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

Volume II

January 1977

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Battelle

Pacific Northwest Laboratories

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

VOLUME II

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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 E

METAL FINNED TUBE VERSION OF THE BNW-I COMPUTER CODE

Figure E-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 E-1. Metal Finned Tube (SOA) Circular Model Subroutine Linkages


```

PROGRAM MFCIR1 (INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT)
C
C      PROGRAM MFCIR1 IS A VERSION OF THE BNM1 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 METAL FINNED TUBE COOLING SURFACE AND
C      CIRCULAR TOWER ARRANGEMENT OF THE TUBE BUNDLES.
C
DIMENSION PCST(8),
LOGICAL FIRST, FXTMP
COMMON
$   AFTR, ALPHA
$   CAPF, CSSPKW, CONF, CONL, COSTLG, CAPCHG, CONMAT, CONVA2, CAFI
$   CBU, CTURB, CDANG, CLUVR, CHAILE, CVM
$   DANGLE, DFIN, DEEPL, DESVEL
$   EEPF
$   FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
$   GEEFF
$   HXNP, HPCST
$   ITMAX, ITMIN
$   JCONC
$   KCONV, KALEAT
$   LMXEXT
$   LOGICAL(2), NTA
COMMON
$   ORR
$   PSIZE, PER, PMCOS, PLANCC, PFACT, POMDPL
$   POHRAF, POHEAN, POHLEC, POHCIR, POHCND, PD-STC, POHSCL
$   QREDU, QREDUCE
$   REP, REDUCE, RODELL, RFIX
$   SIGMA, SIAP
$   TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
$   TDD, TW
$   UCS, UWS
$   VAR(N)
$   WEFV
$   XDEPA, XW, XD
COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W3T, COSM1, EFF1,
$   AIM1, CLAN1, REAIL, Z1, HRFA25, W41, UI, DELPW1, PPBW1,
$   FPOW1, DEFCT, WIDTH1, ELENG1, VAIR1, VWAT1, HI1, HO1, I41,
$   RENAI, UN1, NT1, NP1, ZPLNC2, ZSZIZ, ZSPRP, S#41, SW31,
$   SPAL, DTOT1, PLNC31, AFRO1, AAIR1, YEPMIN, SPCD1, SPS13, MT2MIN,
$   HPZM-N, NWZMIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
$   IL1, UCOS1, PMCS1, FMCS1, FBAC1, EFFC1, CHI, CA1, CS1
$   CLTC1, CFCT, CPCCI, FIICCI, CSC1, CEPRE1, DEPIR1, AST1, OLOCSI
$   CAPCO1, XNEANI, ELGAN1, CPLEN1, DEFL1, WH1, ATTUL, ADIL, ARL1
$   WITHO1, WTTRI, STRUC1, CMPE1, HSPFI, TOYCF1, TP1, EFF11, ANTL1
$   AIRFE1, WATER1, XNVOD1, TOPPR1, FDCPF1, FMTRC1, ACTTP1, ADUTP1
$   ACTBO1, ADUBB1, ACTVH1, ADJVV1, ADUPP1, THPA1, TCTF1, AFCST1
$   CSR1, WATER1, WSTRC1, CPOUN1, HUSD1, TOWLE1, NUMTO1, CTOWD1
$   ATUBO1, CSTLV1, CSTHS1, CYLAN1, CFANE1
COMMON /SCALER/HRFAC1, ATUB, CPERA, SSCD, PLANC1, CASSS1
$   GAIR, FAIR, HPAIR, HOWAT, PLANCT1
COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
$   GIN, CLAND, GRAIR, Z, HRFA2, W4, U, DELPW, PPBW,
$   FPOW, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, I4

```

```

5  REWIT.  MW.  NT.  VP,PLANC2,PSIZ12,  SPRB,  SW4,  SW3,
6  SPC,PTOTAL,PLANC3,SAFROV,  AAIR,  YFP,  SPC5,PSIZ13,  WT2,
60  S  APP,  MW2.  TCOS, DELPA,DELPNT,DELPWC,CONBAS, XNTSX, VELDX
S  TLAX, UCON, PMOST, FMOST, FBACC, EFFC,  CH,  CA,  CS
S  CLTC,  CFC,  CPOC, FITCO,  CSC,CEPREP,DELP12,  AST,OLDCST
S,CAPOST, XNEAN,BLDANG, CPLEN, OPFEL,  WHX, WTTUR, ADIA,  ARLN
65  S  ATHER, WTERW,STRUCO,CPPEP,REPERF, TOTCF,  TPC, EFFIN, ANTU
S  AIRFP,  AITFF,  XNMOD,  TOTPF,  FDCPF,  ENTRC, ACCTIP,  ADJTP
S  ACTABD,  ADJBD,  ACTVH,  ADJUH,  ADJPPF,  THEAIR,  TCTF,  AFCST
S  CSR,  WATERW,  WGRCT,  CFOUNJ,  HUBDIA,  TOWLEN,  MUMTOW,  CTOWD
S  ATURB,  CSTLVN,  CSTHS,  CYLRNG,  CFANEL
COMMON /VARVAR/  TPER(16),  TA(16)
70  COMMON /INDIS/  DIST
COMMON /TIME/  XNS,TTD,TLA,XNTS,ARPS
81  FORMAT('1 TO USED IN THE FOLLOWING CALCULATIONS IS ="F9.3)
930  FORMAT('102,"AMBIENT TURBINE", T28,"HEAT", T93,"COST TO",
S  T92,"POWER COST", T105,"POT TIE",T115,"PORTION OF")
75  931  FORMAT('104,"TEMP", T10,"OUTLET", T20,"BACK", T28,"RATE",T50,"HX"
S,T57,"HX", T54,"POWER", T72,"CHANGE IN", T83,"REPLACE",
S,T91,"AT AMBIENT", T104,"AT AMBIENT", T115,"INCREMENTAL")
932  FORMAT('111,"TEMP",T13,"PRESSURE",T27,"FACTOR", T35,"RANGE"
S,T42,"TEMP", T49,"LIMIT", T57,"TID", T62,"GENERATOR"
80  S,T72,"FUEL COST", T83,"LOST CAP", T95,"TEMP", T106,"TEMP"
S,T115,"POWER COST")
933  FORMAT('102,'131(" ", T9," ",T17," ", T26," ", T33," ", T40," "
S,T47," ", T54," ", T61," ", T71," ", T81," ", T92," ", T103," "
S, T114," ")
85  934  FORMAT('103,"DEG F", T11,"DEG F", T19,"IN. H2O", T35,"DEG F"
S,T41,"DEG F", T43,"DEG F", T56,"DEG F", T62,"MEGAWATTS"
S, T72,"MILLS/KWH", T82,"MILLS/KWH", T93,"MILLS/KWH"
S,T106,"PERCENT", T115,"MILLS/KWH")
944  FORMAT('140,T91,"FINAL INCREMENTAL COST",G11.5)
90  945  FORMAT('140,T96"CAPACITY CHARGE $",G15.9)
FIRST=.TRUE.

C
C  READ IN THE EXTERNALLY FIXED PARAMETERS OF THE DRY COOLING
C  TOWER SYSTEM AND THE INITIAL STARTING POINT OF THE
95  C  OPTIMIZATION ROUTINE, A DESCRIPTION OF THE INPUT CARDS
C  IS GIVEN IN SUBROUTINE SETUP
C
C  CALL SETUP(TSTAR,TEND)

C
C  INPUT PRINTOUT SUMMARY
700  C
C
C  CALL ITPSUM

C
C  THE FOLLOWING IS A ROUTINE WHICH USES PATTERNED AND
705  C  GRADIENT SEARCH ROUTINES TO DETERMINE THE OPTIMUM DRY
C  COOLING TOWER DESIGN
C
C
C  DO 7 IF=1.5
710  7  VAR(15)=0.0
C  TD=TSTAR
C  1  WRITE(6,81)TD
C  K=4
C
C  SCALING THE STEAM SUPPLY AND TURBINE TO ACCOUNT FOR CHANGE

```

```

115      C      IN HEAT RATE OF TURBINE
      C
      CALL SSCALE
      C
      C      COURSE PATTERN SEARCH FOR OPTIMUM POINT
120      4 CALL SHOT(1)
      IF (TCOS1.GT.2.0) GO TO 5
      VAS(4)=VAS(4)/4.
      GO TO 4
      5 L=0
125      C
      C      EXTENDING THE SEARCH BEYOND THE LIMITS OF THE PATTERN
      C      SEARCH
      CALL XTEND(L)
      IF (L.EQ.1) GO TO 4
130      C
      C      FINE PATTERN SEARCH FOR THE OPTIMUM POINT
      CALL SHOT(2)
      2 JCONS=
135      C
      C      GRADIENT SEARCH FOR THE OPTIMUM POINT
      CALL SGRCH
      IF (JCONS.EQ.0) GO TO 10
      K=K-1
      IF (K.GT.0) GO TO 2
140      10 CONTINUE
      C
      C      PRINTOUT OF DRY COOLING TOWER DESIGN
      C
      CALL OUT2(RBP,HREFAC1,SSCO,CASSS1,PLANCJ1,PLANC1,CTURB,TCO)
145      CALL OUT4(1)
      CALL OUT4(2)
      CALL ROTHX
      CALL ROTHXC(AFPO1)
      CALL RORT1(DESVEL, DIST,POHCIR)
      CALL RORT2(EFFC1,CONMAT,CONMA2)
      CALL OPTFAN
      WRITE(4,100)
100  FORMAT(141)
      WRITE(4,930)
155      WRITE(4,931)
      WRITE(4,932)
      WRITE(4,933)
      WRITE(4,934)
      WRITE(4,935)
160      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
165      C
      DO 3 I=1,NTA
      3 CALL VARIT(TA(I),TPER(I),PCST(I),I,CLSUM,FCSUM)
      ACOS=0.0
      DO 3 I=1,NTA
      ACOS=ACOS+PCST(I)
170

```

```
      8 CONTINUE
      WRITE(4,944) ACOS
      WRITE(4,945) CAPCS1
775      C
      C      CAPITAL AND OPERATION COST SUMMARY PRINTOUT
      C
      CALL SUMCOS(FCR, PSIZE, CAPF, CCOS1, CPIP1, CONBA1, ATUBC1, CPLEN1
780      5 ,FRACT, FVCS1, STRUC1, CFOUN1, CAPCS1, SPCD1, SSCD, HRFAC1
      5 ,HREAPS, YFPMIN, PLANC, CLAN1, CLSUM, FCSUM, COSM1, CSTLVI
      5 ,CSTH1, CFANE1=XNEAN1, CYLR1=XNEAN1)
      TD=TD + 5.
      FIRST = .TRUE.
      KALEXT = 0
785      IF(TD.EQ.TEND) GOTO 1
      6 CONTINUE
      STOP
      END
```

SUBROUTINE CALC(T1,RANGE,CWARA,AFRON,WLRAT,M)

SUBROUTINE CALC OF THE METAL FINNED TUBE DRY COOLING TOWER SYSTEM CODE DETERMINES THE DIMENSIONS AND DESIGN PARAMETERS OF THE HEAT EXCHANGER. THE COST OF THE HEAT EXCHANGER SURFACE IS FOUND BY A SEPARATE ROUTINE INITIATED FROM THIS SUBROUTINE. THE DESIGN AND COSTING OF THE FAN AND PIPING SYSTEMS ARE DONE BY SEPARATE ROUTINES ALSO INITIATED FROM THE CALC SUBROUTINE.

THE INPUT PARAMETERS ARE SUPPLIED TO THE CALC SUBROUTINE BY THE OPTIMIZATION ROUTINE DEVELOPED BY M.I.T. IT IS A COMBINATION OF A PATTERN AND GRADIENT SEARCH ROUTINE. THE PURPOSE OF THE OPTIMIZATION PART OF THE CODE IS TO MINIMIZE THE INCREMENTAL COST OF DRY COOLING BY VARYING THE DESIGN OF THE DRY COOLING TOWER. IT THEREFORE SUPPLIES FIVE DESIGN VARIABLES TO SUBROUTINE CALC AND IN RETURN AN INCREMENTAL COST IS FOUND.

THE FOLLOWING ARE THE INPUT PARAMETERS TO SUBROUTINE CALC

T1	- STEAM TURBINE EXHAUST TEMPERATURE (DEGREES F)
RANGE	- TEMPERATURE DIFFERENCE OF THE WATER ENTERING AND LEAVING THE HEAT EXCHANGER (DEGREES F)
CWARA	- RATIO OF THE HEAT CAPACITY OF THE WATER TO THE AIR (DIMENSIONLESS)
AFRON	- FRONTAL AREA OF THE HEAT EXCHANGER IN THE DIRECTION OF AIR FLOW (SQ FT)
WLRAT	- RATIO OF THE WIDTH TO THE LENGTH OF THE HEAT EXCHANGER (DIMENSIONLESS)
M	- PARAMETER WHICH SPECIFIES WHICH OF THE ABOVE HAS BEEN VARIED BY THE OPTIMIZATION ROUTINE SINCE THE LAST TIME THROUGH CALC

DEFINITIONS OF VARIABLES

AAIR	- AIR SIDE HEAT TRANSFER AREA (SQ FT)
APC	- CAPITAL COST OF FAN SYSTEM (\$)
AMTU	- HEAT EXCHANGER NUMBER OF TRANSFER UNITS (DIMENSIONLESS)
BAR	- ATMOSPHERIC PRESSURE FOR A PARTICULAR ELEVATION (IN HGA)
CMIN	- THE SMALLEST HEAT TRANSFER CAPACITY BETWEEN THE AIR AND THE WATER (BTU/HR DEG F)
CONL	- THERMAL CONDUCTIVITY OF THE TUBE WALL (BTU/HR FT DEG F)
DEEPL	- UPPER OR LOWER LIMIT ON THE NUMBER OF TUBES IN DEPTH (DIMENSIONLESS)
DELPA	- AIR SIDE PRESSURE DROP ACROSS THE HEAT EXCHANGER BUNDLE (LBF/SQ FT)
DELPPI	- PRESSURE DROP THROUGH THE SUPPLY AND RETURN PIPING SYSTEM (LBF/SQ FT)
DELPAC	- PRESSURE DROP THROUGH THE CONDENSER (LBF/SQ FT)
DELPWT	- PRESSURE DROP THROUGH THE HEAT EXCHANGER BUNDLE (LBF/SQ FT)

