7400)
      C
      CARD N1
            READ(5,5002) CASTC, EPREPC, CFS
            WRITE(6,6002) CASTC, EPREPC, CFS
            WRITE(6,7450)
      C
      CARD P1
            READ(5,5007) HEDTYP, XHEDTY, HEDMAT, TW
            WRITE(6,6007) HEDTYP, XHEDTY, HEDMAT, TW
            WRITE(6,7480)
      C
      CARD Q1
            READ(5,5002) CRJ, CWJ, CHH, CN, CMW, CST, CBU
            WRITE(6,6002) CRJ, CWJ, CHH, CN, CMW, CST, CBU
            WRITE(6,7510)
      C
      CARD R1
            READ(5,5009) XNS, VELN, ODC, GA, FC, TTD, CONMAT, CONMA2
            WRITE(6,6009) XNS, VELN, ODC, GA, FC, TTD, CONMAT, CONMA2
            WRITE(6,7540)
      C
      CARD S1
            READ(5,5008) LFB, LFE, MXEXT
            WRITE(6,6008) LFB, LFE, MXEXT
            WRITE(6,7570)
            IF (MXEXT .LT. 1) MXEXT = 10
            IF (LFE .LT. LFB) STOP "LFB EXCEEDS LFE ON INPUT CARD"
      C
            EHR = 3414.43 / TEFF
            IF(FIXL.GT.0.0) FXTLNG=.TRUE.
            DO 45 J=1,16
            IF(TPER(J).LT.1.E-20) GOTO 46
            NTA=J
         45 CONTINUE
         46 CONTINUE
            SMPER=0.0
            DO 20 I=1,16
         20 SMPER=SMPER + TPER(I)
            IF(ABS(SMPER-1.0).LT.1.E-10 )GOTO 22
            WRITE(6,89)
            STOP
         22 CONTINUE
      C
      C
      C DETERMINE POSITION OF TUBE O.D. AND GAGE IN RESPECTIVE ARRAYS
      C
            DO 99 I=1,6
             LD = I
```

```
      IF( ABS(ODC-TOD(LD)) .LT. .001) GOTO 1011
   99 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE OD"
C
 1011 DO 98 I= 1,7
      KGA = I
      IF( ABS(GA-TGA(KGA)).LT. .001) GOTO 100
   98 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE GAGE"
C
  100 CONTINUE
C
      CALL COSTEX(DUM1)
C
      RETURN
C
  110 CONTINUE
      READ(5,READIN)
      IF(NUCASE .EQ. 0) RETURN
      WRITE(6,6002) TSTAR,TEND, VAS(1), VAS(3), VAS(4), VAS(5)
     + ,FIXL,DEEPL
      WRITE(6,7060)
      WRITE(6,6003) (TA(I),I=1,8), (TPER(I),I=1,8)
      WRITE(6,7120)
      WRITE(6,6002) PSIZE, TEFF, CAPFL, FCR, PER, CCM, ELEV, ROOFL
      WRITE(6,7150)
      WRITE(6,6002) FCOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
      WRITE(6,7180)
      WRITE(6,6002) POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC
     +              ,POHSCL
      WRITE(6,7185)
      WRITE(6,6004) RBP, (TPO(I),I=1,4)
      WRITE(6,7210)
      WRITE(6,6002) EFFP, DPRESS
      WRITE(6,7240)
      WRITE(6,6002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX, RFIX
     +              ,TOWMAX
      ITMIN = TOWMIN + 1.E-30
      IF (ITMIN .LT. 1) ITMIN = 1
      ITMAX = TOWMAX + 1.E-30
      IF (ITMAX .LT. 1) ITMAX = 9999
      IF (ITMAX .LT. ITMIN) STOP"TOWMAX IS LESS THAN TOWMIN"
      IF (TLIM .LT. 1) TLIM = 180.
      IF (TFIX .GT. 0.0 .AND. RFIX .GT. 0.0) FXTEMP = .TRUE.
      WRITE(6,7270)
      WRITE(6,6002) GBEFF
      WRITE(6,7300)
      WRITE(6,6002) CPM, WPL, CLUVR, CHAILS, UCS, UWS, CVM, WFV
      WRITE(6,7300)
      WRITE(6,6005) NTUCAL, HXNP, WB, NTUB, SS
      WRITE(6,7330)
      WRITE(6,6002) DESVEL, REDUCE, QREDUCE, DIST
      WRITE(6,7335)
      WRITE(6,6006) XW, XD, XDG, TUBARG, HCCALC, DANGLE
      WRITE(6,7360)
      CDANG = COS(DANGLE * 3.14159 / 180.)
      WRITE(6,6006) ODL, DI, GAGLIN, TUBMAT, XTUBMA, CONLI
```

```
      WRITE(6,7390)
      WRITE(6,6005) SPAMAT,CSEALP,TSEALP,CELAST,TELAST,ROESEL,ROEELA
      WRITE(6,7400)
      WRITE(6,6002) CASTC, EPREPC, CFS
      WRITE(6,7450)
      WRITE(6,6007) HEDTYP, XHEDTY, HEDMAT, TW
      WRITE(6,7480)
      WRITE(6,6002) CRJ, CHJ, CHH, CNW, CMW, CST, CBU
      WRITE(6,7510)
      WRITE(6,6009) XNS, VELN, ODC, GA, FC, TTD, CONMAT, CONMA2
      WRITE(6,7540)
      WRITE(6,6008) LFB, LFE, MXEXT
      WRITE(6,7570)
      IF(FIXL.GT.0.0) FXTLNG=.TRUE.
      END
```

```
      SUBROUTINE SHOT(L)
C
C     THIS ROUTINE ESTABLISHES A STARTING PLACE FOR THE MINIMIZING PRO-
C     CEDURE BY SAMPLING POINTS AROUND THE STARTING VALUES PROVIDED.
C
      LOGICAL FXTLNG
      DIMENSION T(3),CWAR(4),RANG(3),AFRO(3),WLRA(4),VAM(5)
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFN
     $ ,XDEPT, XW, XD
      COMMON /FLSW/ FXTLNG
      COMMON /LACALL/ SRN
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BR2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHDR, WTERM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIREF,  WATEF,  XNMOD,  TCTPF, FDCPF, FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFAC2S,   W41,    U1, PPOW1,
     $   FPOW1, DELFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPSI3,WT2MIN,
```

```
      $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
      $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
      $,  CLTC1,  CFC1, CPCC1,FITC01,  CSC1,CEPRE1,DEPIP1,  AST1
      $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
      $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
      $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FOCPF1, FMTPC1, ACTTP1, ADJTP1
      $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
      $,   CSE1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
      $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
       COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
      $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
       COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
 9500 FORMAT("0IN SHOT AT CHECKPOINT A,  VAR(4)=",1PE12.4,6X,"VAM(4)=",
     $E12.4,6X,"DAFRO=",E12.4)
 9501 FORMAT("0IN SHOT AT CHECKPOINT B,  I=",I1,6X,"DAFRO=",1PE12.4,6X,
     $ "VAR(4)=",E12.4,6X,"AFRO(I)=",E12.4)
 9502 FORMAT("0IN SHOT AT CHECKPOINT C,  I=",I1,6X,"VAR(4)=",1PE12.4,
     $ 6X,"FAF=",E12.4)
       IF(FXTEMP) CALL ROOT(TFIX,RFIX,TTD,TD,CWARL)
       IDB=0
       IF(L.EQ.2) GO TO 31
       DO 1 IS=1,5
     1 VAM(IS)=0.0
       TCOS1=0.
       TCOS2=0.
       DO 20 I=1,3
       T(I)=VAS(1)+(I-2)*5.
       IF(FXTEMP) T(I) = TFIX
       IF (T(I) .GT. 180.) T(I) = 180.
    20 IF (T(I) .LE. 0.0) T(I) = 10.0
       DO 21 I=1,4
       CWAR(I)=VAS(3)+(I-2)*2.
    21 IF(CWAR(I).LE.0.) CWAR(I)=.5
       IF(.NOT. FXTEMP) GO TO 24
       CWAR(1) = CWARL*0.90
       CWAR(2) = CWARL*0.80
       CWAR(3) = CWARL*0.70
       CWAR(4) = CWARL*0.60
    24 CONTINUE
       DO 22 I=1,4
       WLRA(I)=VAS(5)+(I-2)*10.
    22 IF(WLRA(I).LE.0.) WLRA(I)=5.
       AFRO(1)=VAS(4)/2.
       AFRO(2)=VAS(4)
       AFRO(3)=VAS(4)*2.
       DT1=1.
       DCWAR=1.
       DAFRO=1.
       DWLRA=1.
       LC=4
       LW=4
       GO TO 61
    31 DT1=VAR(1)-VAM(1)
       DCWAR=VAR(3)-VAM(3)
       DAFRO=VAR(4)-VAM(4)
C                                                          *** CHECKPOINT
       IF(DAFRO.LE.0.0.AND.IDB.NE.0) WRITE(6,9500) VAR(4),VAM(4),DAFRO
```