60	C	DEPTH	- DEPTH OF THE HEAT EXCHANGER PARALLEL TO THE AIR FLOW (FT)
	C	DT	- 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)
65	C	F _{AIR}	- AIR SIDE FRICTION FACTOR (DIMENSIONLESS)
	C	FIXL	- THE FIXED LENGTH OF HEAT EXCHANGER TUBES SPECIFIED BY INPUT TO THE CODE (FT)
	C	G _{AIR}	- MASS FLUX OF AIR THROUGH THE TRANSVERSE AREA BETWEEN TUBES OF THE HEAT EXCHANGER (LBM/SQ FT HR)
70	C	G _{AIRD}	- MASS FLUX OF AIR THROUGH THE DIAGONAL AREA BETWEEN TUBE ROWS OF THE HEAT EXCHANGER (LBM/SQ FT HR)
	C	G _{WAT}	- MASS FLUX OF WATER THROUGH THE EXCHANGER TUBES (LBM/SQ FT HR)
	C	H _T	- WATER SIDE HEAT TRANSFER COEFFICIENT THROUGH THE HEAT EXCHANGER TUBES (BTU/HR SQ FT DEG F)
75	C	H _O	- AIR SIDE HEAT TRANSFER COEFFICIENT THROUGH THE HEAT EXCHANGER BUNDLE (BTU/HR SQ FT DEG F)
	C	H _{OWAT}	- HORSEPOWER REQUIREMENTS OF WATER PUMPING SYSTEM FOR THE CONDENSER, PIPING SYSTEM, AND COOLING TOWER (HP)
80	C	H _{OFAC1}	- HEAT RATE FACTOR OF STEAM TURBINE AT THE RATED BACK PRESSURE (DIMENSIONLESS)
	C	H _{OFAC2}	- HEAT RATE FACTOR OF STEAM TURBINE AT THE DESIGN TEMPERATURE (DIMENSIONLESS)
85	C	H _{WNP}	- NUMBER OF PASSES OF WATER THROUGH THE HEAT EXCHANGER (DIMENSIONLESS)
	C	IMEAT	- INTERNAL VARIABLE FOR SELECTING THE FRICTION FACTOR AND HEAT TRANSFER COEFFICIENT FOR THE INLINE OR STAGGERED TUBE SPACING (DIMENSIONLESS)
90	C	KCONV	- INTERNAL VARIABLE FOR SPECIFYING THAT THE SET OF INPUT VARIABLES LEAD TO UNREASONABLE ANSWERS (DIMENSIONLESS)
	C	NTUCAL	- SPECIFIES THE TYPE OF NTU-EFFECTIVENESS CALCULATION TO BE USED BY THE CODE (DIMENSIONLESS)
95	C	NUMTOW	- NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
	C	N _T	- NUMBER OF HEAT EXCHANGER TUBES IN WIDTH (DIMENSIONLESS)
	C	ODL	- OUTSIDE DIAMETER OF HEAT EXCHANGER TUBES (IN)
	C	P	- STEAM TURBINE BACK PRESSURE (IN HGA)
100	C	P _{OW}	- POWER REQUIREMENTS OF WATER PUMPING SYSTEM FOR THE CONDENSER PIPING SYSTEM AND COOLING TOWER (KW)
	C	P _{SIZE}	- POWER OUTPUT OF PLANT (MW)
	C	Q _{IN}	- HEAT SUPPLIED BY THE STEAM SUPPLY SYSTEM (RTU/HR)
105	C	Q _{REJ}	- HEAT REJECTED BY THE DRY COOLING TOWER (RTU/HR)
	C	RE _{AIRE}	- REYNOLDS NUMBER OF THE AIR FLOWING THROUGH THE MINIMUM CROSS-SECTIONAL AREA OF THE HEAT EXCHANGER (DIMENSIONLESS)
	C	RE _{FF}	- EFFECTIVE HEAT EXCHANGER TUBE WALL THICKNESS BASED ON AIR SIDE TUBE AREA (FT)
110	C	RE _{WAT}	- REYNOLDS NUMBER OF THE WATER FLOWING THROUGH THE HEAT EXCHANGER TUBES (DIMENSIONLESS)
	C	T _{CO5}	- INCREMENTAL COST FOR THE USE OF DRY COOLING TOWERS (MILLS/KWH)
	C	T _{OTFC5}	- TOTAL COST OF THE PIPING SYSTEM (K\$)

```

115      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)
120      C      THO - 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)
125      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
130      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      VADUT - SPECIFIC VOLUME OF THE AIR LEAVING THE HEAT EX-
135      C      CHANGER BUNDLE (CU FT/LBM)
          C      VOL - TOTAL VOLUME OF THE HEAT EXCHANGER (CU FT)
          C      VWT - WATER VELOCITY THROUGH THE HEAT EXCHANGER TUBES
          C      (FT/SEC)
          C      WIDTH - TOTAL HEAT EXCHANGER WIDTH (FT)
140      C      W1 - MASS FLOW RATE OF WATER THROUGH THE COOLING TOWER
          C      (LBM/HR)
          C      W2 - MASS FLOW RATE OF AIR THROUGH THE COOLING TOWER
          C      (LBM/HR)
          C      XD - LONGITUDINAL PITCH BETWEEN ADJACENT TUBE ROWS
145      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
150      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
155      C      HEAT EXCHANGER DIMENSIONAL RELATIONSHIP
          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)
160      C      VALP - HEAT EXCHANGER VOLUME (CU FT/FT)
          C      ACT - CROSS SECTIONAL FOOT 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)
165      C      SIGMA - RATIO OF FREE FLOW AREA TO TOTAL FRONTAL
          C      AREA (DIMENSIONLESS)

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      LOGICAL EXTLNG
      LOGICAL FIRST, EXTEMP
      COMMON
      AFTR, ALPHA

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170

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775  S ,CAPF, C5SPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, COMMA2, CAF
      S ,CBU, CTUP3, CDANG, CLUVR, CHAILE, CVM
      S ,DANGLE, DFIN, DEEPL, DESVEL
      S ,EFFP
      S ,FCR, FIRST, FIXL, FCOs, FFHX, FXTMP
      S ,GREFF
      S ,HYNO, HRCST
      S ,ITMAX, ITMIN
780  S ,JCONG
      S ,KCONG, KALEXT
      S ,MXEX
      S ,NTUCAL(2), NTA
      COMMON
785  S ,ONP
      S ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      S ,POHRA, POHFUN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
      S ,PREU, PREDUCE
      S ,RPP, REDUCE, ROOPL, RFX
790  S ,SIGMA, SAAP
      S ,TD, TPO(4), TEFF, TLM, THFIN, TLPRA, TFIX
      S ,TOD, TW
      S ,UCS, UWS
      S ,VAB(2)
795  S ,WCV
      S ,XDEP, XW, XD
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      S ,QEN, CLAND, REAIR, Z,HRFAC2, W4, U, DELPW, PPOW,
      S ,PPOW, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
800  S ,PFWAT, NW, NT, NP1,PLANC2,PSIZ12, SP30, SW4, SW3,
      S ,STC,PTOTAL,PLANC3,SAFRON, AAIR, YFP, SPC0,PSIZ13, WT2,
      S ,R22, NW2, TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      S ,TLIX, UCON, PNCST, FMOST, FBACC, EFFC, CH, CA, CS
805  S ,CLTC, CFC, CPCC, FITCO, CSC,CEPREP,DEPIR, AST,OLDCST
      S ,CAPCST, XNEAN,BLOANG, CPLEN, DPPEL, WHX, WTTUG, ADIA, ARLN
      S ,WTHR, WTRF,STRUC,CPMPE,HPPEF, TOTCF, TPC, EFFIN, ANTU
      S ,AIRFF, WATER, XNMOD, TOTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      S ,ACTRD, ADURD, ACTVH, ADUVH, ADUPP, THPAIR, TCTF, AFCST
810  S ,CSR, WATERM, WSTRCT, CFOUND, HJBDIA, TOWLEN, NUMTOW, CTOWD
      S ,ATUR, CSTLVR, CSTHS, CYLRNG, CFANEL
      COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
      S ,QEN1, CLAN1, REAIR1, Z1,HRFA2S, W41, U1, DEPW1, PPOW1,
815  S ,PPOW1, DEFC1, WIDTH1, ELN1, VAIP1, VWAT1, HI1, HO1, T41,
      S ,PFWAT1, NW1, NT1, NP1,ZPLNC2,ZSIZ12, ZSP30, SW41, SW31,
      S ,SP1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPC01, SP513,WT2MIN,
      S ,R22MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1
      S ,TLIX1, UCON1, PNCOS1, FMOS1, FBAC1, EFFC1, CH1, CA1, CS1
820  S ,CLTC1, CFC1, CPCC1,FITCO1, CSC1,CEPRE1,DEPIR1, AST1,OLDCS1
      S ,CAPCST1,XNEAN1,BLOAN1,CPLE1,DPPEL1, WH1, WTTU1, ADI1, ARL1
      S ,WTHR1, WTRF1,STRUC1,CPMPE1,HPPE1,TOTCF1, TPC1,EFFIN1, ANTU1
      S ,AIRFF1, WATER1, XNMOD1, TOTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
      S ,ACTRD1, ADURD1, ACTVH1, ADUVH1, ADUPP1, THPA1, TCTF1, AFCST1
825  S ,CSR1, WATER1, WSTRCT1, CFOUND1, HJBD1, TOWLE1, NUMT01, CTOWD1
      S ,ATUR01, CSTLV1, CSTHS1, CYLRN1, CFANEL
      COMMON /SCALER/HRFAC1, ATUR, OPERA, SSCD,PLANC1,CASSS1,
      S ,GAIR, FAIR, HPAIR, HPWAT, PLANC1
      COMMON /DURDI,XOR,ST
      COMMON /FLSH/ FXTENG

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COMMON /INDIS/ DIST
COMMON /HEADX/ DUM12(16), W3
COMMON /LACALL/ SRN
COMMON /TIME/ XNS,TTD,TLA,XNTS,ARPS
COMMON /SURFEX/ DDL,DUM1ST(15)
COMMON /TUBE/ KG4,FGA(7),LD,ESA(5),TID(7.6),PTF(7.6)
COMMON /HXD/ AT,ATOT
COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF,FACPF,P2,R,S,
$VELREC,AFG,ELEV,EHR
300 FORMAT(" CALC N=",I1,3X,"T1=",1PE11.4,3X,"RANGE=",E11.4,3X,
$ "OWARA=",E11.4,3X,"AFRON=",E11.4,3X,"WLRAT=",E11.4)
301 FORMAT(" CALC N=",I1,3X,"T1=",1PE11.4,3X,"RANGE=",E11.4,3X,
$ "OWARA=",E11.4,3X,"AFRON=",E11.4,3X,"WLRAT=",E11.4,T110,"TC05=",
$ E11.4)
302 FORMAT("ZERO 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,"CORR=",," 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")
303 FORMAT("ERROR IN DEPTH CALCULATION LOOP IN SUBROUTINE CALC."
$ /IX,"NW,W3,DI,ZD,AAIR,VOL,AFRON",I3,6G13.5)
303 FORMAT(IX,I3," ITERATIONS IN CALC WITHOUT CONVERGING ON DEPTH, PZO
$ =",G13.5," ZD=",G13.5," AFRON=",G13.5)
DATA MTR /0/
DATA PT /3.14159/

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
360 IF(FXTLG*AND(LVC*EQ*4*AND*W*EQ*5) RETURN
KCONV=0
IF(W*EQ*5) GO TO 23
IF(W*EQ*4) GO TO 22
IF(W*EQ*3) GO TO 21
IF(W*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)
370 P=EXP((7.168-9240.)/(T1+460.))
$PR=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
380 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)
385 TEFFM=TEFF/HRFAC2

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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 TURING EFFICIENCY
590      QIN=3473.*PSIZE*1000./TEFFM
C
C      THE HEAT REJECTED BY THE DRY COOLING TOWER (BTU/HR)
C      IS THE FOLLOWING
595      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)
600      MASS FLOW RATES OF WATER AND AIR THROUGH HEAT EXCHANGER
C
C      20 W3=QREJ/RANGE
C
C      GIVEN THE CAPACITY RATIO OF THE AIR TO THE WATER, THE
C      AIR MASS FLOW RATE CAN BE CALCULATED (LBM/HR)
C
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
715      IF (CWARA.GE.1.) GO TO 30
C
C      CAPACITY RATIO LESS THAN ONE
C
C      22 EFF = RANGE/(T1 - TTD - TD)
C      CMIN=W:
C      G=1.
C      GO TO 31
C
C      CAPACITY RATIO GREATER THAN ONE
725      30 EFF = CWARA*RANGE/(T1 - TTD - TD)
C      CMIN=W4*.24
C      G=CWARA
730      21 H = CWARA*RANGE/(T1-TTD - TD)
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
735      OF THE COLD AND HOT FLUIDS
C
C      COUNTER FLOW HEAT EXCHANGER ARRANGEMENT
C
C      33 IF (NTUCAL(1).EQ."COUNTER FL") CALL NUNO2P(T1,TD,TTD,CWARA,RANGE,W3
740      S,W4,ANTU)
C
C      CROSS FLOW HEAT EXCHANGER ARRANGEMENT

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C      IF (NTUCAL(1).EQ.'CROSS FLOW') ANTU=G*ALOG(1.+ALOG(I.-4)/CWARA)
145 C      SINGLE PASS HEAT EXCHANGER
C
C      IF (HXMP.EQ.1. .AND. NTUCAL(1).EQ.'TABLET') G) CALL
S NTJ1P (CWARA,EFF,ANTU)
150 C      TWO PASS HEAT EXCHANGER
C
C      IF (HXMP.EQ.2. .AND. NTUCAL(1).EQ.'TABLET') G) CALL
S NTJ2P (CWARA,EFF,ANTU)
155 C      22 CONTINUE
C
C      HEAT EXCHANGER DIMENSIONS
C
C      INSIDE AREA PER FOOT (FT**2/FT)
160 C      AI = PI*DI*12.0/144.0
C
C      FIN PITCH (FINS/IN)
C      PF = 1.0/(SF + THFIN)
165 C      SIDE FIN AREA (FT**2/FT)
C      SFA = 2.0*PF*PI*(DFIN**2 - ODR**2)/48.0
C
C      AREA AT THE ENDS OF THE FIN (FT**2/FT)
C      EFA = PF*PI*CFIN*THFIN/12.0
170 C
C      ROOT FIN AREA (FT**2/FT)
C      RFA = PI*ODR*(1.00 - PF*THFIN)/12.0
C
C      TOTAL SURFACE AREA (FT**2/FT)
175 C      ATOT = SFA + EFA + RFA
C
C      HEAT EXCHANGER VOLUME (FT**2/FT)
C      VOLP = XM * XD * 1. / 144.
180 C      CROSS-SECTIONAL ROOT TUBE AREA (FT**2/FT)
C      ART = ODR/12.0
C
C      CROSS-SECTIONAL FIN TUBE AREA (FT**2/FT)
C      AF = PF*(DFIN - ODR)*THFIN/12.0
185 C
C      CROSS-SECTIONAL AREA (FT**2/FT)
C      ACS = XM/12.0
C
C      RATIO OF AIR SIDE FIN AREA TO TOTAL AIR SIDE AREA
190 C      AFTR = (SFA + EFA)/(SFA + EFA + RFA)
C
C      RATIO OF AIR SIDE HEAT TRANSFER AREA TO HEAT EXCHANGER
C      VOLUME
C      ALPHA = ATOT/VOLP
195 C
C      RATIO OF FREE AIR FLOW AREA TO THE TOTAL FRONTAL AREA
C      SIGMA = 1.-(ART + AF)/ACS
C
C      THE AIR FLOW AREA (SQ FT) NORMAL TO THE DIRECTION OF AIR

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400      C      FLOW IS CHECKED TO DETERMINE IF IT IS A REASONABLE VALUE
      C
      IF (AFRON*SIGMA.EQ.0.0) WRITE(6,300) M, I1, RANGE, CWAFA, AFRON, WLRAT
      IF (AFRON*SIGMA.EQ.0.0) WRITE(6,301) TCOS
      IF (AFRON*SIGMA.EQ.0.0) WRITE(6,9) AFRON, SIGMA
405      C
      C      THE AIR MASS FLUX IS DETERMINED FOR THE MINIMUM CROSS-
      C      SECTIONAL FLOW AREA
      C
      GAIR= W4/(AFRON*SIGMA)
410      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
415      REAIR=ODR*GAIR/(.046*12.0)
      C
      C      THE AIR SIDE HEAT TRANSFER (BTU/HR SQ FT DEG F) COEFFICIENT
      C      AND FRICTION FACTOR IS DETERMINED
      C
420      KK=1
      RATIO=XDG/XW
      IF (ABS(RATIO-1.0).GE.1.E-03) KK=2
      IF (FFHX.EQ."PFR") CALL HXPER(ODR, REAIR, DFIN, PF,
425      C
      C      PFR CORRELATIONS
      C
      C      THFIN, HO)
      C
      C      BRIGGS YOUNG AND ROBINSON CORRELATIONS
      C
430      IF (FFHX.EQ."FRICHO") CALL FRICHO(KK, FAIR, HO, ODR, DFIN,
      C
      C      X4, XDG, SF, THFIN, GAIR)
      C
      C      FIN EFFICIENCY AS DEFINED BY DUSINBERRE
      REFIN=(DFIN/ODR + 4./3.) / 7.
435      SFFIN= 1. / (1. + (SFIN*HO*(DFIN-ODR)**2) /
      C
      C      (24.*CONF*THFIN))
      C
      C      THE WIDTH (FT) OF THE HEAT EXCHANGER IS CALCULATED
      C      DEPENDING ON IF THE LENGTH OF THE HEAT EXCHANGER TUBES IS
440      C
      C      FIXED OR ALLOWED TO FLOAT
      C
      23 IF (EXTLNG) WIDTH=AFRON/FIXL
      IF (.NOT.EXTLNG) WIDTH=SQRT(WLRAT*AFRON)
445      C
      C      THE NUMBER OF TUBES IN WIDTH
      C
      NW=WIDTH/XK*12
      C
      C      A CHECK ON THE NUMBER OF TUBES IN WIDTH
450      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) GO TO 10
455      W2=WIDTH
      NW2=NW

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C
C      THIS IS THE START OF THE ITERATION LOOP FOR DETERMINING
C      THE NUMBER OF TUBES IN DEPTH OF THE HEAT EXCHANGER
460 C
C      KN=0
C      ZD=2
C
C      WATER SIDE REYNOLDS NUMBER
465 C
C      5 REWAT=4.8*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
470 C
C      HI=.1826*(REWAT**.8)/DI
C
C      NUSSLETT LAMINAR FLOW RELATIONSHIP
C      IF (REWAT.LT.2400.0) HI=3.66+.364/(DI/12.0)
475 C
C      CHECK ON WATER SIDE HEAT TRANSFER COEFFICIENT TO
C      DETERMINE IF IT IS A REASONABLE VALUE
C
C      IF (.EQV(HI).EQ.0) GOTO 6
480 C
C      WRITE(4,903)NW,W3,DI,ZD,AAIR,VOL,AFRONT
C      STOP
C      6 CONTINUE
C
C      OVERALL SURFACE EFFICIENCY
485 C
C      EFS=1.-AFRONT*(1.-EFFIN)
C
C      OVERALL HEAT TRANSFER COEFFICIENT BASED ON THE OUTSIDE
C      SURFACE AREA (BTU/HR SQ FT DEG F)
C
490 C
C      REFF= ATOT / (2.*3.14159)
C      U = 1. / (1./(EFS*HI)) +
C      REFF * ALOG(ODL/DI) / CONVI +
C      ATOT / (AI*HI)
C
495 C
C      AIR SIDE HEAT TRANSFER SURFACE AREA (SQ FT)
C
C      AAIR=AMTU*CMIN/U
C
C      VOLUME OF THE HEAT EXCHANGER (CU FT)
500 C
C      VOL=AAIR/ALPHA
C
C      DEPTH OF THE HEAT EXCHANGER (FT)
C
505 C
C      DEPTH=VOL/AFRONT
C
C      THE NUMBER OF TUBES IN DEPTH
C
510 C
C      PD=ZD
C      ZD=12.*DEPTH/XD
C
C      CONVERGENCE CRITERION OF ITERATION LOOP

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      IF (ABS(ZD-PZD)/PZD-LT..001) GOTO 11
      C
      C      CHECK ON THE NUMBER OF TIMES THROUGH ITERATIVE LOOP
      C
      KN=KN+1
      IF (KN.GT.70) WRITE(5,303) KN,PZD,ZD,AFRONT
      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 (POMDPL.GT. 0.0 .AND. ABS(DEEPL).GT. 0.0) TEST = ".EQ."
      Z = ZD
      IF (TEST.EQ. ".GT." .AND. ZD.GT. ABS(DEEPL)) GOTO 10
      IF (TEST.EQ. ".LT." .AND. ZD.LT. DEEPL) GOTO 10
      IF (TEST.EQ. ".EQ." .AND. ABS(ZD-DEEPL).GT. POMDPL) GOTO 10
      C
      C      WATER SIDE FRICTION FACTOR AND PRESSURE DROP CALCULATION
      C      OF THE HEAT EXCHANGER
      C
      GWAT = HXNP * 575. * W3 / (3.14159*DI*DI*ZD*WV)
      C
      C      VELOCITY OF WATER THROUGH THE TUBES
      C
      VWAT=GWAT/(62.*3500.)
      C
      C      HEAT EXCHANGER TUBE LENGTH
      C
      IF (EXTLNG) ELENG=FIXL
      IF (.NOT.EXTLNG) 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=.073/(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/3500.)**2 /
      $ (DI * 62. * 64.4)
      PL = SQRT( XDG**2 - (XW/2.)**2 )
      HYDDIA = 4.*((ZD - 1.)*PL + DFIV)*(ACS - (ART + AF))/(ATOT*ZD)
      C
      IF (FFHX.EQ. HPER) 11) CALL HPER(HYDDIA,PL,GAIR,FAIR)

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      AIRFF = FAIR
      WATERF = FRAT
C
C      CONDENSER DESIGN
575 C
      CALL SPDES(T0,T1,RANGE,TTD,XNS,QREJ,VFLD,RHO,ARPS,TLA,XNTS,HOLCS)
      DELPWC=HOLCS*62.
C
C      EXIT AIR TEMPERATURE FROM HEAT EXCHANGER
583 C
      T4 = CWARA * RANGE + T0
C
C      COSTING OF THE HEAT EXCHANGER SURFACE AND HEADERS
      CALL COSTEX(ATOT)
585 C
C      FAN SYSTEM DESIGN
C
      BARLN=3.39853-3.91835E-5*ELEV
      BAR=EXP(BARLN)
593 C
C      SPECIFIC VOLUME OF AIR FOR THE INLET TO THE HEAT EX-
      CHANGER BUNDLE AND THE EXIT OF THE FAN (CU FT/LBM)
      SPVOL=(T4+459.67)/1.325*BAR
      VAIN=      (T0+459.67)/(1.325*BAR)
595 C
      VACUT=      (T4+459.67)/(1.325*BAR)
      VAAV=(VAIN+VACUT)/2.
      VAIR=GAIR*VAAV/3600.
C
C      AIR SIDE PRESSURE DROP THROUGH THE HEAT EXCHANGER
600 C
      DELPA=(GAIR/3600.)*2*VAAV*2*FAIR/32.2
      OPTPSE=DELP
      OPTINW = OPTPSE/ 5.2022
C
      DENSITY CORRECTION TO TOTAL PRESSURE DROP
      IF((OPTINW*.37495*SPVOL).GT.1.35) RETURN
605 C
C      DESIGN AND COST OF THE FAN SYSTEM
      CALL FAN (OPTINW)
C
C      AFC GREATER THAN .49E+9 MEANS NO SUITABLE FAN WAS FOUND BY
      SUBROUTINE FAN SET TCOS TO HIGH VALUE TO THROW OUT THIS POINT
      IN THE SEARCH FOR A MINIMUM
C
      IF( AFC .GT. .49E+9) TCOS = 1.E+38
      IF( AFC .GT. .49E+9) RETURN
615 C
C      DESIGN AND COST OF THE WATER PIPING SYSTEM
C
      CALL PIPECT(T1,W3,TT0,RANGE,CTDWD,DELPWT,DELPWC,DIST
      ,DESVEL,REDUCE,REDUCE,W3,Z0,XW,TCWFCS,NUMTOW
      ,DELPWP,PPWP,HPWAT,RHO,CDANG,POHCIR,POHLEG,EFFP)
620 C
      DELPW = DELPWT + DELPWC + DELPIP
      IF(TCWFCS .GT. 1.E+39) TCOS = 1.E+38
      IF(TCWFCS .GT. 1.E+39) RETURN
      PPWW=HPWAT/(1.341*EFFP)
      ATUB=(1.-AFTER)*AAIW
625 C
C      SCALING UP THE POWER PLANT AND THE DRY COOLING TOWER TO

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SP ROUTINE CALD

74/74 CRT=1

FIN 4.5+414

05/12/77

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      C      MEET THE POWER REQUIREMENTS OF THE FAN AND PIPING SYSTEMS
      C
630    C      CALL SCALP (PANGE, CWAPA, AFRON, WL2AT, TCHPCS, 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
635    C
      C      CALL NCVART (CWAPA,TCOS)
      C      LVC=M
      C      RETURN
      C      END
```

SUBROUTINE CHNGE(M)

THIS ROUTINE IS CALLED BY SUBROUTINE SERCH WHEN PRESSURE DROP RESTRICTION IS ENCOUNTERED. IT SEARCHES BY CHANGING A VARIABLE OTHER THAN THAT SELECTED BY SUBROUTINE SERCH.

LOGICAL FXTLNG

DIMENSION DP(5), DV(5), VAU(5)

COMMON /SCALER/HFAC1, ATUB, CPRA, SSC0, PLANC1, CASS1,

GAIR, PAIR, HPAIR, HPWAT, PLANCT

LOGICAL FIRST, FXTMP

COMMON

AFTR, ALPHA

CAFF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONVA2, CAFI

CBU, CTURB, CDANG, CLUVR, CHAHS, CVM

DANGLE, DFIN, DEEPL, DESVEL

EEFF

FOP, FIRST, FIXL, FCOS, FFHX, FXTMP

GREFF

HXNP, HPCST

ITMAX, ITMIN

JCONC

KCONV, KALEXT

MXEXT

NTUCAL(2), NTA

COMMON

ODR

PSIZE, PER, PMCOS, PLANC, PFACT, POMDPL

POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL

QREU, QREDUCE

RBP, REDUCE, ROOFL, RFX

SIGMA, SAAF

TD, TPO(4), TEFF, TLIM, THIN, TLPRA, TFIX

TCO, TW

UCS, UWS

VAS(5)

VEV

XDER, XW, XD

COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,

GIN, CLAND, REAIR, Z, HFAC2, W4, U, DELPW, PPW,

FPW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,

REWAT, JW, NT, NP, PLANC2, PSIZ12, SP9P, SW4, SW3,

SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPC, PSIZ13, WT2,

BP2, MW2, TCOS, DELPA, DELPWT, DELPWC, CONBAR, XNTSX, VELDX,

FLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS

CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLDCAST

CAPCST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTTUS, ADIA, ABLN

WTHAP, WTRM, STRJCC, CEPREP, HPERF, TOTCF, TPC, EFFIN, ANTU

AIRPF, WATFF, XNMOD, TOTPF, PDCPF, FMTRC, ACCTTP, ADJTP

ACTBND, ADJRPD, ACTVH, ADJWH, ADJPPF, THPAIR, TOTF, AFCST

CSRD, WATERW, WSTROT, CPOJND, HUBDIA, TOWLEN, NUMTOW, CTOWD

AFURC, CSTLVR, CSTHS, CYLRNG, CFANEL

COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,

QIN1, CLAN1, REA11, Z1, HFAC2S, W41, U1, DEPW1, PPW1,

FPW1, DELC1, WIDT1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,

REW1, JW1, NT1, NP1, PLNC2, ZSIZ12, ZSP9P, SW41, SW31,

SPC1, PTOT1, PLNC31, AFR01, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,

```

S  APRMIN, W2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBAT, XNTS1, VELD1
S  , TLA1, JCON1, PMCS1, FMCS1, FBAC1, EFFC1, CHI, CAL, CS1
60 S  , CLTC1, CFCL, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, ASY1, OLDCS1
S  , CAPCS1, XNFAN1, BLOAN1, CPLEN1, DPFE1, WH1, WITU1, ADI1, ABL1
S  , WTH1, WTER1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1
S  , AIRFF1, WATFF1, XNMOD1, TCIPF1, FDCPF1, FMTRC1, ACTIP1, ADJTP1
S  , ACTBP1, ADJBP1, ACTVH1, ADJYH1, ADJPP1, THPA1, TCTF1, AFCST1
65 S  , CSR1, WATER1, WSTRC1, CFOJN1, HUBD1, TOWLE1, NUMT01, CTOWD1
S  , ATIRC1, OSTLV1, OSTHS1, CYLRN1, CFANE1
COMMON /ELSH/ EXTENG
COMMON /LACALL/ SRN
COMMON /TIME/ XNS, TTD, TLA, XNTS, ARPS
70 ID3=0
L=0
KI=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(EXTENG) VAL(1) = TFIX
IF(EXTENG) VAL(2) = RFIX
IF(VAL(M).LE.0.0) GO TO 36
IF(M.GT.3) GO TO 10
85 IF(VAL(1).LE.0.0) GOTO 36
H = VAL(3)*VAJ(2)/(VAJ(1)-TTD-TD)
41 IF(4.GE.1.) GO TO 36
IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 36
10 SRN="X-CHNGE-1/"
CAL= CALC(VA1(1),VAL(2),VAL(3),VAL(4),VAL(5),1)
IF(KCONV.EQ.1) GO TO 36
PA=DELP4
PA1=DEPA1
DP(X)=DELP4-DEPA1
95 IIR=1
IF(EXTENG) IIR=2
DO 35 I=IIR,5
I=4-I
IF(I.EQ.5.AND.DV(1).GT..005) GO TO 35
IF(I.EQ.4) 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(EXTENG) VAJ(1) = TFIX
IF(EXTENG) VAJ(2) = RFIX
IF(I.GT.3) GO TO 17
IF(VAJ(1).LE.0.0) GOTO 12
H = VAL(3)*VAJ(2)/(VAJ(1)-TTD-TD)
105 43 IF(4.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

```

```

115      IF (M.LT.I) J=M
          SRN="/CHANGE-2/"
          CALL CALC(VAU(1),VAU(2),VAU(3),VAU(4),VAU(5),J)
          VAU(I)=VAR(I)
          IF (KCONV.EQ.1) GO TO 34
120      PA=DELP
          PA1=DEPA1
          DP(I)=DELP-DEPA1
          E=0.
          C=1.
          D=1.
125      18 VAL(I)=(1.+DV(I)*(E-DP(M))/DP(I))*VAR(I)
          IF (EXTMP) VAL(1) = TFIX
          IF (EXTMP) VAL(2) = RFIX
          IF (VAL(I).LE.0.0) GO TO 34
130      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.GT.1.) GO TO 34
          IF (ALOG(1.-H)/VAL(3).LE.-1.) GO TO 34
135      24 SRN="/CHANGE-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
140      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 JU=1,5
150      27 VAU(JU)=VAR(JU)
          VAL(M)=(1.+DV(M))*VAR(M)
          IF (EXTMP) VAL(1) = TFIX
          IF (EXTMP) VAL(2) = RFIX
155      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)
160      47 IF (H.GT.1.) GO TO 36
          IF (ALOG(1.-H)/VAL(3).LE.-1.) GO TO 36
          33 SRN="/CHANGE-4/"
          CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
          IF (KCONV.EQ.1) GO TO 36
165      PA1=DEPA1
          PA=DELP
          DP(I)=DELP-DEPA1
          GO TO 11
          34 VAL(I)=VAR(I)
          35 CONTINUE
          36 DO 37 I=1,5

```

SUBROUTINE CHNGE

74/74 OPT=1

FTN 4.2+74351

12/21/76

37 DV(I)=DV(I)
K1=K1+1
IF(K1=2.1) 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
5      EXCHANGER BUNDLE IS BROKEN DOWN INTO SEVERAL SUBCOMPONENTS
C          1. HEADER
C          2. TUBING
C          3. TUBING SEALANT
C          4. SPACERS
10      C          5. BUNDLE FRAME
C          6. BUNDLE ASSEMBLY
C      THE WEIGHT OF THE HEAT EXCHANGER BUNDLE AND THE WATER ARE
C      ALSO CALCULATED.
C
15      C      DEFINITION OF VARIABLES
C
C      ARC      - 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
20      EXCHANGER (DECIMAL)
C      CA       - BUNDLE ASSEMBLY AND FRAME COSTS ($)
C      CBA      - BUNDLE ASSEMBLY COST ($)
C      CAJ      - COST OF BOLTED HEADER JOINT ($/FT)
C      CELAST   - COST OF THE ELASTOMER ($/LBF)
C      CEPREP   - COST OF END PREPARATION FOR EACH TUBE ($/TUBE)
C      CFS      - UNIT FRAME COSTS ($/LOF)
C      CH       - COST OF THE HEADER FOR EACH BUNDLE
C      CHC      - STEEL HEADER COSTS ($/LBF)
C      CHF      - BUNDLE FRAME COST ($)
30      CHX      - COST OF THE HEAT EXCHANGER ($)
C      COATC    - COST OF COATING THE AIR SIDE SURFACE AREA
C                ($/SQ FT)
C      COCC     - COST OF COATING THE HEAT EXCHANGER TUBES ($)
C      COJ      - COST OF ROLLED JOINTS FOR THE HEADER ($/TUBE)
35      CS       - COOLING SURFACE COST ($)
C      CSC      - TUBE SPACER COSTS ($/TUBE-SPACER)
C      CSEALP   - COST OF SEAL PLATE ($/LBF)
C      CWJ      - COST OF WELDED JOINT FOR THE HEADER ($/TUBE)
C      DFIN     - OUTSIDE DIAMETER OF FIN (IN)
40      DI       - INSIDE DIAMETER OF TUBE (IN)
C      ELENG    - LENGTH OF THE HEAT EXCHANGER TUBES (FT)
C      EPREPC   - END PREPARATION COSTS ($/TUBE)
C      FA       - TOTAL TUBE FLOW AREA PER PASS SQ (IN)
C      FACT     - HEADER FACTOR WHICH DEPENDS ON THE TYPE OF HEADER
45      (DIMENSIONLESS)
C      FITCO    - TUBING COST ($/FT)
C      FP       - PRESSURE FACTOR (DIMENSIONLESS)
C      FD       - HEADER DEPTH MATERIAL FACTOR (IN)
C      FW       - HEADER WIDTH MATERIAL FACTOR (IN)
50      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)
55      HF       - FIN HEIGHT (IN)
C      HW       - HEADER WIDTH (IN)
C      HXNP     - NUMBER OF PASSES THROUGH THE HEAT EXCHANGER

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C      (DIMENSIONLESS)
C      NW      - NUMBER OF HEAT EXCHANGER TUBES IN WIDTH
60 C      (DIMENSIONLESS)
C      ONL     - OUTSIDE DIAMETER OF TUBE (IN)
C      ONLINE  - OUTSIDE DIAMETER OF THE LINER (IN)
C      PAF     - PROCURMENT COST FACTOR (DECIMAL)
C      PAMBAF  - INDIRECT CONSTRUCTION COST FOR HEAT EXCHANGER
65 C      PF     - FIN PITCH (FINS/IN)
C      BUNDLE  (DECIMAL)
C      POEL    - TUBING MATERIAL DENSITY (LBM/CU IN)
C      SF      - SPACING BETWEEN FINS (IN)
C      SS      - SPACING BETWEEN SPACERS (FT)
70 C      THFIN  - FIN THICKNESS (IN)
C      TB      - THICKNESS OF THE FIN AT THE ROOT OF THE FIN (IN)
C      THVOL   - 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
75 C      BUNDLE (LBF)
C      Wb      - WIDTH OF THE HEAT EXCHANGER BUNDLE (F)
C      Wf      - WEIGHT OF THE FINS OF THE HEAT EXCHANGER (LBF)
C      WEX     - WEIGHT OF MATERIAL MAKING UP THE EXCHANGER (LBF)
C      Wf      - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
80 C      WFRM   - WEIGHT OF THE HEAT EXCHANGER FRAME (LBF)
C      WTHDR   - WEIGHT OF THE HEAT EXCHANGER HEADER (LBF)
C      WITUB   - WEIGHT OF THE TUBES IN THE HEAT EXCHANGER (LBF)
C      Xd      - LONGITUDINAL TUBE SPACING BETWEEN TUBE ROWS (IN)
C      XBRUN   - NUMBER OF HEAT EXCHANGER BUNDLES (DIMENSIONLESS)
C      XN      - TRANSVERSE TUBE PITCH NORMAL TO AIR FLOW (IN)
85 C      Z      - NUMBER OF HEAT EXCHANGER TUBES IN DEPTH
C      (DIMENSIONLESS)
C      ZINCC   - COST OF THE ZINC FOR THE TUBE SPACERS ($/LBM)
C
C      90
C      C      ARRAYS
C      THBMA - LINER MATERIAL
C      CL    - LINER FIXED COSTS ($)
C      CLM   - LINER MATERIAL COSTS ($/LB)
C      ROEL  - DENSITY OF LINER MATERIALS (LB/CU IN)
95 C      GAGE  - LINER GAGE
C      THLIN - THICKNESS OF LINER (IN)
C      FINTY - TYPE OF FIN
C      CFM   - FIN MATERIAL COSTS ($/LB)
C      CFF   - FINNING FIXED COSTS ($/FT)
100 C      ONLINE - COMMON DIAMETERS OF LINER (IN)
C      MAXFH - MAXIMUM FIN HEIGHT (IN)
C      STANFT - STANDARD FIN THICKNESS (IN)
C      FPL   - LOWEST FIN PITCH (FPI)
C      FPH   - HIGHEST FIN PITCH (FPI)
105 C      HEDTY - TYPE OF HEADER
C      HEDMA - HEADER MATERIAL
C      ROEHM - HEADER MATERIAL DENSITY (LB/CU IN)
C      CHM   - COST OF HEADER MATERIAL ($/LB)
C      CHW   - COST OF HEADER MACHINING AND WELDING ($/FT)
110 C      CHN   - NOZZEL AND ATTACHING COST ($/HOLE)
C      CHH   - TUBE AND PLUGHOLE PREPARATION ($/HOLE)
C      PF    - COST LENGTH FACTOR FOR TUBES (DIMENSIONLESS)
C      FINMA - TYPE OF FIN MATERIAL
C      FPL   - LOWER LIMIT ON STANDARD FIN PITCHES THAT ARE