```
      DWLRA=VAR(5)-VAM(5)
      IF(DT1.EQ.0..OR.DT1.EQ.VAR(1)) GO TO 33
      DO 32 I=1,3
      T(I) = VAR(1) - (I-1) * DT1/2.
      IF(FXTEMP) T(I) = TFIX
   32 CONTINUE
      GO TO 35
   33 DO 34 I=1,3
      T(I)=VAR(1)+(I-2)*2.
      IF(FXTEMP) T(I) = TFIX
   34 IF(T(I).GE.170.) T(I)=170.
   35 IF(DCWAR.EQ.0.0.OR.DCWAR.EQ.VAR(3)) GO TO 37
      DO 36 I=1,4
      CWAR(I)=VAR(3) -(I-1)*DCWAR/3.
      IF(CWAR(I).LE.0.0) CWAR(I)=0.25
   36 CONTINUE
      GO TO 39
   37 DO 38 I=1,3
      CWAR(I)=VAR(3) + (I-2)
      IF(CWAR(I).LE.0.0) CWAR(I)=0.25
   38 CONTINUE
      LC=3
   39 IF(DAFRO.EQ.0.0.OR.DAFRO.EQ.VAR(4)) GO TO 41
      DO 40 I=1,3
   40 AFRO(I)=VAR(4)-(I-1)*DAFRO/2.
C                                                          *** CHECKPOINT
      IF(IDB.EQ.0) GOTO 43
      DO 8040 I=1,3
      IF(AFRO(I).LE.0.0) WRITE(6,9501) I,DAFRO,VAR(4),AFRO(I)
 8040 CONTINUE
      GO TO 43
   41 FAF=.555
      TC=ABS(FAF-VAR(4))
      IF(TC.LT.1.E+4) FAF=FAF*0.9
      DO 42 I=1,3
      AFRO(I)=VAR(4)+(I-2)*FAF
      IF(  AFRO(I).LE. 0.0) AFRO(I)=1000. * I
   42 CONTINUE
C                                                          *** CHECKPOINT
      IF(IDB.EQ.0) GOTO 43
      DO 8042 I=1,3
      IF(AFRO(I).LE.0.0) WRITE(6,9502) I,VAR(4),FAF
 8042 CONTINUE
   43 IF(DWLRA.EQ.0.0.OR.DWLRA.EQ.VAR(5)) GO TO 45
      DO 44 I=1,4
   44 WLRA(I)=VAR(5)-(I-1)*DWLRA/3.
      GO TO 51
   45 DO 46 I=1,3
   46 WLRA(I)=VAR(5)+(I-2)*5.
      LW=3
   51 DO 15 IT=1,3
      DO 15 IC=1,LC
      IF(CWAR(IC).EQ.0.0) WRITE(6,9504) IC
 9504 FORMAT("0IN SHOT, DIVISION BY ZERO.  CWAR(",I2,")=0.0")
      RANGL = (T(IT)-TTO-TO)*(1.-EXP(-CWAR(IC)))/CWAR(IC)
    2 RANG(1)=.9*RANGL
      RANG(2)=.7*RANGL
```

```
      RANG(3)=.5*RANGL
      IF(FXTEMP) RANG(1) = RFIX
      IF(FXTEMP) RANG(2) = RFIX
      IF(FXTEMP) RANG(3) = RFIX
      DO 15 IR=1,3
      DO 15 IA=1,3
      DO 15 IW=1,LW
      KCALC=1
      IF(IR.GT.1.OR.IC.GT.1) KCALC=2
      IF(IA.GT.1) KCALC=4
      IF(IW.GT.1) KCALC=5
      SRN="/SHOT-1/  "
      CALL CALC(T(IT),RANG(IR),CWAR(IC),AFRO(IA),WLRA(IW),KCALC)
      IF(KCONV.EQ.1) GO TO 15
C     IF(DELPA.LT.XDEPA) GO TO 16
      IF(DELPA.LE.XDEPA) GO TO 16
      IF(TCOS1.EQ.0.) GO TO 14
C     IF(TCOS.GT.TCOS1) GO TO 16
      IF(TCOS.GE.TCOS1) GO TO 16
      IF(TCOS2.EQ.0.) GO TO 18
C     IF(TCOS1.GT.TCOS2) GO TO 14
      IF(TCOS1.GE.TCOS2) GO TO 14
   18 TCOS2=TCOS1
      DO 19 II=1,5
   19 VAM(II)=VAR(II)
   14 TCOS1=TCOS
      VAR(1)=T(IT)
      VAR(2)=RANG(IR)
      VAR(3)=CWAR(IC)
      VAR(4)=AFRO(IA)
      VAR(5)=WLRA(IW)
      CAF=AFRO(1)*.1
      GO TO 15
   16 IF(LW.EQ.2) GO TO 15
      IF(TCOS2.EQ.0.) GO TO 17
      IF(TCOS.GE.TCOS2) GO TO 15
C     IF(TCOS.GT.TCOS2) GO TO 15
   17 TCOS2=TCOS
      VAM(1)=T(IT)
      VAM(3)=CWAR(IC)
      VAM(4)=AFRO(IA)
      VAM(5)=WLRA(IW)
   15 CONTINUE
      IF(ID3.EQ.0) RETURN
      WRITE(6,553)TCOS1,VAR(1),VAR(2),VAR(3),VAR(4),VAR(5)
  553 FORMAT(" TCOS1="E12.5," T11="F4.0," RANG1="F7.4," CWAR1="F7.3,
     1" AFRO1="E10.3," WLRA1="F4.0)
      RETURN
      END
```

```
      SUBROUTINE SPDES(TD,TS,TR,TTD,XNS,CHLD,VELD,RHO,ARPS,TLA,XNTS,HDLD
     1S)
C
C
C     SUBROUTINE SPDES DESIGNS A SINGLE PRESSURE SURFACE CONDENSER
C     IN ACCORDANCE WITH HEAT EXCHANGE INSTITUTE (HEI) STANDARDS
C     FOR SURFACE CONDENSERS FOR GIVEN DESIGN VALUES OF TURBINE
C     EXHAUST STEAM SATURATION TEMPERATURE, CIRCULATING WATER
C     TEMPERATURE RISE IN THE CONDENSER, CONDENSER TERMINAL
C     TEMPERATURE DIFFERENCE, CLEANLINESS FACTOR, TUBE SIZE AND
C     NOMINAL VELOCITY THROUGH THE TUBES, AND FOR A GIVEN TUBE
C     MATERIAL
C
C     DEFINITION OF VARIABLES
C
C     ARPS     - AREA PER CONDENSER SHELL (SQ FT)
C     AST      - TOTAL AREA OF CONDENSER SHELLS (SQ FT)
C     CHLD     - HEAT TRANSFERED IN THE CONDENSER (BTU/HR)
C     CU       - ARRAY OF VELOCITY CONSTANTS FOR THE OVERALL HEAT
C                TRANSFER COEFFICIENT AS A FUNCTION OF THE TUBE
C                OUTSIDE DIAMETER (DIMENSIONLESS)
C     DELPWC   - PRESSURE DROP OF THE WATER THROUGH THE CONDENSER
C                (LBF/SQ FT)
C     EFFC     - EFFECTIVENESS OF THE CONDENSER (DIMENSIONLESS)
C     ESA      - ARRAY OF EXTERNAL SURFACE AREA OF CONDENSER TUBE
C                PER LINEAR FOOT AS A FUNCTION OF TUBE OUTSIDE
C                DIAMETER ((SQ FT/FT)
C     FC       - FOULING FACTOR FOR THE OVERALL HEAT TRANSFER
C                COEFFICIENT (DIMENSIONLESS)
C     FGA      - ARRAY OF TUBE WALL GAGE CORRECTION FACTORS FOR THE
C                OVERALL HEAT TRANSFER COEFFICIENT FOR ADMIRALTY
C                METAL, ARSENICAL COPPER OR ALUMINUM TUBES FOR
C                SURFACE CONDENSERS (DIMENSIONLESS)
C     FPL      - LENGTH OF FLOW PATH PER SHELL (FT)
C     FTF      - ARRAY OF GPM PER FPS VELOCITY THRU TUBES AS A
C                FUNCTION OF TUBE GAGE AND TUBE OUTSIDE DIAMETER
C                (GPM/FT/SEC)
C     FTI      - INLET TEMPERATURE CORRECTION FACTOR FOR THE
C                OVERALL HEAT TRANSFER COEFFICIENT (DIMENSIONLESS)
C     FTIN     - ARRAY OF INLET TEMPERATURE CORRECTION FACTORS AS
C                A FUNCTION OF INLET TEMPERATURES (DIMENSIONLESS)
C     GPM      - VOLUMETRIC FLOW RATE THROUGH THE CONDENSER
C     GPM      - VOLUMETRIC FLOW RATE OF WATER THROUGH THE CONDENSER
C                (GALLONS/MINUTE)
C     GPMS     - VOLUMETRIC FLOW RATE OF WATER THROUGH EACH SHELL
C                OF THE CONDENSER (GALLONS/MINUTE)
C     HDLOS    - HEAD LOSS OF THE WATER THROUGH THE CONDENSER (FT)
C     HDLS     - HEAD LOSS OF THE WATER THROUGH THE TUBES OF THE
C                CONDENSER (FT/100 FT)
C     PROP     - ARRAY OF THE WATER PROPERTIES DENSITY AND VISCOSITY
C                AS A FUNCTION OF TEMPERATURE (LBM/CU FT  LBM/FT HR)
C     RHO      - DENSITY OF THE WATER (LBM/CU FT)
C     TAVT     - AVERAGE TEMPERATURE OF THE WATER GOING THROUGH THE
C                CONDENSER (DEG F)
C     TDLM     - LOG MEAN TEMPERATURE DIFFERENCE OF THE CONDENSER
C                (DEG F)
C     TE       - EXIT TEMPERATURE OF THE WATER LEAVING THE CONDENSER
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C                    (DEG F)
C          TELOS   - HEAD LOSS OF THE WATER IN THE CONDENSER DUE TO
C                    TUBE END EFFECTS (FT)
C          TELT    - ARRAY OF HEAD LOSSES DUE TO TUBE END EFFECTS AS A
C                    FUNCTION OF WATER VELOCITY (FT)
C          TH2O    - ARRAY OF WATER TEMPERATURES (DEG F)
C          TI      - INLET TEMPERATURE OF THE WATER ENTERING THE
C                    CONDENSER (DEG F)
C          TID     - ARRAY OF INSIDE TUBE DIAMETERS AS A FUNCTION
C                    OF TUBE GAGE AND OUTSIDE DIAMETER (IN)
C          TIN     - INLET TEMPERATURE ARRAY USED IN CONJUCTION WITH
C                    THE INLET TEMPERATURE CORRECTION FACTOR (DEG F)
C          TLA     - INTEGER VALUE OF FLOW PATH LENGTH PER SHELL (FT)
C          TR      - TEMPERATURE RANGE OF THE WATER FLOWING THROUGH THE
C                    CONDENSER (DEG F)
C          TS      - TURBINE EXHAUST STEAM SATURATION TEMPERATURE
C                    (DEG F)
C          TTD     - TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE
C                    SATURATED STEAM TEMPERATURE AND EXIT TEMPERATURE
C                    OF THE WATER LEAVING THE CONDENSER (DEG F)
C          UCON    - OVERALL HEAT TRANSFER COEFFICIENT OF THE CONDENSER
C                    (BTU/HR-SQ FT-DEG F)
C          VELD    - VELOCITY OF THE WATER THRU THE TUBES OF THE
C                    CONDENSER (FT/SEC)
C          VELN    - INITIAL GUESS OF THE VELOCITY OF THE WATER IN THE
C                    CONDENSER TUBES (FT/SEC)
C          VELT    - ARRAY OF VELOCITIES USED IN CONJUNCTION WITH THE
C                    TUBE END LOSS ARRAY AND THE WATER BOX LOSS ARRAY
C                    (FT/SEC)
C          VIS     - VISCOSITY OF THE WATER (LBM/FT-HR)
C          WBLOS   - ARRAY OF HEAD LOSS IN THE WATER BOXES OF THE
C                    CONDENSER AS A FUNCTION OF THE VELOCITY OF THE
C                    WATER IN THE CONDENSER TUBES (FT)
C          WBLT    - LOSS OF HEAD IN THE WATER BOX OF THE CONDENSER (FT)
C          XNP     - NUMBER OF PASSES THE WATER MAKES THROUGH THE
C                    CONDENSER SHELL (DIMENSIONLESS)
C          XNS     - NUMBER OF CONDENSER SHELLS (DIMENSIONLESS)
C          XNTS    - NUMBER OF TUBES PER CONDENSER SHELL (DIMENSIONLESS)
C
      COMMON /RPRT2/  DMMM  ,TI    ,TE    ,TDLM  ,XNP
     $ ,VELD7,DELPW7,ARPS7,TLA7,XNTS7,XNS7,TS7
      COMMON/TUBE/KGA,FGA(7),LD,ESA(6),TID(7,6),FTF(7,6)
      COMMON/OHTC/FC,CU(6),VELN
      COMMON/INLT/TIN(15),FTIN(15)
      COMMON/PH2O/TH2O(15),PROP(16,2)
      COMMON/STEM/TSTM(51),PSTM(51)
      COMMON/CFHL/VELT(15),TELT(15),WBLT(15,2)
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SWR,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,   NW2,   TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLMX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHOR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
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      $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
C
C          DETERMINE CONDENSER OUTLET, INLET AND AVERAGE COOLING WATER
C          TEMPERATURES, DENSITY OF COOLING WATER BASED ON AVERAGE
C          TEMPERATURE, TOTAL COOLING WATER FLOW, COOLING WATER FLOW PER
C          SHELL, LOG MEAN TEMPERATURE DIFFERENCE AND INLET TEMPERATURE
C          CORRECTION FACTOR
C
  901 FORMAT(" NON INTEGER TLA.  VALUE=",1PE13.6)
  110  TE=TS-TTD
       TI=TE-TR
       TAVT=(TI+TE)/2.
       RHO=TLU(TAVT,THRD,PROP,16)
       GPM=CHLD/(8.021*RHO*TR)
C     WRITE(6,901) RHO,GPM
       GPMS=GPM/XNS
       TDLM=TR/ALOG((TR+TTD)/TTD)
       FTI=1.1+0.001887*(TI-100.)
       IF(TI.LT.100.) FTI=TLU(TI,TIN,FTIN,15)
C
C          SET VELOCITY THROUGH TUBES EQUAL TO NOMINAL DESIGN VALUE AND
C          INITIALIZE INDEX USED TO INDICATE WHETHER INITIAL OR SUB-
C          SEQUENT CALCULATION OF SURFACE AREA FOR GIVEN DESIGN
C          CONDITIONS
C
       VELD=VELN
       ISA=1
C
C          DETERMINE OVERALL HEAT TRANSFER COEFFICIENT AND SURFACE AREA
C          PER SHELL
C
  104  UCON=CU(LD)*SQRT(VELD)*FTI*FGA(KGA)*FC
      DMMM=UCON
       ARPS=(CHLD/XNS)/(UCON*TDLM)
      NAMELIST/DBGPO/
     $        ARPS,VELD,GPMS,XNP,VEL,TLA,XNS,CHLD,UCON,TDLM,ISA
       IF(LEGVAR(ARPS).NE.0) WRITE(6,DBGPO)
       IF(LEGVAR(ARPS).NE.0) STOP "IN SPDES1"
C
C          FOR INITIALLY CALCULATED VALUE OF SURFACE AREA, DETERMINE THE
C          LENGTH OF FLOW PATH PER SHELL, THE NUMBER OF PASSES PER SHELL
C          AND THE ACTUAL TUBE LENGTH ROUNDED TO THE NEAREST FOOT
C
       IF(ISA-1)100,100,101
  100  FPL=ARPS*VELD*FTF(KGA,LD)/(GPMS*ESA(LD))
       IF(FPL.LT.1.E-20) WRITE(6,DBGPO)
       IF(FPL.LT.1.E-20) STOP"INSPDES2"
       XNP=1.
       IF(FPL.GT.50.) XNP=2.
       TLA=ATNT(FPL/XNP)
       IF(TLA.LT.1.0) TLA=FPL/XNP
       IF(TLA.LT.1.0) WRITE(6,901) TLA
       IF(TLA.LT.1.0) GOTO 103
C
```

```
C          CALCULATE ACTUAL VELOCITY THROUGH TUBES AND IF IT DOES NOT
C          AGREE WITHIN SPECIFIED LIMITS WITH THE CURRENT DESIGN VALUE,
C          CHANGE INDEX TO INDICATE SUBSEQUENT CALCULATION AND DETERMINE
C          SURFACE AREA USING CALCULATED VALUE OF VELOCITY
C
  101  VEL=GPMS*ESA(LD)*TLA*XNP/(ARPS*FTF(KGA,LD))
       IF(VEL.LT.1.E-20) WRITE(6,DBGPD)
       IF(VEL.LT.1.E-20) STOP "IN SPDES3"
C
        IF((ABS(VEL-VELD)/VELD)-0.002)103,103,102
  102   ISA=2
        VELD=VEL
        GO TO 104
C
C          DETERMINE NUMBER OF TUBES OF GIVEN SIZE PER SHELL AND TOTAL
C          CONDENSER HEAT TRANSFER SURFACE AREA
C
  103  XNTS=AINT(GPMS/(VELD*FTF(KGA,LD))+0.5)*XNP
       XNTSX=XNTS * XNS
        AST=ARPS*XNS
C
C          DETERMINE HEAD LOSS THRU THE CONDENSER, INCLUDING TUBE-END
C          AND WATERBOX LOSSES
C
        VIS=TLU(TAVT,TH2O,PROP(1,2),15)
        CALL HYDLOS(FID(KGA,LD),VELD,VIS,RHO,1,HDLS)
        TELOS=TLU(VELD,VELT,TELT,15)*XNP
       INP=XNP
       WBLOS = TLU(VELD, VELT,WBLT(1,INP),15)
        HDLOS=TLA*XNP/100.*HDLS+TELOS+WBLOS
       DELPWC=HDLOS  * RHO
C
C          STORAGE OF VARIABLES
C
       TLAX=TLA
       VELDX=VELD
       EFFC=TR/(TR+TTD)
       VELD7=VELD
       DELPW7=DELPWC
       ARPS7=ARPS
       TLA7=TLA
       XNTS7=XNTS
       XNS7=XNS
       TS7=TS
        RETURN
        END
```

```
      SUBROUTINE SSCALE
C
C          SUBROUTINE SSCALES SCALES THE STEAM SUPPLY SYSTEM UP TO
C          OBTAIN THE SPECIFIED POWER OUTPUT OF THE PLANT (PSIZE) AT THE
C          RATED BACK PRESSURE OF THE STEAM TURBINE. THE INCREMENTAL
C          COST OVER THAT OF THE SYSTEM USING A CONVENTIONAL TURBINE IS
C          CALCULATED AT THE RATED BACK PRESSURE.
C
C          DEFINITION OF VARIABLES
C
C          CASSS1   - INCREMENTAL COST OF STEAM SUPPLY FOR MAKE UP OF
C                     POWER OUTPUT DUE TO INCREASED HEAT RATE AT RATED
C                     BACK PRESSURE ($)
C          CSSPKW   - COST OF STEAM SUPPLY SYSTEM PER KILOWATT ($/KW)
C          HRFAC1   - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
C                     PRESSURE (DIMENSIONLESS)
C          PLANC    - COST OF POWER PLANT PER KILOWATT ($/KW)
C          PSIZE    - PLANT SIZE (MW)
C          RBP      - STEAM TURBINE RATED BACK PRESSURE (IN HGA)
C          SSCD     - INCREMENTAL PLANT COST DUE TO INCREASED HEAT RATE
C                     AT RATED BACK PRESSURE OF STEAM TURBINE ($)
C          TPO      - COEFFICIENTS OF THIRD ORDER HEAT RATE CURVE FIT
C                     FOR STEAM TURBINE (DIMENSIONLESS)
C
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAPF
     $ ,CBJ, CSEALP, CELAST, CFS, COANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFW
     $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
```