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115      C      COMMERCIALLY AVAILABLE (FINS/IN)
      C      FPM - UPPER LIMIT ON STANDARD FIN PITCHES THAT ARE
      C      COMMERCIALLY AVAILABLE (FINS/IN)
      C      MAXFH - MAXIMUM FIN HEIGHT FOUND COMMERCIALY (IN)
      C      ROEF - DENSITY OF FIN MATERIAL (LBM/CU IN)
120      C      STANFT- FIN THICKNESS LIMITS FOUND COMMERCIALY (IN)
      C
      C      REAL NTUB
      C
      LOGICAL FIRST, FXTMP
125      COMMON
      C      $ AFTR, ALPHA
      C      $ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP
      C      $ CBU, CTURB, CDANG, CLUVR, CHAILE, CVM
      C      $ DANGIE, DFIN, DEEPL, DESVEL
130      C      $ DEFF
      C      $ FOR, FIRST, FIXL, FODS, FFHX, FXTMP
      C      $ GIEFF
      C      $ HXNP, HPOST
      C      $ ITMAX, ITMIN
135      C      $ JCONC
      C      $ KCONV, KALEXT
      C      $ KXEXT
      C      $ NTUCAL(2), NTA
      C      COMMON
140      C      $ ODR
      C      $ RSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      C      $ POH9AF, POH9AN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
      C      $ QREU, QREDUCE
      C      $ R3P, REDUCE, ROOFL, RFIX
145      C      $ SIGMA, SAAF
      C      $ TD, TPO(4), TEFF, TLIM, THFIN, TLPA, TFIX
      C      $ TCD, TW
      C      $ UCS, UWS
      C      $ VAS(5)
150      C      $ WPM
      C      $ XDEP, XW, XD
      C      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      C      $ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPW,
155      C      $ FPMW, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
      C      $ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
      C      $ SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
      C      $ R22, NNP, TCOS, DELPA, DELPWT, DELPWC, CONRAS, XNTSX, VELDX
      C      $ TLAX, UCON, PACST, FMCST, FBACC, EFFC, CH, CA, CS
160      C      $ CLTC, OFC, CPCC, FITCO, CSC, CERRCP, DELPIR, ACT, CLUCST
      C      $ CAPST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTTUR, ADIA, ABLN
      C      $ WTHOR, WIFR, STRUC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU
      C      $ AIRFF, WATERF, XNMOD, TOTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      C      $ ACTBRD, ADUBPD, ACTVH, ADUVH, ADUPPF, THPAIR, TCTF, AFCST
165      C      $ CSRA, WATERW, WSTRT, CFUND, HUSDA, TOWLEN, NUMTOW, CTOWD
      C      $ ATUB, CSTLVR, CSHS, CYLRNG, CFANEL
      C      COMMON /DUB/ DI, XDG, SF
      C      COMMON /PLCOST/ WPL
      C      COMMON /FLSW/ FXTLNG
      C      COMMON /SCALER/ HRFAC1, ATUB, CPERA, SSCD, PLANC1, CASS1, GAIR, FAIR,
170      C      $ HPAIR, HPWAT, WLRTD
      C      COMMON /HEADEX/ CHH, CN, CHM, CMW, CRJ, CWJ, CST, CMO, CSR, CSM, PITCHF, CPM,

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530      C      TABLE V
      C      HEADER FABRICATION COSTS
      C
      DATA HEDTY / "WELD REMOV", "WELD PLUG ", "FORM REMOV",
      C      "FORM PLUG " /
      C      DATA (HEDMA(I),I=1,3)/"STEEL" "ALUMINUM" "GALVANIZED"/
535      DATA ROER / .234, .09751, .284/
      DATA CUMAT / .53, 1.3, .57/
      DATA CHC / 1.05, 1.00, 0.95, 0.90 /

540      C      TABLE VI
      C      TUBING LENGTH PENALTIES
      C
      C      FOR COPPER ALLOYS
      DATA (FF(1,J),J=1,6)/ 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
      DATA (FF(2,J),J=1,6)/ 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
545      DATA (FF(3,J),J=1,6)/ 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /
      DATA (FF(4,J),J=1,6)/ 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /

      C      FOR ALUMINUM
      DATA (FF(5,J),J=1,6)/ 1.00, 1.05, 1.10, 1.14, 1.18, 1.22 /
550      C      FOR STEEL
      DATA (FF(6,J),J=1,6)/ 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /
      DATA (FF(7,J),J=1,6)/ 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /

555      C      FOR STAINLESS STEEL
      DATA (FF(8,J),J=1,6)/ 1.00, 1.00, 1.04, 1.08, 1.12, 1.16 /

      C      DEFINING THE TYPE OF TUBING UNDER CONSIDERATION

560      IF (.NOT. FIRST) GOTO 55
      DO 10 J=1,3
      ITUBMA = J
      IF (TUBMAT .EQ. TUBMA(I)) GO TO 15
10  CONTINUE
565      PRINT 11
      STOP
11  FORMAT(5X,"NO MATCH FOR LINER MATERIAL")
15  DO 20 I=1,13
      IGAGLI = J
570      IF (ABS(GAGLIN-GAGLI(J)).LT..001) GOTO 25
20  CONTINUE
      PRINT 21
21  FORMAT(5X,"NO MATCH FOR LINER GAGE")
      STOP
575      DO 30 K=1,6
      IFINTY = K
      IF (FINTYP .EQ. FINTY(K)) GO TO 35
30  CONTINUE
      PRINT 31
580      31  FORMAT(5X,"NO MATCH FOR TYPE OF FIN")
35  DO 40 L=1,2
      IFINMA = L
      IF (FINMAT .EQ. FINMA(L)) GO TO 45
585      40  CONTINUE
      PRINT 41

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```

41 FORMAT(5X,"NO MATCH FOR FIN MATERIAL")
45 DO 50 I=1,6
   IDLJN = I
   IF (IDL.EQ. ODLINE(I)) GO TO 55
50 CONTINUE
   PRINT *
51 FORMAT(5X,"NO MATCH FOR OUTSIDE DIAMETER OF LINER")
   STOP
55 CONTINUE
   IF (FIRST) GOTO 59

C
C***** FINNED TUBE COSTS
C
C      LINER TUBING COSTS
C
300 C      WL = 37.69911*ROEL(ITUBMA)*(ODL-THKLIN(IGAGLI))*THKLIN(IGAGLI)
C
C      LI=6
C      DO 57 I=3,8
C      IF (ELEND.GE.(10*I)) LI=I-2
57 CONTINUE
   F=FF(ITUBMA,LI)
   ADDER=0.0
   IF (ITUBMA.LT.5) ADDER = F
   IF (ITUBMA.LT.5) FF=1.0
310 CLTC = (CLM(ITUBMA) * WL + CLM(ITUBMA)) * F + ADDER
   PCF = 1.10
   CLTC = CLTC*PCF

C
C      FINNING COSTS
C
315 C      59 PF = 1. / (SF + THFIN)
C      GO TO (60,70,80,90,100,110) IFINTY

C
C      FIN WEIGHTS
C
320 C      STRAIGHT FIN
C
60 ODR=ODL
   HF=(ODFIN-ODR)/2.0
   WF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
   GO TO 120

C
C      FOOTED FIN
C
330 C      70 ODR=ODL + 2.*THFIN
C      HF=(ODFIN-ODR)/2.0
C      WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
C      WF = WSF*(SF-1./PF)*WSF/HF
C      GO TO 120

C
C      DOUBLE FOOTED FIN
C
335 C      80 ODR=ODL + 4.*THFIN
C      HF=(ODFIN-ODR)/2.0
C      WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
C      WF = WSF*(SF-2./PF)*WSF/HF
340 C      GO TO 120

C
C      EMBEDDED FIN

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90 ODR=ODI
   HF=(DFIN-ODR)/2.0
345   WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
      WF = 0.54*WSF
      GOTO 120

C
C      EXTRUDED FINS
350 100 CONTINUE
      TR = 0.035
      ODR=ODI + 2.*TR
      HF=(DFIN-ODR)/2.
      IPF = PF+1
355      TM = 0.016
      IF (IPF .LT. 11) TM = 0.018
      IF (IPF .LT. 10) TM = 0.019
      IF (IPF .LT. 9) TM = 0.020
      IF (IPF .LT. 8) TM = 0.021
360      IF (IPF .LT. 7) TM = 0.022
      IF (IPF .LT. 6) TM = 0.023
      WF=37.69911*ROEF(IFINMA)*(THFIN*PF*HF*(ODR+HF)+(ODL*TR)*TR)
      GO TO 120

C
C      PLATE FINS
365 110 ODR=ODL+2.*THFIN
      IF (IFINTY .EQ. 6) GO TO 120
      IF (HF .GT. MAXFH(ODLIN,IFINTY,IFINMA)) PRINT 115
370 115 FORMAT(5X,"HEIGHT OF FIN IS LARGER THAN THE MAXIMUM ALLOWABLE VALU
      *E")
      IF (THFIN .LT. STANFT(ODLIN,IFINTY,1)) PRINT 116
375 116 FORMAT(5X,"FIN THICKNESS IS LESS THAN THE SPECIFIED LIMIT")
      IF (THFIN .GT. STANFT(ODLIN,IFINTY,2)) PRINT 117
      IF (PF .LT. FPL(ODLIN,IFINTY,IFINMA)) PRINT 118
      IF (PF .GT. FPH(ODLIN,IFINTY,IFINMA)) PRINT 119
380 119 FORMAT(5X,"FIN PITCH IS GREATER THAN THE SPECIFIED LIMIT")
      APLATE = KW*XD
      WF=37.69911*ROEF(IFINMA)*(APLATE*THFIN*PF+3.14159*ODR*THFIN)
385 120 AB = 37.69911*ODL*PF*THFIN
      IF (FIRST) GO TO 125

C
C      COST OF BONDING THE FIN TO THE TUBING - IF THERE IS NO
390 BONDING TO BE DONE, CFB SHOULD BE EQUAL TO ZERO
C
C      CFC = CFM(IFINTY,IFINMA)*WF+(CF(IFINTY)+CFB*AB)
C
C      PROTECTIVE COATING COSTS
395 IF A PROTECTIVE COATING IS NOT WANTED, COATC IS SET
      EQUAL TO ZERO IN THE INPUT
C
      AS = APTOT * ELENG * Z * NW
      CPCC = COATC*AS
C
C      COST OF THE TUBING AND FINS PER FOOT
      FITOT = CLTC+CFC+CPCC

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700      C
      C***** TUBE SPACER COSTS
      C
      CSC = ZINCC * 0.1 * (XW**2 - ODR**2) * CASTC
705      C***** END PREPARATION COSTS
      C
      CEPREP = ECPREDC
710      C***** TOTAL COOLING SURFACE COSTS
      C
      CS = ZINCC*(FITCO+ELENG+CSC*((ELENG**5*SS)/SS)+CEPREP)
      CS = CS * PDHRAF
715      C
      C      OFFERING THE CASE FOR THE HEADER
      C
      125 IF (.NOT. FIRST) GOTO 145
      DO 130 I=1,4
      IHEDTY = I
      IF (HEDTYP.EQ. IHEDTY(I)) GO TO 135
720      130 CONTINUE
      PRINT 131
      STOP
      131 FORMAT(5X,"NO MATCH FOR HEADER TYPE")
      135 DO 140 I=1,3
      IHEDMA = I
      IF (HEDMAT.EQ. IHEDMA(I)) GOTO 142
725      140 CONTINUE
      PRINT 141
      STOP
      141 FORMAT(5X,"NO MATCH FOR HEADER MATERIAL")
730      142 FIRST=.FALSE.
      RETURN
      C
      C***** HEADER AND NOZZEL COSTS
735      C
      145 DI=ODL-2.*THKLIN(TGAGLT)
      C
      C      NUMBER OF BUNDLES IN COOLING TOWERS
      XNRJ1 = NW*XW/(12.0*WB)
      XNRJ2 = XNRJ1/4.0
740      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
      FB=1.00
      FA = .785398*DI*DI*HEDTUB/HXNP
745      C
      C      HEADER DEPTH AND WIDTH
      HD = X1 * (Z/HXNP) + 1.0
      HW = FA / (2.0 * HD) + 2.0
      F1 = 2.0 * HXND * HXNP * HD / 10.0
      F2 = 2.0 * HXND*FA/(20.0*HD)
      IF (IHEDTY.EQ.1.OR. IHEDTY.EQ.2) FACT=2.*F1+4.
750      IF (IHEDTY.EQ.3.OR. IHEDTY.EQ.4) FACT=2.*F1
755      C

```


C COST OF HEADERS

C

460 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*CMW*(H*HD+HD/12.*WB)
 ICHH=(24.0*ABC+7*WB/XW)+4.0*CN*SQRT(FA/3.14159))*XNBUN*FP
 CH=CH*POHBAF
 465 IF(WB.GT.14.0) PRINT 150
 150 FORMAT(5X,"THE SPECIFIED HEADER LENGTH IS BEYOND THE PRACTICAL LIM
 +IT")

C

C***** BUNDLE ASSEMBLY AND FRAME COSTS

C

470 CA=HEDTUB*(CRJ+CWJ)+CST*ELEN3*(86.+2.*WB)
 CA=CA*XNBUN*POHBAF

C

C***** WEIGHT OF HEAT EXCHANGER

C

475 MATERIAL TUBE WEIGHT OF THE COOLING TOWER
 WTTUB=Z*NW*ELEN3*(WL+WF)

C

C MATERIAL HEADER WEIGHT OF THE COOLING TOWER

C

480 WTHDR=ROEHM(IHEDMA)*(12.*WB*TW*(2.*F1*HD+(F2+2.)*HW)+
 \$ F1*FA*TW)*XNBUN

C

C TOTAL FRAME WEIGHT OF THE HEAT EXCHANGER

C

485 WTFRM=20.*ELEN3*(2.*WB/(2.*SS))*SQRT(Z/6.)*XNBUN

C

C TOTAL WEIGHT OF WATER IN THE HEAT EXCHANGER

C

490 TURVOL=Z*NW*ELEN3*3.14159*DI*DI/(144.0*4.0)
 HEDVOL=2.0*HXNP*HD*HW*WB/144.*XNBUN
 WATERV=(TURVOL+HEDVOL)*62.4

C

C WEIGHT OF THE HEAT EXCHANGER

C

WHX=WTTUB+WTHDR+WTFRM

C

C***** TOTAL COST OF THE HEAT EXCHANGER

C

495 PSECF=1.12
 CHX=PSECF*(CA+CH+CS)
 RETURN
 END

SUBROUTINE FAN (OPT=1)