```
      $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
      $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
      $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
      $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
      $,  WTHER, WTERM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
      $,  AIRFF,  WATFF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
      $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
      $,   CSCD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
      $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
       COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
      $,  CLAN1, REAI1,    Z1,HRFA2S,   W41,    U1, PPOW1,
      $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
      $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
      $    SPC1, PTOT1,PLNC31, AFR01, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
      $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
      $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
      $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
      $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
      $,  WTHO1, WTER1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
      $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
      $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
      $,   CSE1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
      $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
       COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
      $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
C
C          EQUATION FOR HEAT RATE FACTOR AS A FUNCTION OF TURBINE
C          BACK PRESSURE
C
      HRF(P)=TPO(1) + TPO(2)*P + TPO(3)*P**2 + TPO(4)*P**3
C
C          HEAT RATE FACTOR AT RATED BACK PRESSURE
C
      HRFAC1=HRF(RBP)
C
C          INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
C          FACTOR AT RATED BACK PRESSURE ($)
C
      CASSS1=CSSPKW*(HRFAC1-1.)*PSIZE*1000.
C
C          PLANT COST TAKING INTO ACCOUNT INCREASED STEAM SUPPLY
C          COST ($/MW)
C
      PLANCT1=PLANC * PSIZE*1000. + CASSS1
      PLANC1=PLANCT1/(PSIZE*1000.)
C
C
C          INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
C          OF TURBINE ($)
C
      SSCD=(PLANC1-PLANC)*1000.* PSIZE
      RETURN
      END
```

```
      SUBROUTINE STORE
C
C     THIS ROUTINE IS CALLED EACH TIME A NEW LOW COST IS FOUND.
C     IT STORES VALUES OF COST, DESIGN, ETC. FOR THE FINAL REPORT
C
      COMMON /RPRT1/ R1(2038)
      COMMON /RPRT2/ R2(12)
      COMMON /RPRT3/ R3(4)
      COMMON /KPRT1/ SPRT1(203B)
      COMMON /KPRT2/ SPRT2(12)
      COMMON /KPRT3/ SPRT3(4)
      COMMON /SINK/ VSTO(116)
      COMMON /SUPPLY/ VIN(116)
      LOGICAL FIRST, FXTEMP
      COMMON
     $ AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAFI
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,OREJ, OREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBARG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
      DO 1 I=1,116
       VSTO(I)=VIN(I)
    1 CONTINUE
      DO 2 I=1,2038
      SPRT1(I)=R1(I)
    2 CONTINUE
      DO 3 I=1,12
      SPRT2(I)=R2(I)
    3 CONTINUE
      DO 4 I=1,4
      SPRT3(I)=R3(I)
    4 CONTINUE
      JCONS=1
      RETURN
      END
```

```
      SUBROUTINE SUMCOS(FCR,PSIZE,CAPF,CCOS1,CPIP1,CONBA1,ATUBC,CPLEN,
     $FBACC,FMCST,STRUCC,CFOUND,CAPCST,SPCD1,SSCD,HRFAC1,HRFAC2,YFP,
     $ PLANC, CLAN1, CLSUM, FCSUM, COSM1, CSTLV1, CSTHS1, CFANE1, CYLRN1
     $ )
C
C     THIS ROUTINE REPORTS THE FINAL COST SUMMARY
C
 6001 FORMAT(1H1///,T17,"C A P I T A L   C O S T   S U M M A R Y "
     $,T72,"U N I T   E N E R G Y   C O S T   S U M M A R Y"/
     $,T16,43("-"), T71,52("-")///)
 6010 FORMAT(
     L T2,"COOLING SYSTEM CAPITAL",T48,F13.0
     R,T69,"COOLING SYSTEM CAPITAL",T119,G12.6/)
 6020 FORMAT(
     L T4,"TOWER",T35,F13.0
     R,T72,"TOWER",T106,G12.6)
 6030 FORMAT(
     L T7,"HEAT EXCHANGER",T23,F13.0
     R,T75,"HEAT EXCHANGER",T93,G12.6)
 6040 FORMAT(
     L T7,"PLENUM",T23,F13.0
     R,T75,"PLENUM",T93,G12.6)
 6042 FORMAT(
     L T7,"LOUVERS",T23,F13.0
     R,T75,"LOUVERS",T93,G12.6)
 6044 FORMAT(
     L T7,"HAIL SCREENS",T23,F13.0
     R,T75,"HAIL SCREENS",T93,G12.6)
 6050 FORMAT(
     L T7,"FAN SYSTEM",T23,F13.0
     R,T75,"FAN SYSTEM",T93,G12.6)
 6060 FORMAT(
     L T7,"STRUCTURE",T23,F13.0
     R,T75,"STRUCTURE",T93,G12.6)
 6070 FORMAT(
     L T7,"FOUNDATION",T23,F13.0
     R,T75,"FOUNDATION",T93,G12.6/)
 6080 FORMAT(
     L T4,"PIPING",T35,F13.0
     R,T72,"PIPING",T106,G12.6)
 6090 FORMAT(
     L T4,"CONDENSER",T35,F13.0
     R,T72,"CONDENSER",T106,G12.6)
 6100 FORMAT(
     L T2,"CAPACITY PENALTY",T48,F13.0
     R,T69,"CAPACITY PENALTY",T119,G12.6/)
 6110 FORMAT(
     L T2,"PLANT SCALING",T48,F13.0
     R,T69,"PLANT SCALING",T119,G12.6)
 6120 FORMAT(
     L T4,"STEAM SUPPLY",T35,F13.0
     R,T72,"STEAM SUPPLY",T106,G12.6)
 6130 FORMAT(
     L T4,"BASE PLANT",T35,F13.0
     R,T72,"BASE PLANT",T106,G12.6/)
 6140 FORMAT(
     L T2,"LAND",T48,F13.0/)
```

```
6150 FORMAT(
     L T48,13("-")/)
6160 FORMAT(
     L T2,"TOTAL CAPITAL COST",T46,"$",T48,F13.0
     R,T69,"TOTAL CAPITAL COST",T119,G12.6/)
6170 FORMAT(
     R T69,"ENERGY PENALTY",T119,G12.6/)
6180 FORMAT(
     R T69,"ADDITIONAL BASE PLANT FUEL",T119,G12.6/)
6190 FORMAT(
     R T69,"OPERATION AND MAINTENANCE",T119,G12.6/)
6200 FORMAT(
     R,T72,"TOTAL",T119,G12.6)
      YFPP1 = YFP + 1.
      FACTOR= FCR/(PSIZE*CAPF*8760)
      WRITE(6,6001)
      WRITE(6,6010) (CCOS1+CPIP1+CONBA1),((CCOS1+CPIP1+CONBA1)*FACTOR)
      WRITE(6,6020) CCOS1,CCOS1*FACTOR
      WRITE(6,6030) ATUBC,ATUBC*FACTOR
      WRITE(6,6040) CPLEN,CPLEN*FACTOR
      WRITE(6,6042) CSTLV1, CSTLV1*FACTOR
      WRITE(6,6044) CSTHS1, CSTHS1*FACTOR
      WRITE(6,6050) (FBACC + FMCST + CYLRN1 + CFANE1)
     $              , (FBACC + FMCST + CYLRN1 + CFANE1) * FACTOR
      WRITE(6,6060) STRUCC,STRUCC*FACTOR
      WRITE(6,6070) CFOUND,CFOUND*FACTOR
      WRITE(6,6080) CPIP1,CPIP1*FACTOR
      WRITE(6,6090) CONBA1,CONBA1*FACTOR
      WRITE(6,6100) CAPCST,CAPCST*FACTOR
      WRITE(6,6110) SPCD1,SPCD1*FACTOR
      WRITE(6,6120) SSCD*HRFAC2/HRFAC1*YFPP1,SSCD*HRFAC2/HRFAC1*YFPP1*
     $FACTOR
      WRITE(6,6130) PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10.**3 * PSIZE,
     $ PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10**3 * PSIZE * FACTOR
      WRITE(6,6140) CLAN1
      WRITE(6,6150)
      WRITE(6,6160) CLAN1+SPCD1+CAPCST+CCOS1+CPIP1+CONBA1
     $,(CLAN1+SPCD1+CAPCST+CCOS1+CPIP1+CONBA1)*FACTOR
      WRITE(6,6170) CLSUM
      WRITE(6,6180) FCSUM
      WRITE(6,6190) COSM1
      TOTAL = (CLAN1 + SPCD1 + CAPCST + CCOS1 + CPIP1 + CONBA1) *
     $ FACTOR + CLSUM + FCSUM + COSM1
      WRITE(6,6200) TOTAL
      END
```