```

C
C
C
5 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
C      1. BLADE DIAMETER
C      2. HUB DIAMETER
C      3. NUMBER OF BLADES PER FAN
C      4. BLADE ANGLE
10 C
C      KNOWING THE NUMBER OF FANS AND THE PACKING FACTOR OF THE
C      FANS, THE CIRCULAR 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.
15 C
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 FANDAR CONTAINS THE FOLLOWING INFORMATION-
20 C
C      FANDAR(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)
25 C      J=7 - UPPER 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
30 C      PERFORMANCE POINT
C      THE DATA ARRAY FANDARH CONTAINS THE FOLLOWING INFORMATION-
C      FANDARH(I,J)
C      J=1,5 - COEFFICIENTS FOR FOURTH ORDER CURVE FIT OF
C      HORSEPOWER VERSUS VOLUMETRIC FLOW RATE
35 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)
40 C      J=9 - NUMBER OF BLADES PER FAN
C      J=10 - BLADE ANGLE (DEGREES)
C
C
C
45 C      DEFINITION OF VARIABLES
C      A - AIR FLOW AREA OF THE FAN (SQ FT)
C      ANLN - NUMBER OF FAN BLADES (DIMENSIONLESS)
C      ADIA - FAN DIAMETER (FT)
C      ANFCOS - ANNUAL FAN COSTS ($)
50 C      ANSEPC - ANNUAL CAPITAL COST OF PLENUM, FOUNDATION, AND
C      STRUCTURES ($)
C      ANSEPCF - 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
55 C      (PERCENT)
C      CHANG - COSINE OF THE ANGLE FOR THE DELTA HEAT EXCHANGER
C      ARRANGEMENT (DIMENSIONLESS)

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C
C
60 C      CFM      - ESTIMATE OF THE VOLUMETRIC FLOW RATE OF AIR THROUGH
C      EACH FAN (CU FT/MIN)
C
C      CEPOS     - FAN STACK COSTS WITH AND WITHOUT VELOCITY RECOVERY
C      ($)
C
C      CT       - CONVERGENCE PARAMETER FOR THE VOLUMETRIC FLOW RATE
C      THROUGH EACH FAN (DIMENSIONLESS)
C
65 C      CINC     - INCREMENTAL VOLUMETRIC FLOW RATE OF AIR USED IN
C      DETERMINING THE FAN PERFORMANCE POINT (CU FT/MIN)
C
C      COT      - COST OF FAN MOTORS PER FAN ($)
C
C      CPL      - COST OF PLENUM FOR THE ENTIRE TOWER SYSTEM ($)
C
C      CPM      - COST OF PLENUM MATERIAL ($/LBM)
C
C      CCR      - COST OF THE SPEED REDUCER ($)
C
70 C      CVM      - FAN RING MATERIAL UNIT COST ($/LBF)
C
C      DIST     - DISTANCE FROM THE CONDENSER ROOM TO THE FIRST
C      CIRCULAR TOWER (FT)
C
C      DPTINH   - PRESSURE DROP ACROSS THE HEAT EXCHANGER (IN H2O)
C
C      DCGTH    - DISTANCE FROM THE SWITCH GEAR TO THE MOTOR (FT)
C
75 C      DTON     - DIAMETER OF THE CIRCULAR TOWERS (FT)
C
C      DTSG     - DISTANCE FROM THE TOWER TO THE SWITCH GEAR (FT)
C
C      EPCSF    - ESCALATION FACTOR FOR FAN COST (DIMENSIONLESS)
C
C      EPR      - HEAT RATE OF PLANT (BTU/KW-HR)
C
C      ELENG    - LENGTH OF HEAT EXCHANGER TUBES (FT)
C
80 C      ELELEV   - PLANT ELEVATION FROM SEA LEVEL (FT)
C
C      FMD      - FAN DIAMETER (FT)
C
C      FEMLEC   - ELECTRICAL WIRING COSTS FOR THE FAN SYSTEM ($)
C
C      FADS     - PLANT FUEL COST (CENTS/MMBTU)
C
C      FCR      - FIXED CHARGE RATE ON CAPITAL FOR ONE
C      YEAR (FRACTIONAL)
C
85 C      FCST     - CAPITAL COST OF THE FAN ($)
C
C      FMC      - FAN MOTOR COST PER HORSEPOWER FOR MOTORS OF SMALL
C      HORSEPOWER ($/HP)
C
C      FMDG     - FOUNDATION COSTS FOR THE CIRCULAR TOWERS ($)
C
90 C      FROW     - POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
C
C      GREFF    - GEAR BOX EFFICIENCY OF THE FAN SYSTEM (PERCENT)
C
C      HCR      - HEIGHT OF THE FAN RING (FT)
C
C      HPAIR    - HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
C
95 C      HPEF    - HORSEPOWER REQUIREMENTS OF EACH FAN (HP)
C
C      HUBDIA   - DIAMETER OF THE FAN HUB (FT)
C
C      I        - PERFORMANCE POINT OF A FAN (DIMENSIONLESS)
C
C      ITMAX    - MAXIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
C      (DIMENSIONLESS)
C
100 C      ITMIN   - MINIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
C      (DIMENSIONLESS)
C
C      ITOWN    - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C
C      LAF,LFE  - VARIABLES USED IN SPECIFYING WHICH FANS ARE TO BE
C      CONSIDERED FOR USE IN THE FAN SYSTEM
C      (DIMENSIONLESS)
C
105 C      Nof     - NUMBER OF FANS MAKING UP THE FAN SYSTEM
C      (DIMENSIONLESS)
C
C      PFACT    - PACKING FACTOR, RATIO OF CIRCULAR TOWER ROOF AREA
C      TO FAN SWEEP AREA (DIMENSIONLESS)
C
110 C      PANC    - BASE PLANT COSTS ($/KW)
C
C      POHFAN   - INDIRECT COST FACTOR FOR FANS (DECIMAL)
C
C      POHSTC   - INDIRECT COST FACTOR FOR CIRCULAR TOWER STRUCTURES
C      (DECIMAL)
C
C      ROOFL    - CIRCULAR TOWER ROOF LOAD (LBF/SQ FT)

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115      C      SAAF - SHIPPING AND ASSEMBLY FACTOR (DECIMAL)
      C      SSVOL - SPECIFIC VOLUME OF THE AIR EXITING THE HEAT
      C              EXCHANGER (LBM/CU FT)
      C      STRUCO - CIRCULAR TOWER STRUCTURE COST ($)
120      C      TAN19 - TANGENT OF 19 DEGREES TO BE USED IN COSTING OF
      C              ENTRY BELL TO THE FAN (DECIMAL)
      C      TAN 8 - TANGENT OF 8 DEGREES TO BE USED IN COSTING OF EXIT
      C              STACK FROM THE FAN (DECIMAL)
      C      TCOSTF - TOTAL COST OF THE FAN SYSTEM ($)
      C      TCSTPF - TOTAL COST OF A FAN ($)
125      C      TOTCFM - TOTAL VOLUMETRIC FLOW RATE FOR THE AIR THROUGH
      C              THE FAN SYSTEM (CU FT/MIN)
      C      TOTHP - TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM (HP)
      C      TP - TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN (IN H2O)
      C      TA - AIR EXIT TEMPERATURE FROM THE HEAT EXCHANGER
130      C              (DEG F)
      C      UBS - UNIT COST OF THE STACK ($/LBF)
      C      UWS - UNIT WEIGHT OF THE STACK (LBF/CU FT)
      C      VEL - AVERAGE VELOCITY OF THE AIR LEAVING THE FAN
      C              (FT/SEC)
135      C      VELREC - SPECIFIES WHETHER VELOCITY RECOVERY STACKS ARE
      C              GOING TO BE USED OR NOT (DIMENSIONLESS)
      C      VFR - NON RECOVERABLE AIR VELOCITY HEAT EXITING THE FAN
      C              (IN H2O)
      C      WATERM - WEIGHT OF WATER IN THE HEAT EXCHANGER TUBES AND
140      C              BUNDLES (LBF)
      C      WEFV - UNIT WEIGHT OF THE ENTRY BELL (LBF/SQ FT)
      C      WHEX - WEIGHT OF THE HEAT EXCHANGER (LBF)
      C      WIDTH - WIDTH OF THE HEAT EXCHANGER (FT)
      C      WPL - WEIGHT OF THE PLENUM MATERIAL (LBF/ SQ FT)
145      C      WA - MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER
      C              (LBM/HR)
      C      XNFAN - NUMBER OF FANS (DIMENSIONLESS)

      REAL NOF
150      COMMON/FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF,FCOPF,P2,R,S,
      $VELREC,AFQ,ELEV,FHP
      LOGICAL FIRST, EXTEMP
      COMMON
155      $ APTP, ALPHA
      $ CAPF, C5SPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAP
      $ CBJ, CTURB, CDANG, CLUVR, CHA1LS, CVM
      $ DANGLE, DFIH, DEEPL, DESVEL
      $ FEED
160      $ FCR, FIRST, FIXL, FCOS, FFHX, EXTEMP
      $ GREEF
      $ HXNP, HPCST
      $ ITMAX, ITMIN
      $ JCONC
165      $ KCONV, KALEXT
      $ MXEXT
      $ NUCAL(2), NTA
      COMMON
      $ ONP
170      $ PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      $ POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLI
      $ QREU, QREDUCE

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$ ,QBP, REDUCE, ROOFL, RFIX
$ ,SIGMA, SIAF
775 $ ,TD, TPO(4), TEFF, TLIM, THEIN, TLPRA, TFIX
$ ,TCD, TW
$ ,UCS, UWS
$ ,VAS(5)
$ ,WFM
780 $ ,XDEPA, XW, XD
COMMON /SUPPLY/ VAL(5), CPLV, CPIP, CCOS, W3, COSM, EFF,
$ ,QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, POW,
$ ,SPCW, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
$ ,REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
785 $ ,SPC, PTOTAL, PLANC3, SAIRON, AIR, YFP, SPCN, PSIZ13, WT2,
$ ,RP2, RW2, TCOS, DELTA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX
$ ,TLAX, UCON, PMOST, FMCST, FBACC, EFFC, CH, CA, CS
$ ,CLTC, CFC, CPOC, FITC, CSC, CEPRE, DELPIP, AST, OLOCST
$ ,CAPOST, KVELN, RLDRNG, CPLEV, DPFL, WHX, ATTUR, ADIA, ABLN
790 $ ,VTHRP, WIFRM, STRUCC, CEPRE, HPRERF, TOTCF, TPC, EFFIN, ANTI
$ ,AIRFF, WATFF, XNMOD, TOTPF, FDCPF, FMTRC, ACCITP, ADJTP
$ ,ACTHPD, ADJHPD, ACTVH, ADJVVH, ADJPPF, THAIR, TCTF, AFCST
$ ,CSRD, WATERW, WSTRICT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
$ ,ATURC, CSTLVR, CSTHS, CYLRNG, CFANEL
795 COMMON /SCALER/ HRFAC1, ATUB, CPERA, SSCD, PLANC1, CASSS1,
$ ,GATR, FATP, HPAIR, HPWAT, PLANC1
COMMON /HEADAX/ CHH, CN, CHM, CMW, CRU, CWJ, CST, CVO, CSR, CSM, PITCHF, CPM,
EXPRESS, HEDMAT, HEDTYP, NPASS, WA
COMMON /ENVELOP/ LFB, LFE
800 COMMON /PLCOST/ WPL
COMMON /INDIS/ DIST
COMMON /PME/ PMELEC
DATA (FANDAP( 1,J),J=1,10) /
$ ,7.751 , ,.6320 , ,-.6.316 , ,11.944 , ,-.8.252 , ,
805 $ ,.19 , ,.625 , ,24. , ,5. , ,5. /
DATA (FANDAP( 2,J),J=1,10) /
$ ,1.249 , ,-.9172 , ,-.1262 , ,.2533 , ,-.2331 , ,
$ ,.23 , ,.765 , ,24. , ,5. , ,8. /
DATA (FANDAP( 3,J),J=1,10) /
810 $ ,1.346 , ,-.1.635 , ,1.685 , ,-.1.666 , ,.5396 , ,
$ ,.31 , ,.91 , ,24. , ,5. , ,10. /
DATA (FANDAP( 4,J),J=1,10) /
$ ,.5643 , ,4.692 , ,-.14.335 , ,15.960 , ,-.6.562 , ,
$ ,.365 , ,.94 , ,24. , ,5. , ,12. /
DATA (FANDAP( 5,J),J=1,10) /
815 $ ,.4015 , ,.6.037 , ,-.16.629 , ,17.327 , ,-.6.713 , ,
$ ,.47 , ,.90 , ,24. , ,5. , ,14. /
DATA (FANDAP( 6,J),J=1,10) /
$ ,1.337 , ,.9316 , ,-.4.656 , ,5.368 , ,-.2.424 , ,
$ ,.477 , ,.95 , ,24. , ,5. , ,16. /
DATA (FANDAP( 7,J),J=1,10) /
820 $ ,-.3.076 , ,26.409 , ,-.57.905 , ,54.456 , ,-.19.577 , ,
$ ,.532 , ,1.01 , ,24. , ,5. , ,18. /
DATA (FANDAP( 8,J),J=1,10) /
$ ,1.226 , ,3.429 , ,-.11.905 , ,12.904 , ,-.5.363 , ,
825 $ ,.605 , ,.98 , ,24. , ,5. , ,20. /
DATA (FANDAP( 9,J),J=1,10) /
$ ,-.17.189 , ,96.0 , ,-.182.414 , ,152.343 , ,-.47.879 , ,
$ ,.69 , ,1.015 , ,24. , ,5. , ,22. /

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530      DATA (FANDAP( 10,J),J=1,10) /
$ .9109      ,-.6216      ,-.0575      ,.09596      ,-.0758      ,
$ .275      ,.795      , 24.      , 8.      , 5. /
      DATA (FANDAP( 11,J),J=1,10) /
$ 1.069      ,-.7222      ,.0581      ,.0394      ,-.0675      ,
$ .264      ,-.949      , 24.      , 9.      , 8. /
535      DATA (FANDAP( 12,J),J=1,10) /
$ 1.194      ,-.6306      ,-.0933      ,.01957      ,-.00947      ,
$ .327      ,.138      , 24.      , 8.      , 10. /
      DATA (FANDAP( 13,J),J=1,10) /
540      $ 1.442      ,-.1399      ,.1550      ,-.1413      ,.4354      ,
$ .393      ,.112      , 24.      , 8.      , 12. /
      DATA (FANDAP( 14,J),J=1,10) /
$ .4597      ,.4639      ,-.10373      ,.8728      ,-.2718      ,
$ .445      ,.121      , 24.      , 8.      , 14. /
      DATA (FANDAP( 15,J),J=1,10) /
545      $ 1.533      ,-.5932      ,-.5343      ,.5505      ,-.3261      ,
$ .529      ,.114      , 24.      , 9.      , 16. /
      DATA (FANDAP( 16,J),J=1,10) /
$ .244      ,.7202      ,-.14895      ,.12133      ,-.3683      ,
$ .612      ,.125      , 24.      , 8.      , 18. /
550      DATA (FANDAP( 17,J),J=1,10) /
$ 2.321      ,-.2232      ,.1862      ,-.7451      ,-.0714      ,
$ .694      ,.115      , 24.      , 9.      , 20. /
      DATA (FANDAP( 18,J),J=1,10) /
555      $ -12.148      ,.5565      ,-.83947      ,.55657      ,-.13939      ,
$ .755      ,.124      , 24.      , 9.      , 22. /
      DATA (FANDAP( 19,J),J=1,10) /
$ .8525      ,-.2121      ,-.6814      ,.5934      ,-.1994      ,
$ .214      ,.95      , 24.      , 10.      , -5. /
560      DATA (FANDAP( 20,J),J=1,10) /
$ 1.307      ,-.2057      ,.3129      ,-.2750      ,.8715      ,
$ .275      ,.116      , 24.      , 10.      , 8. /
      DATA (FANDAP( 21,J),J=1,10) /
565      $ 1.140      ,-.3050      ,-.4077      ,.2543      ,-.0612      ,
$ .34      ,.1365      , 24.      , 10.      , 10. /
      DATA (FANDAP( 22,J),J=1,10) /
$ 1.511      ,-.1516      ,-.5855      ,.3418      ,-.07576      ,
$ .397      ,.134      , 24.      , 10.      , 12. /
570      DATA (FANDAP( 23,J),J=1,10) /
$ 1.247      ,.0813      ,-.6502      ,.1965      ,-.01156      ,
$ .455      ,.14      , 24.      , 10.      , 14. /
      DATA (FANDAP( 24,J),J=1,10) /
$ 1.214      ,-.5641      ,-.1534      ,.8592      ,-.1909      ,
$ .55      ,.137      , 24.      , 10.      , 16. /
575      DATA (FANDAP( 25,J),J=1,10) /
$ .5157      ,.4363      ,-.75248      ,.4951      ,-.1231      ,
$ .652      ,.155      , 24.      , 10.      , 18. /
      DATA (FANDAP( 26,J),J=1,10) /
$ -.075      ,.6982      ,-.10753      ,.5933      ,-.1667      ,
$ .745      ,.144      , 24.      , 10.      , 20. /
580      DATA (FANDAP( 27,J),J=1,10) /
$ -158.095      ,.54834      ,-.65902      ,.35092      ,-.69909      ,
$ 1.02      ,.149      , 24.      , 10.      , 22. /
      DATA (FANDAP( 28,J),J=1,10) /
585      $ 1.090      ,-.1005      ,.2432      ,.1717      ,-.1515      ,
$ .205      ,.55      , 26.      , 6.      , 6. /