```
      SUBROUTINE STRUCT(DTOW, WHX, WATERW, ROOFL, CSTRUC, CFND, WSTRC,
     $                  ITOWN, ELENG, POHSTC)
C
C          SUBROUTINE STRUCT DETERMINES THE COST OF THE STRUCTURES
C          AND THE FOUNDATION FOR THE CIRCULAR TOWERS .  THE STRUCTURE
C          COST IS BASED ON THE HEIGTH AND DIAMETER OF EACH TOWER AND
C          THE DESIGN ROOF LOAD.  THE FOUNDATION COST IS BASED ON THE
C          TOTAL WEIGHT OF THE HEAT EXCHANGERS AND THE SURFACE AREA
C          COVERED BY THE TOWERS.
C
C          DEFINITION OF VARIABLES
C
C          CFND     - COST OF FOUNDATION ($)
C          CSTRUC   - COST OF STRUCTURES ($)
C          DTOW     - TOWER DIAMETER (FT)
C          ITOWN    - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C          ITOWN    - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C          POHSTC   - DIRECT AND INDIRECT CONSTRUCTION COSTS FOR THE
C                     STRUCTURES (DECIMAL PERCENT)
C          ROOFL    - DESIGN ROOF LOAD (LBF/SQ FT)
C          WATERW   - WEIGHT OF THE WATER IN THE HEAT EXCHANGER (LBF)
C          WHX      - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
C          WSTRC    - CIRCULAR TOWERS STRUCTURAL WEIGHT (LBF)
C
      DATA PI /3.14156265/
C
C          STRUCTURAL COSTS
C
      CSTRUC = ELENG * .2458 * PI/4. * DTOW**2 * ITOWN *
     $ (.00685 * ROOFL + .726)
C
C          FOUNDATION COSTS
C
      CFND = .019 * (WHX + WATERW) + .82 * PI/4. * DTOW**2 * ITOWN
C
C          STRUCTURAL WEIGHT OF COOLING TOWERS BASED ON $0.63/LB
C
      WSTRC = CSTRUC / .63
C
C          STRUCTURAL COST TAKING INTO ACCOUNT DIRECT AND INDIRECT
C          CONSTRUCTION COSTS.
C
      CSTRUC = CSTRUC * POHSTC
      RETURN
      END
```