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      DATA (FANDAP( 29,J),J=1,10) /
      $ 1.144      ,-.0621      , -3.590      , 6.245      , -4.382      ,
      $ .248      , .56      , 26.      , 5.      , 8.      /
290      DATA (FANDAP( 30,J),J=1,10) /
      $ 1.196      ,.1327      , -2.291      , 1.492      , -.2797      ,
      $ .205      ,.773      , 26.      , 5.      , 10.      /
      DATA (FANDAP( 31,J),J=1,10) /
      $ 1.576      , -1.413      , -1.077      , -.8904      , -.2331      ,
      $ .35      ,.34      , 26.      , 5.      , 12.      /
295      DATA (FANDAP( 32,J),J=1,10) /
      $ -.3974      ,13.678      , -38.403      , 44.263      , -19.254      ,
      $ .41      ,.87      , 26.      , 5.      , 14.      /
      DATA (FANDAP( 33,J),J=1,10) /
      $ 2.497      , -4.479      , 5.789      , -2.571      , -1.061      ,
      $ .466      ,.85      , 26.      , 6.      , 16.      /
300      DATA (FANDAP( 34,J),J=1,10) /
      $ -31.543      ,200.29      , -450.42      , 445.5      , -164.67      ,
      $ .525      ,.86      , 26.      , 5.      , 18.      /
      DATA (FANDAP( 35,J),J=1,10) /
305      $ 37.926      ,229.06      , -493.08      , 468.48      , -166.93      ,
      $ .585      ,.88      , 26.      , 6.      , 20.      /
      DATA (FANDAP( 36,J),J=1,10) /
      $ 199.88      , -940.76      , 1563.3      , -1295.9      , 373.75      ,
      $ .65      ,.90      , 26.      , 6.      , 22.      /
310      DATA (FANDAP( 37,J),J=1,10) /
      $ 1.156      , -1.456      , 2.750      , -4.222      , 1.818      ,
      $ .22      ,.55      , 26.      , 8.      , 6.      /
      DATA (FANDAP( 38,J),J=1,10) /
      $ 1.178      , -.1032      , -2.070      , 3.033      , -1.935      ,
315      $ .275      ,.755      , 26.      , 8.      , 8.      /
      DATA (FANDAP( 39,J),J=1,10) /
      $ 1.431      , -.0674      , .04504      , .5361      , -.5993      ,
      $ .333      ,.885      , 26.      , 8.      , 10.      /
      DATA (FANDAP( 40,J),J=1,10) /
320      $ 1.330      ,.5823      , -3.195      , 3.499      , -1.643      ,
      $ .29      ,.95      , 26.      , 8.      , 12.      /
      DATA (FANDAP( 41,J),J=1,10) /
      $ .8602      ,3.768      , -8.974      , 7.814      , -2.788      ,
325      $ .45      ,1.683      , 26.      , 8.      , 14.      /
      DATA (FANDAP( 42,J),J=1,10) /
      $ 1.329      , -.6431      , -.5585      , .9619      , -.6973      ,
      $ .518      ,1.03      , 26.      , 8.      , 16.      /
      DATA (FANDAP( 43,J),J=1,10) /
      $ -6.904      ,44.985      , -87.056      , 72.668      , -22.435      ,
330      $ .526      ,1.14      , 26.      , 8.      , 18.      /
      DATA (FANDAP( 44,J),J=1,10) /
      $ -13.827      ,76.312      , -138.97      , 111.051      , -33.333      ,
      $ .65      ,1.05      , 26.      , 8.      , 20.      /
      DATA (FANDAP( 45,J),J=1,10) /
335      $ -14.567      ,68.914      , -108.52      , 75.63      , -20.6      ,
      $ .74      ,1.125      , 26.      , 8.      , 22.      /
      DATA (FANDAP( 46,J),J=1,10) /
      $ 1.084      , -.5941      , .3743      , -.6713      , .2033      ,
      $ .23      ,.78      , 26.      , 11.      , 6.      /
340      DATA (FANDAP( 47,J),J=1,10) /
      $ 1.284      , -.9283      , .9886      , -1.0606      , .303      ,
      $ .29      ,.98      , 26.      , 11.      , 8.      /

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      DATA (FANDAP( 48,J),J=1,10) /
345  $ 1.320 ,-.09005 , -1.233 , 1.396 , -.6345 ,
      $ .365 , 1.15 , 26. , 11. , 10. /
      DATA (FANDAP( 49,J),J=1,10) /
      $ 1.385 ,.3155 , -1.953 , 1.880 , -.7164 ,
      $ .415 , 1.28 , 26. , 11. , 12. /
      DATA (FANDAP( 50,J),J=1,10) /
350  $ 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. /
355  DATA (FANDAP( 52,J),J=1,10) /
      $ -6.278 ,.34.035 , -53.2555 , 35.676 , -.8.8459 ,
      $ .65 , 1.525 , 26. , 11. , 18. /
      DATA (FANDAP( 53,J),J=1,10) /
      $ -25.743 ,103.427 , -144.937 , 99.296 , -20.622 ,
360  $ .75 , 1.39 , 26. , 11. , 20. /
      DATA (FANDAP( 54,J),J=1,10) /
      $ -67.904 ,225.823 , -273.144 , 146.373 , -29.455 ,
      $ 1.11 , 1.46 , 26. , 11. , 22. /
      DATA (FANDAP( 55,J),J=1,10) /
365  $ 1.141 ,-.331 , -1.453 , -1.591 , 2.453 ,
      $ .12 , .54 , 28. , 6. , 6. /
      DATA (FANDAP( 56,J),J=1,10) /
      $ 1.045 ,.5.745 , -16.374 , 30.038 , -20.517 ,
      $ .23 , .63 , 28. , 6. , 8. /
370  DATA (FANDAP( 57,J),J=1,10) /
      $ .0281 ,.5.303 , -23.573 , 36.246 , -20.781 ,
      $ .28 , .71 , 28. , 6. , 10. /
      DATA (FANDAP( 58,J),J=1,10) /
375  $ 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 , -64.632 ,
      $ .39 , .78 , 28. , 6. , 14. /
380  DATA (FANDAP( 60,J),J=1,10) /
      $ -1.430 ,.26.222 , -79.047 , 102.926 , -50.00 ,
      $ .435 , .70 , 28. , 6. , 16. /
      DATA (FANDAP( 61,J),J=1,10) /
      $ -22.954 ,.167.722 , -422.785 , 467.638 , -193.335 ,
385  $ .46 , .785 , 26. , 6. , 18. /
      DATA (FANDAP( 62,J),J=1,10) /
      $ -4.125 ,.46.711 , -131.305 , 158.511 , -71.4578 ,
      $ .53 , .76 , 28. , 6. , 20. /
      DATA (FANDAP( 63,J),J=1,10) /
390  $ -38.262 ,.667.748 , -1365.6 , 1350.4 , -508.349 ,
      $ .55 , .79 , 22. , 6. , 22. /
      DATA (FANDAP( 64,J),J=1,10) /
      $ 1.149 ,-.0283 , -3.051 , 3.750 , -1.911 ,
      $ .20 , .67 , 28. , 6. , 6. /
395  DATA (FANDAP( 65,J),J=1,10) /
      $ 1.386 ,-.4003 , -2.450 , 3.275 , -1.665 ,
      $ .255 , .79 , 28. , 6. , 8. /
      DATA (FANDAP( 66,J),J=1,10) /
      $ 1.479 ,-.4131 , -8.8639 , -0.0806 , .3017 ,
      $ .3 , .9 , 28. , 8. , 10. /

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400      DATA (FANDAP( 67,J),J=1,10) /
$ 1.342      .1.115      , -5.959      , 9.507      , -4.848      ,
$ .35      .9      . 28.      , 9.      12. /
      DATA (FANDAP( 68,J),J=1,10) /
$ .4543      .9.663      , -26.857      , 28.991      , -11.655      ,
405      $ .44      .99      . 28.      , 8.      14. /
      DATA (FANDAP( 69,J),J=1,10) /
$ -.1495      .13.991      , -36.402      , 38.619      , -15.385      ,
$ .42      .94      . 28.      , 8.      16. /
      DATA (FANDAP( 70,J),J=1,10) /
410      $ -.1526      .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      , -56.07      ,
$ .6      .96      . 28.      , 8.      20. /
415      DATA (FANDAP( 72,J),J=1,10) /
$ -182.795      .850.555      , -1466.4      , 1121.9      , -321.933      ,
$ .8      .1.01      . 28.      , 8.      22. /
      DATA (FANDAP( 73,J),J=1,10) /
$ 1.907      .-8.155      , 26.542      , -39.870      , 20.833      ,
420      $ .203      .72      . 28.      , 9.      6. /
      DATA (FANDAP( 74,J),J=1,10) /
$ 1.707      .-2.471      , 5.482      , -7.257      , 3.078      ,
$ .3      .1.225      . 28.      , 9.      10. /
425      DATA (FANDAP( 75,J),J=1,10) /
$ -.3.471      .43.171      , -95.561      , 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. /
430      DATA (FANDAP( 77,J),J=1,10) /
$ -111.138      .485.02      , -778.16      , 553.442      , -147.595      ,
$ .67      .1.11      . 28.      , 9.      22. /
      DATA (FANDAP( 78,J),J=1,10) /
$ .9182      .-1.6397      , .1263      , -1.283      , 1.09      ,
435      $ .118      .54      . 28.      , 10.      2. /
      DATA (FANDAP( 79,J),J=1,10) /
$ 1.191      .-1.5515      , -.046      , -.974      , .6976      ,
$ .2      .8      . 28.      , 10.      6. /
440      DATA (FANDAP( 80,J),J=1,10) /
$ 1.478      .-1.2616      , -2.349      , 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. /
445      DATA (FANDAP( 82,J),J=1,10) /
$ -12.855      .75.341      , -141.915      , 115.921      , -35.119      ,
$ .58      .1.17      . 28.      , 10.      18. /
      DATA (FANDAP( 83,J),J=1,10) /
$ -131.140      .528.522      , -784.754      , 516.323      , -127.273      ,
450      $ .71      .1.21      . 28.      , 10.      22. /
      DATA (FANDAP( 84,J),J=1,10) /
$ .9394      .-1.6355      , .3495      , -1.169      , .7752      ,
$ .122      .64      . 28.      , 12.      2. /
455      DATA (FANDAP( 85,J),J=1,10) /
$ 1.205      .-1.51      , .1897      , -1.018      , .6163      ,
$ .216      .94      . 28.      , 12.      6. /

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      DATA (FANDAP( 86,J),J=1,10) /
$ 1.504      ,-.1562      , -1.506      ,1.699      , -.7334      ,
$ .33      ,1.2      , 28.      , 12.      , 10. /
260 DATA (FANDAP( 87,J),J=1,10) /
$ .6086      ,6.967      , -15.551      ,13.341      , -4.276      ,
$ .43      ,1.32      , 28.      , 12.      , 14. /
      DATA (FANDAP( 88,J),J=1,10) /
$ 1.227      ,4.415      , -9.275      ,7.309      , -2.178      ,
265 $ .62      ,1.44      , 28.      , 12.      , 18. /
      DATA (FANDAP( 89,J),J=1,10) /
$ 1.036      ,-.4416      , -6.142      ,15.126      , -14.698      ,
$ .12      ,.36      , 30.      , 8.      , 2. /
      DATA (FANDAP( 90,J),J=1,10) /
270 $ 2.034      , -5.828      ,13.159      , -16.404      ,6.562      ,
$ .22      ,.64      , 30.      , 8.      , 6. /
      DATA (FANDAP( 91,J),J=1,10) /
$ 1.109      ,6.519      , -25.233      ,35.842      , -18.721      ,
$ .32      ,.74      , 30.      , 8.      , 10. /
275 DATA (FANDAP( 92,J),J=1,10) /
$ -9.489      ,76.085      , -183.815      ,190.215      , -73.502      ,
$ .45      ,.85      , 30.      , 8.      , 14. /
      DATA (FANDAP( 93,J),J=1,10) /
$ -1009.5      ,5246.17      , -10188.02      ,8781.48      , -2936.03      ,
280 $ .7      ,.68      , 30.      , 8.      , 18. /
      DATA (FANDAP( 94,J),J=1,10) /
$ 5.7448      , -4.975      ,0.      ,0.      ,0.      ,
$ .83      ,.91      , 30.      , 8.      , 22. /
      DATA (FANDAP( 95,J),J=1,10) /
285 $ 1.055      ,-.7416      , -2.354      ,6.096      , -6.679      ,
$ .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. /
290 DATA (FANDAP( 97,J),J=1,10) /
$ .8192      ,9.050      , -26.526      ,29.287      , -12.093      ,
$ .34      ,.9      , 30.      , 10.      , 10. /
      DATA (FANDAP( 98,J),J=1,10) /
295 $ -9.716      ,71.057      , -157.855      ,150.679      , -53.458      ,
$ .45      ,1.0      , 30.      , 10.      , 14. /
      DATA (FANDAP( 99,J),J=1,10) /
$ -604.715      ,2299.6      , -3604.35      ,2507.84      , -706.956      ,
$ .32      ,1.045      , 30.      , 10.      , 18. /
300 DATA (FANDAP(100,J),J=1,10) /
$ -3515.6      ,13939.07      , -20703.7      ,13672.5      , -3395.42      ,
$ .97      ,1.08      , 30.      , 10.      , 22. /
      DATA (FANDAP(101,J),J=1,10) /
$ 1.075      ,-.0225      , -.3826      ,.4569      , -.8643      ,
$ .12      ,.44      , 30.      , 11.      , 2. /
305 DATA (FANDAP(102,J),J=1,10) /
$ 1.555      , -1.09      , -.4653      ,.5259      , -.2670      ,
$ .24      ,.765      , 30.      , 11.      , 6. /
      DATA (FANDAP(103,J),J=1,10) /
$ .9216      ,6.142      , -18.702      ,18.969      , -7.475      ,
310 $ .25      ,.96      , 30.      , 11.      , 10. /
      DATA (FANDAP(104,J),J=1,10) /
$ -18.274      ,109.641      , -219.930      ,188.787      , -60.351      ,
$ .575      ,1.07      , 30.      , 11.      , 14. /

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      DATA (FANDAP(105,J),J=1,10) /
E15  $ -3000.2 ,12053.9 , -18124.3 ,12095.4 , -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. /
E20  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 ,
E25  $ .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) /
E30  $ -14.005 ,83.329 , -160.549 ,132.786 , -40.673 ,
      $ .51 ,1.14 , 30. , 12. , 14. /
      DATA (FANDAP(111,J),J=1,10) /
      $ -4799.04 ,17939.56 , -25154.2 ,15654.5 , -3648.91 ,
      $ .978 ,1.19 , 30. , 12. , 18. /
E35  DATA (FANDAP(112,J),J=1,10) /
      $ 1.376 , -1865 , -15.958 ,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 ,
E40  $ .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) /
E45  $ -6.160 ,53.616 , -156.502 ,153.373 , -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. /
E50  DATA (FANDAP(117,J),J=1,10) /
      $ -191.805 ,955.903 , -1748.194 ,1419.53 , -433.33 ,
      $ .675 ,1.0 , 40. , 8. , 22. /
      DATA (FANDAP(118,J),J=1,10) /
      $ 1.302 ,.454 , -11.977 ,27.924 , -27.693 ,
E55  $ .14 ,.38 , 40. , 10. , 2. /
      DATA (FANDAP(119,J),J=1,10) /
      $ 2.222 ,2.029 , -9.762 ,10.841 , -5.528 ,
      $ .253 ,.72 , 40. , 10. , 6. /
      DATA (FANDAP(120,J),J=1,10) /
E60  $ 1.717 ,10.358 , -31.846 ,36.638 , -16.245 ,
      $ .357 ,.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. /
E65  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) /
E70  $ -251.346 ,1060.7 , -1650.93 ,1141.51 , -296.667 ,
      $ .80 ,1.127 , 40. , 10. , 22. /

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      DATA (FANDAP(124,J),J=1,10) /
      $ 1.920      , -1.595      , 3.019      , -8.274      , 3.907      ,
      $ .14      , .44      , .40.      , 12.      , 2.      /
      DATA (FANDAP(125,J),J=1,10) /
      $ 2.661      , -1.195      , .1299      , -1.262      , .399      ,
      $ .265      , .84      , .40.      , 12.      , 5.      /
      DATA (FANDAP(126,J),J=1,10) /
      $ .4204      , .17.453      , -.43.194      , .42.370      , -.15.566      ,
      $ .39      , .1.66      , .40.      , 12.      , 10.      /
      DATA (FANDAP(127,J),J=1,10) /
      $ -11.44      , .76.814      , -.145.249      , .117.876      , -.35.539      ,
      $ .52      , .1.17      , .40.      , 12.      , 14.      /
      DATA (FANDAP(128,J),J=1,10) /
      $ -7.134      , .61.677      , -.90.389      , .68.768      , -.19.929      ,
      $ .635      , .1.24      , .40.      , 12.      , 18.      /
      DATA (FANDAP(129,J),J=1,10) /
      $ -448.499      , .1536.46      , -.2116.83      , .1245.43      , -.275.191      ,
      $ .92      , .1.3      , .40.      , 12.      , 22.      /
      DATA (FANDAP(130,J),J=1,10) /
      $ 1.343      , -.07846      , -.6.995      , .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.      , 5.      /
      DATA (FANDAP(132,J),J=1,10) /
      $ .4452      , .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) /
      $ -39.126      , .178.576      , -.272.965      , .181.609      , -.44.911      ,
      $ .64      , .1.35      , .40.      , 14.      , 18.      /
      DATA (FANDAP(135,J),J=1,10) /
      $ -118.22      , .406.731      , -.504.396      , .278.236      , -.57.944      ,
      $ .85      , .1.435      , .40.      , 14.      , 22.      /
      DATA (FANDAP(136,J),J=1,10) /
      $ 4.228      , -.2.091      , -.24.207      , .55.248      , -.45.947      ,
      $ .155      , .422      , .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) /
      $ 2.869      , .28.609      , -.157.76      , .240.715      , -.137.116      ,
      $ .235      , .66      , .60.      , 12.      , 8.      /
      DATA (FANDAP(139,J),J=1,10) /
      $ 2.844      , .37.353      , -.146.207      , .215.777      , -.119.45      ,
      $ .28      , .73      , .60.      , 12.      , 10.      /
      DATA (FANDAP(140,J),J=1,10) /
      $ -41.688      , .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      , .436.25      , -.210.91      ,
      $ .327      , .76      , .60.      , 12.      , 14.      /
      DATA (FANDAP(142,J),J=1,10) /
      $ -40.774      , .249.5      , -.929.9      , .1076.8      , -.468.43      ,
      $ .45      , .76      , .60.      , 12.      , 16.      /