```
      SUBROUTINE SURCON (ISUR, KGA, LD, TLA, XNTS, ARPS, XNS, CONCST
     $                   ,CONMAT, POHCND)
C
C          PROGRAM SURCON DETERMINES THE CAPITAL COST OF A SINGLE
C          PRESSURE OR SERIES-CONNECTED SURFACE CONDENSER.  REFERENCE
C          "SURFACE CONDENSERS FOR LAND INSTALLATION", FORM PL1312,
C          WESTINGHOUSE ELECTRIC CORPORATION, 26 NOVEMBER 1968
C          UPDATED ON FEBRUARY 12, 1976 TO CURRENT PRICES
C
C          DEFINITION OF VARIABLES
C
C          ACCF     - ACCESSORY COST CORRECTION FACTOR FOR THE CONDENSER
C          ADDER    - INCREASES COST OF TUBING MATERIAL
C          ARPS     - AREA PER SHELL OF THE CONDENSER (SQ FT)
C          AUXCST   - AUXILIARY COST ($)
C          CFAC     - LENGTH CORRECTION FACTOR (DIMENSIONLESS)
C          CONCST   - CONDENSER COST ($)
C          CONMAT   - VARIABLE FOR CONDENSER MATERIAL (DIMENSIONLESS)
C          DSCT     - QUANTITY DISCOUNT FOR TUBES (DIMENSIONLESS)
C          ERTCST   - ERECTION COST ($/SQ FT)
C          F        - TUBING LENGTH PENALTY (DIMENSIONLESS)
C          FETCST   - FIELD ERECTION COST ($/SQ FT)
C          FOD      - TUBE SIZE FACTOR (DIMENSIONLESS)
C          POHCND   - INDIRECT COST FACTOR FOR THE TUBE, SHELL, AND
C                     FIELD ERECTION COSTS (DIMENSIONLESS)
C          SHLCST   - SHELL COST FOR THE CONDENSER ($)
C          TCSTPF   - TOTAL COST OF TUBING MATERIAL ($/FT)
C          WT       - WEIGHT OF TOTAL AMOUNT OF TUBES IN THE CONDENSER
C                     (LBF)
C          XNS      - NUMBER OF SHELLS IN THE CONDENSER (DIMENSIONLESS)
C          XNTS     - NUMBER OF TUBES PER SHELL (DIMENSIONLESS)
C
C          DEFINITION OF ARRAYS
C
C          TUBMA    - TUBE MATERIAL (NAMES)
C          CL       - TUBE FIXED COSTS ($)
C          CLM      - TUBE MATERIAL COSTS ($/LBM)
C          ROEL     - DENSITY OF TUBE MATERIALS (LBM/CU IN)
C          GAGLI    - TUBE GAGE (DIMENSIONLESS)
C          THKLIN   - THICKNESS OF TUBE (IN)
C          ODLINE   - COMMON DIAMETERS OF TUBES (IN)
C
      LOGICAL FIRST
      DIMENSION SCC1(6), SCC2(6)
      DIMENSION TUBMA(10), CL(10), CLM(10), ROEL(10), GAGLI(7),
     * THKLIN(7), ODLINE(6), FF(10,7)
      COMMON /RPRT3/  TUBCST,SHLCST,FETCST,CONBAT
C
C          TUBING MATERIALS, COSTS, AND DENSITY
C
      DATA CL / 0.00, 0.00, 0.00, 0.08, 0.04, 0.38, 0.12, 0.20, 0.15,
     * 0.10 /
      DATA CLM / 1.30, 1.52, 1.83, 1.40, 1.36, 0.44, 0.32, 1.63, 7.60,
     * 7.00 /
      DATA ROEL / 0.308, 0.323, 0.323, 0.0975, .0975, 0.284, 0.284, .290
     $ ,0.163, 0.163 /
      DATA TUBMA / "ADMIRALTY ", "CU-10 NI  ", "CU-30 NI  ",
```

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     *            "6061-T6 AL", "3003-H14 A", "STEEL SEAM",
     *            "STEEL WELD", "304 S/S WE", "TITANIUM 1",
     *            "TITANIUM 2" /
C
C          STANDARD TUBE DIAMETERS, GAGE, AND THICKNESSES
C
      DATA ODLINE / 0.625, 0.750, 0.875, 1.000, 1.125, 1.250 /
      DATA GAGLI / 12., 14., 16., 18., 20., 22., 24. /
      DATA THKLIN /.109, .083, .065, .049, .035, .028, .021 /
C
C          TUBING LENGTH PENALITIES
C
C          FOR COPPER ALLOYS
      DATA (FF(1,J),J=1,7)/ 0.00, 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
      DATA (FF(2,J),J=1,7)/ 0.00, 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
      DATA (FF(3,J),J=1,7)/ 0.00, 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
C
C          FOR ALUMINUM
      DATA (FF(4,J),J=1,7)/ 1.00, 1.00, 1.06, 1.10, 1.14, 1.18, 1.22 /
      DATA (FF(5,J),J=1,7)/ 1.00, 1.00, 1.06, 1.10, 1.14, 1.18, 1.22 /
C
C          FOR STEEL
      DATA (FF(6,J),J=1,7)/ 1.00, 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /
      DATA (FF(7,J),J=1,7)/ 1.00, 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /
C
C          FOR STAINLESS STEEL
      DATA (FF(8,J),J=1,7)/ 1.00, 1.00, 1.00, 1.04, 1.08, 1.12, 1.16 /
C
C          FOR TITANIUM
      DATA (FF(9,J),J=1,7)/ 0.00, 0.00, 0.00, 1.05, 1.05, 1.10, 1.10 /
      DATA (FF(10,J),J=1,7)/ 0.00, 0.00, 0.00, 1.05, 1.05, 1.10, 1.10 /
C
C          CONSTANTS FOR COST EQUATION FOR BASIC CONDENSER SHELL AS A
C          FUNCTION OF TUBE O.D. (UPDATED FEBRUARY, 1976)
C
      DATA SCC1 / 0.00000, 7.69583, 8.805882, 10.83636, 12.954545,
     *            15.22326 /
      DATA SCC2 / 00000.00, 97125.00, 102164.71, 102181.82, 103272.73,
     *            102237.21 /
C
C          COST OF FIELD ERECTION AND TUBING PER SQUARE FOOT OF
C          SURFACE AREA IS BASED UPON INFORMATION SUPPLIED BY
C          WESTINGHOUSE COMPANY AND AVERAGE WAGE LABOR RATES OBTAINED
C          FROM JUNE 1975 CONSTRUCTION REVIEW
C
      DATA EDTCST / 2.50 /
C
      DATA FIRST/.TRUE./
C
C          DEFINING THE CASE UNDER CONSIDERATION
C
      IF(.NOT.FIRST) GOTO 55
      LFLAG=0
      DO 10 I = 1, 10
      ITUBMA = I
      IF(CONMAT .EQ. TUBMA(I)) GO TO 55
   10 CONTINUE
```

```
      WRITE(6,11)
      LFLAG=1
   11 FORMAT(5X,"NO MATCH FOR CONDENSER TUBE MATERIAL")
      IF(LFLAG.NE.0) STOP
   55 CONTINUE
      FIRST = .FALSE.
C
C
C           DETERMINE TOTAL LENGTH OF TUBING REQUIRED AND CORRESPONDING
C           QUANTITY DISCOUNT
C
       TOTLT=TLA*XNTS*XNS
C
       IF(TOTLT-60000.)102,101,101
  101  DSCT=0.04
       GO TO 103
  102  IF(TOTLT-30000.)105,104,104
  104  DSCT=0.02
       GO TO 103
  105  DSCT=0.
  103 KK = 7
      DO 106 I = 2, 8
      IF(TLA .GE. (10.0*I)) KK = I - 2
  106 CONTINUE
      F = FF(ITUBMA,KK)
      ADDER = 0.00
      IF(ITUBMA .LT. 4) ADDER = F
      IF(ITUBMA .LT. 4) F = 1.00
C
C           DETERMINE TOTAL COST OF TUBING MATERIAL
C
  109 WT = 12. * 3.14159 * ROEL(ITUBMA) * (ODLINE(LD)-THKLIN(KGA))
     $ * THKLIN(KGA)
      TCSTPF = CLM(ITUBMA)*WT + CL(ITUBMA)
      TCSTPF = TCSTPF*F + ADDER
C
C           TUBE COST ARE F.O.B. COSTS, 1.11 ACCOUNTS FOR PURCHASING
C           AND SHIPPING
C
      TUBCST = TOTLT * TCSTPF * (1.11-DSCT)
      TUBCST = TUBCST * POHCND
C
C           DETERMINE SHELL COST INCLUDING LENGTH, MULTIPRESSURE, AND
C           ACCESSORY COST CORRECTIONS, AS APPROPRIATE
C
      CFAC = 0.016*TLA + 0.58
       GO TO(100,111,112,113),ISUR
  111  CFAC=CFAC+0.08
       GO TO 100
  112  CFAC=CFAC+0.16
       GO TO 100
  113  CFAC=CFAC+0.03+XNS*0.02
C
  100 FOD = 1.00
      IF(LD .LT. 4) FOD = 0.95
      IF(LD .EQ. 6) FOD = 1.05
      ACCFL = (0.116*ALOG(XNTS) - 0.4859)*FOD
```

```
      IF(ITURMA .EQ. 2) ACCF = (0.239*ALOG(XNTS) - 1.416)*FOD
C
C          THE CONDENSER SHELL COSTS WERE OBTAINED FROM WESTINGHOUSE'S
C          1973 PRICE LISTING 1312
C
      AUXCST = 0.45*ARPS*XNS
       BSHCST = (SCC1(LD)*XNTS + SCC2(LD))
       SHLCST=BSHCST*(CFAC+ACCF)*XNS + AUXCST
      SHLCST = SHLCST * POHCND
C
C          DETERMINE COST OF FIELD ERECTION AND TUBING
C
       FETCST=ERTCST*ARPS*XNS
      FETCST = FETCST * POHCND
C
C          DETERMINE TOTAL COST OF CONDENSER
C
       CONCST=TURCST+SHLCST+FETCST
      CONB47=CONCST
C
       RETURN
       END
```

```
      FUNCTION TLU(X,XT,YT,NT)
C
C         FUNCTION TLU IS A FOUR-POINT LAGRANGIAN INTERPOLATION
C         TABLE LOOK-UP ROUTINE
C
C         DEFINITION OF VARIABLES
C
C         NT       - NUMBER OF DATA POINTS
C         TLU      - DEPENDENT VARIABLE
C         X        - INDEPENDENT VARIABLE
C         XT       - INDEPENDENT VARIABLE ARRAY
C         YT       - DEPENDENT VARIABLE ARRAY
C
      DIMENSION XT(NT),YT(NT)
C
C         DETERMINE IF INDEPENDENT VARIABLE IS WITHIN RANGE OF
C         TABULATED DATA
C
      IF((X-XT(1))*(X-XT(NT)))100,100,101
C
C         DETERMINE IF TABULATED VALUES OF INDEPENDENT VARIABLE ARE
C         IN ASCENDING OR DESCENDING ORDER
C
  100 IF(XT(1)-XT(2))102,102,103
C
C         DETERMINE POSITION OF INDEPENDENT VARIABLE IN ASCENDING
C         ARRAY
C
  102 DO 99 I=1,NT
      IF(X-XT(I))105,104,99
   99 CONTINUE
C
C         DETERMINE POSITION OF INDEPENDENT VARIABLE IN DESCENDING
C         ARRAY
C
  103 DO 98 I=1,NT
      IF(X-XT(I))98,104,105
   98 CONTINUE
C
C         IF INDEPENDENT VARIABLE IS EQUAL TO TABULATED VALUE, SET
C         FUNCTION EQUAL TO CORRESPONDING VALUE OF DEPENDENT VARIABLE
C
  104 TLU=YT(I)
C
      RETURN
C
C         IF INDEPENDENT VARIABLE IS BETWEEN FIRST TWO OR LAST TWO
C         TABULATED VALUES, ADJUST INDEX TO OBTAIN FOUR POINTS FOR
C         INTERPOLATION
C
  105 IF(I-2)106,106,107
  106 I=I+1
      GO TO 108
  107 IF(I-NT)108,109,109
  109 I=I-1
C
C         DETERMINE FUNCTION VALUE USING FOUR-POINT LAGRANGIAN
```

```
C          INTERPOLATION
C
  108  X1=XT(I-2)
       X2=XT(I-1)
       X3=XT(I)
       X4=XT(I+1)
C
       TLU=(X-X2)*(X-X3)*(X-X4)/((X1-X2)*(X1-X3)*(X1-X4))*YT(I-2)
     $    +(X-X1)*(X-X3)*(X-X4)/((X2-X1)*(X2-X3)*(X2-X4))*YT(I-1)
     $    +(X-X1)*(X-X2)*(X-X4)/((X3-X1)*(X3-X2)*(X3-X4))*YT(I)
     $    +(X-X1)*(X-X2)*(X-X3)/((X4-X1)*(X4-X2)*(X4-X3))*YT(I+1)
C
       RETURN
C
  101  WRITE(6,1000)X,XT(1),YT(1)
 1000  FORMAT(1H1,39H TABLE LOOK-UP: X NOT IN RANGE OF TABLE//
     $    5X,3HX =,F15.5,5X,7HXT(1) =,F15.5,5X,7HYT(1) =,F15.5)
C
       STOP
       END
```

```
      SUBROUTINE VARIT(TA, TPER, PCST, KALL, CLSUM, FCSUM)
C
C     SUBROUTINE VARIT CALCULATES THE PERFORMANCE OF THE POWER
C     PLANT AND DRY COOLING TOWER UNDER THE ASSUMPTION THAT THE
C     AIR SIDE HEAT TRANSFER COEFFICIENTS AND AIR VELOCITY
C     THROUGH THE HEAT EXCHANGER TUBES ARE UNCHANGED.  THIS IS
C     DONE FOR THE CASE HAVING THE MINIMUM INCREMENTAL COST.
C
C     DEFINITION OF VARIABLES
C
C     CAPCHG  - GAS TURBINE CAPITAL COST ($/MW)
C     CAPCST  - COST OF GAS TURBINE ($)
C     CAPF    - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER
C               (PERCENT)
C     COS1    - COST OF THE DRY COOLING TOWERS ($)
C     CLAN1   - COST OF LAND TAKEN UP BY THE DRY COOLING TOWERS ($)
C     CONBA1  - COST OF SURFACE CONDENSER ($)
C     COSM1   - COST OF MAINTAINING THE DRY COOLING TOWER ($)
C     CPIP1   - COST OF PIPING AND PUMPING SYSTEMS ($)
C     CSTCL   - COST OF MAKE-UP POWER BY GAS TURBINES AT EACH
C               AMBIENT AIR TEMPERATURE (MILLS/KW-HR)
C     DELFC   - INCREMENTAL FUEL COST FOR STEAM SUPPLY SYSTEM
C               (MILLS/KW HR)
C     EFF1    - HEAT EXCHANGER EFFECTIVENESS OF DRY COOLING
C               TOWERS (DIMENSIONLESS)
C     EFFC1   - CONDENSER EFFECTIVENESS
C     FCOS    - FUEL COST FOR THE STEAM SUPPLY SYSTEM (MILLS/BTU)
C     FCR     - FIXED CHARGE RATE ON CAPITAL PER YEAR (PERCENT)
C     FPOW1   - POWER REQUIREMENTS OF FAN SYSTEM (KW)
C     HRFAC1  - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
C               PRESSURE (DIMENSIONLESS)
C     HRFA2S  - HEAT RATE FACTOR OF STEAM TURBINE AT DESIGN
C               CONDITIONS OF POWER PLANT (DIMENSIONLESS)
C     HRFAC4  - HEAT RATE FACTOR OF STEAM TURBINE AT A PARTICULAR
C               AMBIENT AIR TEMPERATURE (DIMENSIONLESS)
C     P       - BACK PRESSURE OF STEAM TURBINE (IN. HG.)
C     TCOS    - INCREMENTAL POWER PRODUCTION COST OF THE DRY
C               COOLED POWER PLANT FOR A PARTICULAR AMBIENT AIR
C               TEMPERATURE (MILLS/KW-HR)
C     PGEN    - POWER OUTPUT OF PLANT AT A PARTICULAR AMBIENT AIR
C               TEMPERATURE (MW)
C     PPOW1   - POWER REQUIREMENTS OF THE PIPING SYSTEM (KW)
C     SPS13   - POWER OUTPUT OF STEAM TURBINE AT RATED BACK
C               PRESSURE TO PRODUCE REQUIRED OUTPUT OF PLANT
C               OF PLANT AT DESIGN CONDITIONS (MW)
C     PTOTAL  - POWER OUTPUT OF PLANT AT SPECIFIED AMBIENT AIR
C               TEMPERATURE (MW)
C     PWCOS   - COST OF FUEL FOR GAS TURBINE (MILLS/KW-HR)
C     QIN1    - THERMAL ENERGY OUTPUT OF STEAM SUPPLY SYSTEM AT
C               RATED BACK PRESSURE OF TURBINE (BTU/HR)
C     QREJ    - HEAT REJECTED AT A SPECIFIED AMBIENT AIR TEMPERA-
C               TURE (BTU/HR)
C     RANGE   - TEMPERATURE RANGE OF WATER PASSING THROUGH THE
C               HEAT EXCHANGER (DEG F)
C     SPCO1   - INCREMENTAL COST OF PLANT DUE TO SCALE-UP OF STEAM
C               SUPPLY SYSTEM AND THE SCALE UP OF THE PLANT TO
C               TAKE INTO ACCOUNT FOR FAN AND PUMP POWER
```

```
C                          REQUIREMENTS ($)
C              TA        - AMBIENT AIR TEMPERATURE (DEG F)
C              TEFF      - THERMAL EFFICIENCY OF CONVENTIONAL STEAM TURBINE
C                          AT RATED BACK PRESSURE (DIMENSIONLESS)
C              TEFF1     - THERMAL EFFICIENCY OF STEAM TURBINE AT RATED
C                          BACK PRESSURE (DIMENSIONLESS)
C              TEFF3     - THERMAL EFFICIENCY OF STEAM TURBINE AT POWER
C                          PLANT DESIGN CONDITIONS (DIMENSIONLESS)
C              TEFF4     - THERMAL EFFICIENCY OF STEAM TURBINE ASSOCIEATED
C                          WITH A PARTICULAR AMBIENT AIR TEMPERATURE
C                          (DIMENSIONLESS)
C              TPER      - PERCENT OF TIME AN AMBIENT TEMPERATURE OCCURS
C                          DURING THE YEAR (PERCENT)
C              TPO       - COEFFICIENTS FOR THIRD ORDER CURVE FIT OF STEAM
C                          TURBINE HEAT RATE FACTOR (DIMENSIONLESS)
C              TTDP      - TERMINAL TEMPERATURE DIFFERENCE OF SURFACE
C                          CONDENSER FOR A PARTICULAR AMBIENT AIR TEMPERATURE
C              TTD       - TERMINAL TEMPERATURE DIFFERENCE OF SURFACE CONDENS-
C                          ER AT DESIGN CONDITIONS (DEG F)
C              TT        - EXIT TEMPERATURE OF STEAM TURBINE (DEG F)
C              VCST      - TOTAL INCREMENTAL COST OF DRY COOLING (MILLS/KW-HR)
C              WR        - MASS FLOW RATE OF WATER THROUGH THE HEAT EXCHANGER
C                          (LBM/HR)
C              PCST      - INCREMENTAL COST OF DRY COOLING FOR EACH AMBIENT
C                          AIR TEMPERATURE (MILLS/KW-HR)
C              YEPMIN    - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR FAN
C                          AND PUMP POWER (DIMENSIONLESS)
C
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DESPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GREFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ ODR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QREJ, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
     $ ,TJBANG, TW
     $ ,UCS, UWS
     $ ,VAS(5)
     $ ,WFV
     $ ,XDEPA, XW, XD
```

```
      COMMON /SCALER/ HRFAC1, SSCD, PLANC1, CASSS1,
     $  GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /SUPPLY/ VAL(5),  CPIP,  CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $   FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,   NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCO,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHDR, WTFRM,STRUCC,CFMPRF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIRFF,  WATFF,  XNMOD,  TCTPF, FDCPF, FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,   TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,    CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31, COSM1,  EFF1
     $,  CLAN1, REAI1,     Z1,HRFA2S,   W41,    U1, PPOW1,
     $   FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $     SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCO1,  CSC1,CEPRE1,DEPIP1,  AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHD1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSP1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
C
C          THERMAL EFFICIENCY OF TURBINE AT THE DESIGN POINT OF THE
C          PLANT
C
      TEFFD=TEFF/HRFA2S
C
C          THERMAL EFFICIENCY OF TURBINE AT THE RATED BACK PRESSURE
C
      TEFF1=TEFF/HRFAC1
C
C          HEAT SUPPLIED BY THE STEAM SUPPLY SYSTEM
C
      QIN1=3413.E+3 *  SPS13/TEFF1
      T1=140.
C
C          AMBIENT AIR TEMPERATURE AND PERCENTAGE OF YEAR OVER WHICH
C          TEMPERATURE OCCURS.
C
    1 P=EXP(17.168-9240./(T1+460.))
      HRFAC4=TPO(1)+TPO(2)*P+TPO(3)*P**2+TPO(4)*P**3
      TEFF4=TEFF/HRFAC4
C
C          ITERATIVE LOOP FOR CALCULATING THE EXIT TEMPERATURE OF THE
C          STEAM TURBINE AS A FUNCTION OF THE AMBIENT AIR TEMPERATURE.
C
C          CALCULATION OF HEAT REJECTED BY THE DRY COOLING TOWERS
```

```
      QREJ=QIN1*(1.-TEFF4)
C
C          TEMPERATURE RANGE OF WATER FLOWING THROUGH THE HEAT EXCHANGER
      RANGE=QREJ/(W31*(1.+YFPMIN))
C
C          TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND THE
C          STEAM OF THE SURFACE CONDENSER
      TTDP = RANGE/EFFC1- RANGE
C
C          EXIT TEMPERATURE OF THE STEAM TURBINE ON PREVIOUS EXTIMATE
      IF(VAR(3).GT.1.) GO TO 2
      T11 = RANGE/EFF1 + TA + TTDP
      GO TO 3
    2 T11 = RANGE*VAR(3)/EFF1 + TA + TTDP
C
C          CONVERGENCE CRITERION FOR EXIT TEMPERATURE OF TURBINE