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      DATA (FANDAP(143,J),J=1,10) /
430  $ -1619.9 , 9661.7 , -21438.7 , 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 , .50 , .15 , .2 , /
      DATA (FANDAP(145,J),J=1,10) /
435  $ 4.804 , -3.223 , -1.142 , -3.317 , 2.953 ,
      $ .154 , .62 , .60 , .16 , .4 , /
      DATA (FANDAP(146,J),J=1,10) /
      $ 5.226 , -7.899 , -9.21 , 8.711 , -3.366 ,
      $ .202 , .76 , .50 , .16 , .6 , /
440  DATA (FANDAP(147,J),J=1,10) /
      $ 5.2175 , -3.071 , -1.695 , -2.459 , 2.489 ,
      $ .25 , .75 , .60 , .16 , .8 , /
      DATA (FANDAP(148,J),J=1,10) /
      $ 5.008 , 14.169 , -55.056 , 58.651 , -31.803 ,
445  $ .31 , -.93 , .60 , .16 , .10 , /
      DATA (FANDAP(149,J),J=1,10) /
      $ 5.504 , 13.941 , -45.551 , 47.755 , -19.574 ,
      $ .366 , .90 , .60 , .16 , .12 , /
      DATA (FANDAP(150,J),J=1,10) /
450  $ -34.35 , 265.14 , -612.11 , 504.01 , -220.51 ,
      $ .435 , .95 , .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 , /
455  DATA (FANDAP(152,J),J=1,10) /
      $ -220.25 , 1153.5 , -2169. , 1802.6 , -562.09 ,
      $ .55 , .93 , .60 , .16 , .18 , /
      DATA (FANDAP(153,J),J=1,10) /
      $ -320.236 , 841.7 , -445.22 , 0.0 , 0.0 ,
460  $ .95 , 1.0 , .60 , .16 , .22 , /
      DATA (FANDAP( 1,J),J=1,10) /
      $ -93.346 , 983.578 , -2375.14 , 2520.20 , -1060.61 ,
      $ 400000. , 760000. , 24. , 6. , 6. /
      DATA (FANDAP( 2,J),J=1,10) /
465  $ 7.793 , 289.38 , -481.24 , 349.55 , -139.86 ,
      $ 400000. , 860000. , 24. , 6. , 8. /
      DATA (FANDAP( 3,J),J=1,10) /
      $ -115.79 , 1085.09 , -1846.07 , 1498.74 , -486.6 ,
      $ 400000. , 950000. , 24. , 6. , 10. /
470  DATA (FANDAP( 4,J),J=1,10) /
      $ 80.754 , -163.62 , 729.59 , -849.42 , 281.78 ,
      $ 400000. , 1025000. , 24. , 6. , 12. /
      DATA (FANDAP( 5,J),J=1,10) /
      $ 155.98 , -527.75 , 1454.59 , -1447.2 , 460.83 ,
475  $ 400000. , 1100000. , 24. , 6. , 14. /
      DATA (FANDAP( 6,J),J=1,10) /
      $ -125.02 , 1138.24 , -1400.75 , 749.81 , -163.17 ,
      $ 500000. , 1180000. , 24. , 6. , 16. /
      DATA (FANDAP( 7,J),J=1,10) /
480  $ 205.61 , -579.20 , 1312.33 , -1087.12 , 295.46 ,
      $ 500000. , 1250000. , 24. , 6. , 18. /
      DATA (FANDAP( 8,J),J=1,10) /
      $ 705.77 , -2402.05 , 3785.21 , -2521.58 , 601.4 ,
      $ 800000. , 1330000. , 24. , 6. , 20. /

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685      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 , -2005.05 , 757.58 ,
690 $ 400000. , 780000. , 24. , 8. , 5. /
      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) /
695 $ 143.97 , -102.78 , 439.12 , -444.8 , 119.46 ,
$ 400000. , 970000. , 24. , 8. , 10. /
      DATA (FANDAH( 13,J),J=1,10) /
$ 162.15 , -256.19 , 512.11 , -351.99 , 36.131 ,
$ 500000. , 1050000. , 24. , 8. , 12. /
700      DATA (FANDAH( 14,J),J=1,10) /
$ -77.675 , 1059.7 , -1875.53 , 1567.15 , -530.3 ,
$ 500000. , 1140000. , 24. , 8. , 14. /
      DATA (FANDAH( 15,J),J=1,10) /
$ 148.09 , -164.8 , 627.53 , -604.74 , 160.84 ,
705 $ 700000. , 1240000. , 24. , 8. , 15. /
      DATA (FANDAH( 16,J),J=1,10) /
$ 142.97 , -189.66 , 786.1 , -749.62 , 204.99 ,
$ 650000. , 1330000. , 24. , 8. , 18. /
      DATA (FANDAH( 17,J),J=1,10) /
710 $ -235.84 , 1584.71 , -2094.92 , 1360.06 , -354.31 ,
$ 900000. , 1400000. , 24. , 8. , 20. /
      DATA (FANDAH( 18,J),J=1,10) /
$ -112.86 , 847.65 , -906.93 , 554.88 , -163.17 ,
$ 900000. , 1400000. , 24. , 8. , 22. /
715      DATA (FANDAH( 19,J),J=1,10) /
$ 22.074 , 483.11 , -1315.1 , 1503.54 , -833.33 ,
$ 400000. , 780000. , 24. , 10. , 5. /
      DATA (FANDAH( 20,J),J=1,10) /
$ 58.107 , 431.89 , -1131.38 , 1196.97 , -524.48 ,
720 $ 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) /
725 $ -100.05 , 1345.81 , -2651.05 , 2365.19 , -839.16 ,
$ 550000. , 1060000. , 24. , 10. , 12. /
      DATA (FANDAH( 23,J),J=1,10) /
$ -196.47 , 1864.5 , -3537.84 , 3051.97 , -1031.47 ,
$ 580000. , 1140000. , 24. , 10. , 14. /
730      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) /
$ -27.569 , 620.11 , -769.57 , 558.36 , -191.62 ,
735 $ 650000. , 1330000. , 24. , 10. , 18. /
      DATA (FANDAH( 26,J),J=1,10) /
$ -752.88 , 3309.25 , -4177.95 , 2502.21 , -599.65 ,
$ 850000. , 1400000. , 24. , 10. , 20. /
      DATA (FANDAH( 27,J),J=1,10) /
740 $ -279.88 , 1653.67 , -2140.73 , 1475.52 , -414.92 ,
$ 900000. , 1400000. , 24. , 10. , 22. /

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      DATA (FANDAH( 28,J),J=1,10) /
      $ -59.965 ,541.02 , -1263.85 ,1123.39 , -414.92 ,
      $ 500000. ,500000. , 26. , 5. , 5. /
745 DATA (FANDAH( 29,J),J=1,10) /
      $ 147.46 , -436.19 ,915.07 , -784.62 ,209.79 ,
      $ 500000. ,990000. , 26. , 5. , 9. /
      DATA (FANDAH( 30,J),J=1,10) /
      $ 46.13 , 166.75 , -282.52 ,272.1 , -126.46 ,
750 $ 500000. ,1080000. , 26. , 5. , 10. /
      DATA (FANDAH( 31,J),J=1,10) /
      $ 139.96 , -252.12 ,498.13 , -354.08 ,67.873 ,
      $ 500000. ,1180000. , 26. , 5. , 12. /
      DATA (FANDAH( 32,J),J=1,10) /
755 $ 172.97 , -372.85 ,722.82 , -517.47 ,114.80 ,
      $ 500000. ,1270000. , 26. , 5. , 14. /
      DATA (FANDAH( 33,J),J=1,10) /
      $ -13206 ,452.26 , -648.81 ,493.49 , -156.59 ,
      $ 750000. ,1350000. , 26. , 5. , 16. /
760 DATA (FANDAH( 34,J),J=1,10) /
      $ 130.3 , -92.296 ,235.95 , -117.56 ,2.759 ,
      $ 700000. ,1430000. , 26. , 5. , 18. /
      DATA (FANDAH( 35,J),J=1,10) /
765 $ 162.1 , -104.34 ,432.03 , -278.64 ,53.34 ,
      $ 900000. ,1500000. , 26. , 5. , 20. /
      DATA (FANDAH( 36,J),J=1,10) /
      $ 322.0 , -447.74 ,423.14 , -35.091 , -15.494 ,
      $ 940000. ,1500000. , 26. , 5. , 22. /
770 DATA (FANDAH( 37,J),J=1,10) /
      $ -350.23 ,2212.31 , -4250. ,3636.35 , -1212.12 ,
      $ 600000. ,940000. , 26. , 8. , 5. /
      DATA (FANDAH( 38,J),J=1,10) /
775 $ 83.709 , 7433 ,115.75 , -152.03 ,23.37 ,
      $ 500000. ,1040000. , 26. , 8. , 8. /
      DATA (FANDAH( 39,J),J=1,10) /
      $ 160.02 , -245.62 ,483.62 , -354.34 ,67.599 ,
      $ 600000. ,1150000. , 26. , 8. , 10. /
780 DATA (FANDAH( 40,J),J=1,10) /
      $ 77.046 ,115.59 , -11.039 , -49.109 , -3.771 ,
      $ 600000. ,1250000. , 26. , 8. , 12. /
      DATA (FANDAH( 41,J),J=1,10) /
      $ 176.39 , -257.33 ,583.44 , -449.33 ,100.18 ,
      $ 600000. ,1340000. , 26. , 8. , 14. /
785 DATA (FANDAH( 42,J),J=1,10) /
      $ -474.23 ,2139.22 , -2769.16 ,1597.82 , -363.64 ,
      $ 840000. ,1440000. , 26. , 8. , 16. /
      DATA (FANDAH( 43,J),J=1,10) /
      $ 193.55 , -258.44 ,672.44 , -479.25 ,100.02 ,
      $ 600000. ,1520000. , 26. , 8. , 18. /
790 DATA (FANDAH( 44,J),J=1,10) /
      $ -559.64 ,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 ,
      $ 600000. ,976000. , 26. , 11. , 5. /

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      DATA (FANDAH( 47,J),J=1,10) /
000  $ 247.45 , -674.34 , 923.03 , -453.77 , 0.0 ,
      $ 500000. , 1050000. , 26. , 11. , 8. /
      DATA (FANDAH( 48,J),J=1,10) /
      $ 166.72 , -105.07 , 169.48 , -24.391 , -71.678 ,
005  $ 600000. , 1190000. , 26. , 11. , 10. /
      DATA (FANDAH( 49,J),J=1,10) /
      $ -121.21 , 1159.54 , -1704.69 , 1170.09 , -335.11 ,
      $ 600000. , 1300000. , 26. , 11. , 12. /
      DATA (FANDAH( 50,J),J=1,10) /
010  $ -34.067 , 818.03 , -1115.29 , 766.02 , -230.43 ,
      $ 500000. , 1300000. , 26. , 11. , 14. /
      DATA (FANDAH( 51,J),J=1,10) /
      $ 12.912 , 602.92 , -670.08 , 415.16 , -126.02 ,
      $ 600000. , 1500000. , 26. , 11. , 16. /
      DATA (FANDAH( 52,J),J=1,10) /
015  $ 223.46 , -1.098 , 30.012 , 1.166 , -34.965 ,
      $ 500000. , 1600000. , 26. , 11. , 18. /
      DATA (FANDAH( 53,J),J=1,10) /
      $ -3.923 , 1038.49 , -1360.42 , 847.22 , -208.33 ,
      $ 1000000. , 1600000. , 26. , 11. , 20. /
      DATA (FANDAH( 54,J),J=1,10) /
020  $ -3555.68 , 11081.15 , -11777.03 , 5652.78 , -1041.67 ,
      $ 1170000. , 1600000. , 26. , 11. , 22. /
      DATA (FANDAH( 55,J),J=1,10) /
      $ 32.976 , 97.97 , -185.66 , 215.99 , -110.55 ,
025  $ 500000. , 1020000. , 28. , 6. , 6. /
      DATA (FANDAH( 56,J),J=1,10) /
      $ 30.295 , -71.86 , 154.45 , -110.7 , 11.083 ,
      $ 500000. , 1110000. , 28. , 6. , 8. /
      DATA (FANDAH( 57,J),J=1,10) /
030  $ 85.02 , -39.55 , 76.619 , -26.452 , -17.992 ,
      $ 500000. , 1220000. , 28. , 6. , 10. /
      DATA (FANDAH( 58,J),J=1,10) /
      $ 163.75 , -352.71 , 598.45 , -352.27 , 56.818 ,
      $ 730000. , 1330000. , 28. , 6. , 12. /
      DATA (FANDAH( 59,J),J=1,10) /
035  $ -30.521 , 391.0 , -385.6 , 205.0 , -55.028 ,
      $ 500000. , 1450000. , 28. , 6. , 14. /
      DATA (FANDAH( 60,J),J=1,10) /
      $ 522.91 , -1352.27 , 1563.48 , -941.6 , 145.26 ,
040  $ 1030000. , 1560000. , 28. , 6. , 16. /
      DATA (FANDAH( 61,J),J=1,10) /
      $ 744.28 , -1995.75 , 2170. , -1022.22 , 166.67 ,
      $ 1000000. , 1630000. , 28. , 6. , 18. /
      DATA (FANDAH( 62,J),J=1,10) /
045  $ 550.31 , -1015.79 , 914.44 , -298.92 , 21.461 ,
      $ 1250000. , 1700000. , 28. , 6. , 20. /
      DATA (FANDAH( 63,J),J=1,10) /
      $ -130.67 , 1135.05 , -1362.37 , 760.4 , -159.66 ,
      $ 1230000. , 1760000. , 28. , 6. , 22. /
      DATA (FANDAH( 64,J),J=1,10) /
050  $ -51.422 , 598.46 , -1395.44 , 1273.01 , -461.14 ,
      $ 500000. , 1050000. , 28. , 8. , 6. /
      DATA (FANDAH( 65,J),J=1,10) /
      $ 27.124 , 271.6 , -455.19 , 391.06 , -143.86 ,
055  $ 530000. , 1180000. , 28. , 8. , 8. /

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      DATA (FANDAH( 56,J),J=1,10) /
      $ 157.25 , -318.65 , 623.34 , -446.78 , 91.05 ,
      $ 550000. , 1200000. , 28. , 8. , 10. /
      DATA (FANDAH( 57,J),J=1,10) /
      $ 297.63 , -873.87 , 1501.13 , -1021.21 , 231.07 ,
      $ 650000. , 1400000. , 23. , 5. , 12. /
      DATA (FANDAH( 58,J),J=1,10) /
      $ 177.36 , -395.03 , 859.53 , -672.74 , 160.98 ,
      $ 600000. , 1500000. , 28. , 8. , 14. /
      DATA (FANDAH( 59,J),J=1,10) /
      $ 79.60 , -25.75 , 395.79 , -348.17 , 80.492 ,
      $ 900000. , 1600000. , 23. , 9. , 16. /
      DATA (FANDAH( 70,J),J=1,10) /
      $ 250.75 , -520.49 , 949.34 , -600.17 , 122.38 ,
      $ 930000. , 1700000. , 28. , 9. , 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) /
      $ -257.26 , 1167.2 , -1145.64 , 581.78 , -120.54 ,
      $ 1250000. , 1770000. , 28. , 8. , 22. /
      DATA (FANDAH( 73,J),J=1,10) /
      $ -18.151 , 433.24 , -828.15 , 703.03 , -274.70 ,
      $ 500000. , 1050000. , 28. , 9. , 6. /
      DATA (FANDAH( 74,J),J=1,10) /
      $ 102.65 , 1179 , 38.104 , 39.954 , -66.374 ,
      $ 500000. , 1200000. , 28. , 9. , 10. /
      DATA (FANDAH( 75,J),J=1,10) /
      $ 125.15 , -54.834 , 318.54 , -250.86 , 51.635 ,
      $ 600000. , 1570000. , 28. , 9. , 14. /
      DATA (FANDAH( 76,J),J=1,10) /
      $ 184.11 , -95.277 , 404.53 , -307.01 , 61.861 ,
      $ 450000. , 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) /
      $ 1416.84 , -8770.24 , 21006.05 , -22060.6 , 8484.84 ,
      $ 300000. , 230000. , 28. , 10. , 2. /
      DATA (FANDAH( 79,J),J=1,10) /
      $ -83.9 , 814.41 , -1370.32 , 1144.03 , -422. ,
      $ 550000. , 1070000. , 28. , 10. , 6. /
      DATA (FANDAH( 80,J),J=1,10) /
      $ 131.94 , -73.089 , 191.65 , -63.245 , -48.295 ,
      $ 570000. , 1220000. , 20. , 10. , 10. /
      DATA (FANDAH( 81,J),J=1,10) /
      $ 224.05 , -284.12 , 540.09 , -336.89 , 55.139 ,
      $ 500000. , 1580000. , 28. , 10. , 14. /
      DATA (FANDAH( 82,J),J=1,10) /
      $ 718.7 , -1794.52 , 2459.25 , -1335.48 , 259.29 ,
      $ 850000. , 1770000. , 28. , 10. , 18. /
      DATA (FANDAH( 83,J),J=1,10) /
      $ -1153.75 , 4131.1 , -4529.52 , 2243.75 , -426.4 ,
      $ 1200000. , 1770000. , 28. , 10. , 22. /
      DATA (FANDAH( 84,J),J=1,10) /
      $ 1151.37 , -6675.67 , 14912.2 , -14463.5 , 5109.47 ,
      $ 500000. , 860000. , 28. , 12. , 2. /