    3 IF(.NOT. EXTEMP .AND. (T11-T1)**2 .LT. .001) GOTO 4
      CVT = ABS( (T11-T1) / T11)
      IF (EXTEMP .AND. CVT .LT. 0.0001) GOTO 4
      T1=T11
      GO TO 1
C
C          TOTAL POWER OUTPUT OF TURBINE AT THE PARTICULAR AMBIENT
C          AIR TEMPERATURE
C
    4 PTOTAL = QIN1*TEFF4/3413.E+3
C
C          POWER OUTPUT FROM PLANT AT THE PARTICULAR AMBIENT AIR
C          TEMPERATURE
C
      PGEN=PTOTAL-PPOW1/1000. - FPOW1/1000.
      TEFFD=TEFF4
      IF(PGEN.GE.PSIZE) GOTO 5
C
C          COST OF FUEL FOR GAS TURBINE MAKE UP POWER
C
      CSTCL=(PSIZE-PGEN)/PSIZE*PWCOS
      TEFFD=TEFF3
      GO TO 6
    5 CSTCL=0
C
C          INCREMENTAL COST OF FUEL FOR STEAM SUPPLY SYSTEM DUE TO STEAM
C          TURBINE OPERATING AT OFF DESIGN CONDITIONS
C
    6 DELFC=FCOS*3413.E-5*((1.+YFPMIN)/TEFFD-1./TEFF)
C
C          CAPITAL COST OF GAS TURBINE FOR MAKE UP POWER
C
C
      IF (KAIL.NE.1) GO TO 10
      CAPCST=0.0
      IF (PSIZE.LE.PGEN) GO TO 10
      CAPCST=CAPCHG*(PSIZE-PGEN)
   10 CONTINUE
C
C          INCREMENTAL COST OF FUEL FOR STEAM SUPPLY SYSTEM DUE
C          TO STEAM TURBINE OPERATING AT OFF DESIGN CONDITIONS (RATED
```

```
C          BACK PRESSURE)
C
      TCOS = (CCOS1+SPCD1+CLAN1+CPIP1+CONBA1+CAPCST)*FCR/(PSIZE*CAPF*
     $ 876^0.) + COSM1+DELFC+CSTCL
      PCST=TPER*TCOS
      CLSUM = CLSUM + CSTCL * TPER
      FCSUM = FCSUM + DELFC * TPER
  935 FORMAT(T2,F6.1, T10,F6.1, T18,F5.2, T26,F7.4, T33,F7.3
     $,T41,F6.3, T47,F7.2, T54,F7.2, T62,F8.3, T72,F7.5, T81,G11.5
     $ T93,F7.4, T106,F7.3, T115,G11.5)
 2939 FORMAT(T2,"TAI,TAO,TWI,TWO,T11,RANGE,TTD",7G15.6)
  800 CONTINUE
C
C          TEMPERATURES OF FLUIDS ENTERING AND EXITING THE HEAT
C          EXCHANGER
C
C          TEMPERATURE OF AIR ENTERING THE HEAT EXCHANGER
      TAI = TA
C
C          TEMPERATURE OF AIR EXITING THE HEAT EXCHANGER
      TAO = TAI + VAR(3) * RANGE
C
C          TEMPERATURE OF WATER EXITING THE HEAT EXCHANGER
      TWO = T11 - RANGE - TTD
C
C          TEMPERATURE OF WATER ENTERING THE HEAT EXCHANGER
      TWI = RANGE + TWO
C
C          THE LOG MEAN TEMPERATURE DIFFENENCE OF THE FLUIDS IN THE
C          HEAT EXCHANGER
C
      HXLMTD = 1.E+30
      TESTR = (TWI-TAO) / (TWO-TAI)
      IF(TESTR .GT. 0.0) GOTO 820
      WRITE(6,2939) TAI,TAO,TWI,TWO,T11,RANGE,TTD
      GOTO 830
  820 IF (TESTR .EQ. 1.0)  HXLMTD = TWI-TAO
      IF(TESTR .NE. 1.0) HXLMTD =
     $ ((TWI-TAO) - (TWO-TAI) ) /   ALOG( (TWI-TAO) / (TWO-TAI) )
  830 CONTINUE
C
C          INITIAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND AIR IN
C          THE HEAT EXCHANGER
      HXITD = TWI - TAI
C
C          PRINTOUT OF HEAT EXCHANGER PERFORMANCE PARAMETERS
      WRITE(6,935) TA
     $,T1
     $,P
     $,HPFAC4
     $,RANGE
     $,TTDP
     $,HXLMTD
     $,HXITD
     $,PGEN
     $,DELFC
     $,CSTCL
```

```
      $,TCOS
      $,TPER = 100.
      $,PCST
       RETURN
290    END
```

```
      SUBROUTINE XTEND(L)
C
C     THIS ROUTINE CHECKS EXTREME VALUES AT MINIMAL COST POINT.
C
      DIMENSION TTRY(2),RTRY(2),CTRY(2),ATRY(2),WTRY(2)
      COMMON /SINK/   VAR(5), CPIP1, CCOS1,   W31,  COSM1,  EFF1
     $,  CLAN1, REAI1,    Z1,HRFAC2S,   W41,    U1, PPOW1,
     $   FPOW1, DELFC1, WIDTH1, ELEN1, VAIR1, VWAT1,   HI1,   HO1,   T41,
     $   REWA1,   NW1,ZPLNC2,ZSIZ12, ZSPBP,  SW41,  SW31,
     $    SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,
     $  BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
     $,   TLA1, UCON1, FMCS1, FBAC1, EFFC1,   CH1,   CA1,   CS1
     $,  CLTC1,  CFC1, CPCC1,FITCD1,  CSC1,CEPRE1,DELPIP1,  AST1
     $,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1,   WH1, WTTU1,  ADI1,  ABL1
     $,  WTHR1, WTFR1,STRUC1,CFMPF1, HPPF1,TOTCF1,EFFIN1, ANTU1
     $, AIREF1, WATEF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
     $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPAI1, TCTF1 , AFCST1
     $,   CSD1, WATER1, WSTRC1, CFOUN1, HUBDI1, TOWLE1,   CSE1,   CHF1
     $ ,CBA1, NUMTOW1, CTOWD1, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SUPPLY/ VAL(5),  CPIP,   CCOS,    W3,  COSM,   EFF
     $,  CLAND, REAIR,     Z,HRFAC2,    W4,     U,  PPOW,
     $    FPOW, DELFC, WIDTH, ELENG,  VAIR,  VWAT,    HI,    HO,    T4,
     $   REWAT,    NW,PLANC2,PSIZ12,  SPBP,   SW4,   SW3,
     $     SPC,PTOTAL,PLANC3,SAFRON,  AAIR,   YFP,  SPCD,PSIZ13,   WT2,
     $     BP2,    NW2,  TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
     $,   TLAX,  UCON, FMCST, FBACC,  EFFC,    CH,    CA,    CS
     $,   CLTC,   CFC,  CPCC, FITCD,   CSC,CEPREP,DELPIP,   AST
     $,CAPCST, XNFAN,BLDANG, CPLEN, DPFEL,   WHX, WTTUB,  ADIA,  ABLN
     $,  WTHR, WTFRM,STRUCC,CFPERF,HPPERF, TOTCF, EFFIN,  ANTU
     $,  AIREF,  WATEF,  XNMOD,  TCTPF,  FDCPF,  FMTRC, ACCTTP,  ADJTP
     $, ACTBPD, ADJBPD,  ACTVH,  ADJVH, ADJPPF, THPAIR,  TCTF,  AFCST
     $,   CSPD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN,   CSE,    CHF
     $ ,CBA, NUMTOW, CTOWD, ATUBC, CSTLVR, CSTHS, CYLRNG, CFANEL
      LOGICAL FIRST, FXTEMP
      COMMON
     $  AFTR, ALPHA
     $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAF
     $ ,CBJ, CSEALP, CELAST, CFS, CDANG, CLUVR, CHAILS, CVM
     $ ,DEEPL, DESVEL, DANGLE
     $ ,EFFP
     $ ,FCR, FIRST, FIXL, FCOS, FXTEMP
     $ ,GBEFF
     $ ,HXNP, HPCST
     $ ,IHEAT
     $ ,ITMAX, ITMIN
     $ ,JCONS
     $ ,KCONV, KALEXT
     $ ,MXEXT
     $ ,NTUCAL(2), NTA
      COMMON
     $ QDR
     $ ,PSIZE, PER, PWCOS, PLANC, PFACT
     $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
     $ ,QRED, QREDUCE
     $ ,RBP, REDUCE, ROESEL, ROEELA, ROOFL, RFIX
     $ ,SAAF, SIGMA, SPAMAT(2)
     $ ,TD, TPO(4), TEFF, TLIM, TLPRA, TSEALP, TELAST, THFIN, TFIX
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      $ ,TJRAEG, TW
      $ ,UCS, UWS
      $ ,VAS(5)
      $ ,WFV
      $ ,XDEPA, XW, XD
      COMMON /LACALL/ SRN
      COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
      TTRY(1)=VAR(1)-20.
      IF (TTRY(1) .LE. 0.0) TTRY(1)=10.
      TTRY(2)=VAR(1)+20.
      IF(FXTEMP) TTRY(1) = TFIX
      IF(FXTEMP) TTRY(2) = TFIX
      CTRY(1)=VAR(3)-3.
      IF(CTRY(1).LE.0.) CTRY(1)=.5
      CTRY(2)=VAR(3)+2.
      ATRY(1)=VAR(4)*4.
      ATRY(2)=VAR(4)/4.
      WTRY(1)=VAR(5)+40.
      WTRY(2)=VAR(5)/3.
      DO 3 I=1,2
      RANGL=(TTRY(I)-TTD-TD)*(1.-EXP(-VAR(3)))/VAR(3)
    2 RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
      IF(FXTEMP) RTRY(1) = RFIX
      IF(FXTEMP) RTRY(2) = RFIX
      SRN="/XTEND-1/ "
      DO 3 IR=1,2
      CALL CALC(TTRY(I),RTRY(IR),VAR(3),VAR(4),VAR(5),1)
      IF(KCONV.EQ.1) GO TO 3
C     IF(DELPA.LT.XDEPA) GO TO 3
      IF(DELPA.LE.XDEPA) GO TO 3
      IF(TCOS.GT..99*TCOS1) GO TO 3
      TCOS1=TCOS
      VAS(1)=TTRY(I)
      VAS(3)=VAR(3)
      VAS(4)=VAR(4)
      VAS(5)=VAR(5)
      L=1
    3 CONTINUE
      DO 10 I=1,2
      RANGL=(VAR(1)-TTD-TD)*(1.-EXP(-CTRY(I)))/CTRY(I)
    9 RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
      IF(FXTEMP) RTRY(1) = RFIX
      IF(FXTEMP) RTRY(2) = RFIX
      SRN="/XTEND-3/"
      DO 10 IR=1,2
      CALL CALC(VAR(1),RTRY(IR),CTRY(I),VAR(4),VAR(5),1)
      IF(KCONV.EQ.1) GO TO 10
C     IF(DELPA.LT.XDEPA) GO TO 10
      IF(DELPA.LE.XDEPA) GO TO 10
      IF(TCOS.GT..99*TCOS1) GO TO 10
      TCOS1=TCOS
      VAS(1)=VAR(1)
      VAS(3)=CTRY(I)
      VAS(4)=VAR(4)
      VAS(5)=VAR(5)
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      L=1
   10 CONTINUE
      DO 11 I=1,2
      CALL CALC(VAR(1),VAR(2),VAR(3),ATRY(I),VAR(5),2+I)
      IF(KCONV.EQ.1) GO TO 11
C     IF(DELPA.LT.XDEPA) GO TO 11
      IF(DELPA.LE.XDEPA) GO TO 11
      IF(TCOS.GT..99*TCOS1) GO TO 11
      TCOS1=TCOS
      VAS(1)=VAR(1)
      VAS(3)=VAR(3)
      VAS(4)=ATRY(I)
      VAS(5)=VAR(5)
      L=1
   11 CONTINUE
      SRN="/XTEND-4/"
      DO 12 I=1,2
      CALL CALC(VAR(1),VAR(2),VAR(3),VAR(4),WTRY(I),3+I)
      IF(KCONV.EQ.1) GO TO 12
C     IF(DELPA.LT.XDEPA) GO TO 12
      IF(DELPA.LE.XDEPA) GO TO 12
      IF(TCOS.GT..99*TCOS1) GO TO 12
      TCOS1=TCOS
      VAS(1)=VAR(1)
      VAS(3)=VAR(3)
      VAS(4)=VAR(4)
      VAS(5)=WTRY(I)
      L=1
   12 CONTINUE
      IF(L.EQ.1) WRITE(6,13)
   13 FORMAT(" XTEND CALLED, AND CHANGE MADE")
      IF (L .EQ. 1) KALEXT = KALEXT + 1
      IF (KALEXT .GT. MXEXT) STOP "CALLS TO S.R. EXTEND EXCEED MXEXT"
      RETURN
      END
```