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      DATA (FANDAH( 85,J),J=1,10) /
015  $ -257.57 ,1727.79 , -2934.3 ,2274.14 , -724.96 ,
      $ 550000. ,1180000. , 28. , 12. , 6. /
      DATA (FANDAH( 86,J),J=1,10) /
      $ 90.637 ,287.03 , -415.77 ,341.86 , -146.78 ,
      $ 570000. ,1340000. , 28. , 12. , 10. /
020  DATA (FANDAH( 87,J),J=1,10) /
      $ 454.87 , -1066. ,1726.52 , -1109.2 ,233.1 ,
      $ 500000. ,1630000. , 28. , 12. , 14. /
      DATA (FANDAH( 88,J),J=1,10) /
      $ 555.85 , -920.47 ,1271.54 , -574.15 ,108.39 ,
      $ 650000. ,1770000. , 28. , 12. , 18. /
025  DATA (FANDAH( 89,J),J=1,10) /
      $ 71.003 , -131.14 ,292.2 , -268.88 ,66.078 ,
      $ 500000. ,220000. , 30. , 8. , 2. /
      DATA (FANDAH( 90,J),J=1,10) /
030  $ 6823 ,399.34 , -784.08 ,705.5 , -243.37 ,
      $ 500000. ,1220000. , 30. , 8. , 5. /
      DATA (FANDAH( 91,J),J=1,10) /
      $ 140.32 , -267.89 ,605.71 , -450.68 ,109.65 ,
      $ 500000. ,1400000. , 30. , 8. , 10. /
035  DATA (FANDAH( 92,J),J=1,10) /
      $ 223.24 , -353.83 ,529.45 , -270.74 ,40.306 ,
      $ 500000. ,1770000. , 30. , 8. , 14. /
      DATA (FANDAH( 93,J),J=1,10) /
      $ -459.74 ,1952.01 , -2176.9 ,1114.75 , -216.07 ,
      $ 1000000. ,1770000. , 30. , 8. , 18. /
040  DATA (FANDAH( 94,J),J=1,10) /
      $ -2730.78 ,7918.48 , -7719.93 ,3355.91 , -546.08 ,
      $ 1400000. ,1770000. , 30. , 8. , 22. /
      DATA (FANDAH( 95,J),J=1,10) /
045  $ -2115.54 ,11989.3 , -24400. ,21919.2 , -7272.73 ,
      $ 500000. ,240000. , 30. , 10. , 2. /
      DATA (FANDAH( 96,J),J=1,10) /
      $ -155.27 ,1062. , -1749.99 ,1354.18 , -420.48 ,
      $ 500000. ,1260000. , 30. , 10. , 6. /
050  DATA (FANDAH( 97,J),J=1,10) /
      $ 70.014 ,275.3 , -479.35 ,404.31 , -129.79 ,
      $ 600000. ,1530000. , 30. , 10. , 10. /
      DATA (FANDAH( 98,J),J=1,10) /
      $ 48.686 ,424.63 , -556.3 ,358.77 , -94.019 ,
      $ 500000. ,1870000. , 30. , 10. , 14. /
055  DATA (FANDAH( 99,J),J=1,10) /
      $ 1834.02 , -4736.59 ,5146.5 , -2396.56 ,400.67 ,
      $ 1110000. ,1870000. , 30. , 10. , 18. /
      DATA (FANDAH(100,J),J=1,10) /
060  $ 3840.5 , -8653.67 ,7719.75 , -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 ,
      $ 500000. ,950000. , 30. , 11. , 2. /
065  DATA (FANDAH(102,J),J=1,10) /
      $ 104.31 , -77.393 ,150.7 , -29.672 , -47.348 ,
      $ 500000. ,1280000. , 30. , 11. , 6. /
      DATA (FANDAH(103,J),J=1,10) /
      $ -155.27 ,1106.85 , -1431.07 ,844.31 , -197.5 ,
      $ 500000. ,1560000. , 30. , 11. , 10. /

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670      DATA (FANDAH(104,J),J=1,10) /
$ 108.35      .142.39      -19.234      -15.095      -2.55      ,
$ 700000.      .1870000.      , 30. , 11. , 14. /
      DATA (FANDAH(105,J),J=1,10) /
675      $ 1252.38      -3070.33      ,3409.94      -1571.34      ,255.48      ,
$ 1040000.      .1870000.      , 30. , 11. , 16. /
      DATA (FANDAH(106,J),J=1,10) /
      $ 6422.22      -14958.6      ,13595.      -5504.54      ,821.78      ,
$ 1450000.      .1870000.      , 30. , 11. , 22. /
      DATA (FANDAH(107,J),J=1,10) /
680      $ -53.04      ,308.6      ,102.27      -616.16      ,303.63      ,
$ 600000.      .950000.      , 30. , 12. , 2. /
      DATA (FANDAH(108,J),J=1,10) /
      $ -272.65      ,1420.3      -1840.91      ,1030.3      -227.27      ,
$ 600000.      .1290000.      , 30. , 12. , 6. /
685      DATA (FANDAH(109,J),J=1,10) /
      $ -107.44      ,844.15      -980.15      ,527.      -119.46      ,
$ 600000.      .1580000.      , 30. , 12. , 10. /
      DATA (FANDAH(110,J),J=1,10) /
690      $ 172.04      -76.343      ,334.05      -244.14      ,48.077      ,
$ 700000.      .1870000.      , 30. , 12. , 14. /
      DATA (FANDAH(111,J),J=1,10) /
      $ 967.44      -1854.72      ,2097.31      -952.54      ,148.6      ,
$ 1050000.      .1870000.      , 30. , 12. , 18. /
      DATA (FANDAH(112,J),J=1,10) /
695      $ 642.52      -1657.55      ,1862.59      -928.03      ,170.45      ,
$ 1000000.      .1620000.      , 40. , 8. , 2. /
      DATA (FANDAH(113,J),J=1,10) /
      $ -234.8      ,936.73      -837.05      ,339.55      -55.0      ,
$ 1000000.      .2160000.      , 40. , 8. , 6. /
1000      DATA (FANDAH(114,J),J=1,10) /
      $ 59.02      ,212.2      -31.972      ,14.603      -2.878      ,
$ 1000000.      .2570000.      , 40. , 8. , 10. /
      DATA (FANDAH(115,J),J=1,10) /
1005      $ 420.1      -458.47      ,450.55      -159.25      ,18.324      ,
$ 1200000.      .3040000.      , 40. , 8. , 14. /
      DATA (FANDAH(116,J),J=1,10) /
      $ 502.09      -434.25      ,352.15      -95.755      ,7.843      ,
$ 1700000.      .3320000.      , 40. , 8. , 18. /
      DATA (FANDAH(117,J),J=1,10) /
1010      $ -256.24      ,1014.48      -557.15      ,149.48      -15.597      ,
$ 2200000.      .3550000.      , 40. , 8. , 22. /
      DATA (FANDAH(118,J),J=1,10) /
      $ 2875.51      -7685.44      ,8025.59      -3689.81      ,625.0      ,
$ 1200000.      .1700000.      , 40. , 10. , 2. /
1015      DATA (FANDAH(119,J),J=1,10) /
      $ -904.43      ,2572.53      -2225.35      ,956.9      -130.21      ,
$ 1200000.      .2260000.      , 40. , 10. , 6. /
      DATA (FANDAH(120,J),J=1,10) /
1020      $ 29.645      ,465.32      -341.49      ,132.62      -22.635      ,
$ 1200000.      .2740000.      , 40. , 10. , 10. /
      DATA (FANDAH(121,J),J=1,10) /
      $ -556.0      ,1461.13      -834.02      ,221.53      -23.765      ,
$ 1270000.      .3180000.      , 40. , 10. , 14. /
      DATA (FANDAH(122,J),J=1,10) /
1025      $ 621.15      -423.07      ,299.22      -60.185      ,1.457      ,
$ 1800000.      .3460000.      , 40. , 10. , 18. /

```

	DATA (FANDAH(123,J),J=1,10) /			
	\$ 9056.43 , -11235.5 , 5513.37 , -1173.03 , 91.146 ,			
	\$ 2500000. , 3740000. , 40. , 10. , 22. /			
1630	DATA (FANDAH(124,J),J=1,10) /			
	\$ -230.79 , 658.95 , -336.11 , 37.037 , 0.0 ,			
	\$ 1200000. , 1720000. , 40. , 12. , 2. /			
	DATA (FANDAH(125,J),J=1,10) /			
	\$ -254.45 , 908.1 , -574.52 , 157.2 , -18.939 ,			
1635	\$ 1200000. , 2330000. , 40. , 12. , 6. /			
	DATA (FANDAH(126,J),J=1,10) /			
	\$ -151.19 , 779.21 , -444.03 , 119.08 , -14.569 ,			
	\$ 1200000. , 2030000. , 40. , 12. , 10. /			
	DATA (FANDAH(127,J),J=1,10) /			
1640	\$ 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 ,			
	\$ 1850000. , 3510000. , 40. , 12. , 18. /			
1645	DATA (FANDAH(129,J),J=1,10) /			
	\$ -13201.1 , 17441.5 , -3397.4 , 1786.5 , -143.23 ,			
	\$ 2540000. , 3750000. , 40. , 12. , 22. /			
	DATA (FANDAH(130,J),J=1,10) /			
	\$ -6179.5 , 17637.9 , -18314.5 , 8430.56 , -1459.33 ,			
1650	\$ 1200000. , 1730000. , 40. , 14. , 2. /			
	DATA (FANDAH(131,J),J=1,10) /			
	\$ 227.15 , 112.24 , -105.4 , 50.29 , -16.572 ,			
	\$ 1200000. , 2330000. , 40. , 14. , 6. /			
	DATA (FANDAH(132,J),J=1,10) /			
	\$ 151.36 , 234.11 , -57.839 , -7284 , -1.093 ,			
1655	\$ 1200000. , 2870000. , 40. , 14. , 10. /			
	DATA (FANDAH(133,J),J=1,10) /			
	\$ -123.26 , 846.19 , -428.34 , 105.65 , -11.837 ,			
	\$ 1270000. , 3360000. , 40. , 14. , 14. /			
	DATA (FANDAH(134,J),J=1,10) /			
	\$ 754.94 , -762.92 , 618.55 , -182.21 , 16.936 ,			
	\$ 1920000. , 3720000. , 40. , 14. , 18. /			
	DATA (FANDAH(135,J),J=1,10) /			
	\$ 1717.77 , -1161.5 , 466.83 , -55.358 , -8156 ,			
1665	\$ 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. /			
	DATA (FANDAH(137,J),J=1,10) /			
	\$ -15.869 , 293.54 , -122.47 , 23.347 , -2.262 ,			
1670	\$ 2000000. , 4750000. , 60. , 12. , 6. /			
	DATA (FANDAH(138,J),J=1,10) /			
	\$ 253.5 , -26.009 , 41.5 , -9.273 , 4242 ,			
	\$ 2000000. , 5220000. , 60. , 12. , 8. /			
	DATA (FANDAH(139,J),J=1,10) /			
1675	\$ 218.04 , 37.044 , 28.93 , -3.833 , 5606 ,			
	\$ 2000000. , 5650000. , 60. , 12. , 10. /			
	DATA (FANDAH(140,J),J=1,10) /			
	\$ 417. , -96.1665 , 67.171 , -11.709 , 5367 ,			
1680	\$ 2250000. , 6170000. , 60. , 12. , 12. /			
	DATA (FANDAH(141,J),J=1,10) /			
	\$ -750.45 , 915.56 , -243.21 , 30.626 , -1.576 ,			
	\$ 3250000. , 6700000. , 60. , 12. , 14. /			

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1685      DATA (FANDAH(142,J),J=1,10) /
$ -1493.86 ,1518.16 , -419.53 ,53.4 , -2.675 ,
$ 4100000. ,7000000. , 60. , 12. , 16. /
      DATA (FANDAH(143,J),J=1,10) /
$ 2257.4 , -1224.36 ,330.67 , -36. , 1.33 ,
$ 4500000. ,7000000. , 60. , 12. , 18. /
1690      DATA (FANDAH(144,J),J=1,10) /
$ -155.08 ,544.46 , -304.18 ,79.677 , -8.757 ,
$ 2000000. ,3700000. , 60. , 15. , 2. /
      DATA (FANDAH(145,J),J=1,10) /
$ -75.06 ,442.02 , -203.89 ,41.82 , -3.623 ,
1695      DATA (FANDAH(146,J),J=1,10) /
$ 2000000. ,4250000. , 60. , 15. , 4. /
      DATA (FANDAH(147,J),J=1,10) /
$ 70.414 ,251.15 , -86.013 ,14.616 , -1.245 ,
$ 2000000. ,4850000. , 60. , 15. , 6. /
      DATA (FANDAH(148,J),J=1,10) /
1700      DATA (FANDAH(149,J),J=1,10) /
$ -94.021 ,440.34 , -147.35 ,24.961 , -1.953 ,
$ 2700000. ,5250000. , 60. , 16. , 8. /
      DATA (FANDAH(150,J),J=1,10) /
$ -20.122 ,394.28 , -107.34 ,14.133 , -.9076 ,
1705      DATA (FANDAH(151,J),J=1,10) /
$ 2000000. ,5930000. , 60. , 15. , 10. /
      DATA (FANDAH(152,J),J=1,10) /
$ 502.56 , -132.89 ,102.98 , -19.495 , 1.03 ,
$ 3170000. ,6370000. , 60. , 15. , 12. /
      DATA (FANDAH(153,J),J=1,10) /
1710      DATA (FANDAH(154,J),J=1,10) /
$ 390.34 ,84.842 ,12.235 , -3.344 , .0746 ,
$ 2500000. ,7000000. , 60. , 15. , 14. /
      DATA (FANDAH(155,J),J=1,10) /
$ -1498.49 ,1558.69 , -401.72 ,48.621 , -2.346 ,
$ 4700000. ,7000000. , 60. , 15. , 16. /
      DATA (FANDAH(156,J),J=1,10) /
1715      DATA (FANDAH(157,J),J=1,10) /
$ 5655.16 , -3754.3 ,1080.28 , -133.41 , 6. ,
$ 4200000. ,7000000. , 60. , 15. , 18. /
      DATA (FANDAH(158,J),J=1,10) /
$ 1251.03 , -90.429 ,13.143 , 0.0 , 0.0 ,
$ 5250000. ,7000000. , 60. , 15. , 22. /
1720      DATA P1 /3.14159265/
      DATA TANB /1.1405/, TANIS /3.44/, H2 /5./

C
C      SPECIFIC VOLUME OF AIR LEAVING THE HEAT EXCHANGER AT THE
C      ELEVATION SPECIFIED FOR THE PLANT
1725      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=5.508
      AC=0.
      AHP=0.
      ADIA=0.
      APLV=0.
      AVEL=0.
1735      IF(LFE.LT.1) LFE = 163
      IF(LFB.LT.1) LFB = 1
1740

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C      START OF ITERATIVE LOOP FOR DETERMINING THE OPTIMUM FAN
C      SYSTEM
1145      DO 400 I=LFB,LFE
C      INITIALIZATION OF FAN OPTIMIZATION PARAMETERS
C      TP=0.
1150      PCFMPF=0.
C      CFMPF=0.
C      NPF=0
C      HDPF=0
C      TOTHP=0.
1155      FCST=0.
C      CMOT=0.
C      CSP=0.
C      CPL=0.
C      TCSTPF=0.
1160      TCSTF=0.
C      VEL=0.
C      CINC=30000.
C      CFM=400000.
C      FLOWP=0.
1165      TP=0.
C      DP=0.
C      CI=0.
C      CROSS-SECTIONAL FLOW AREA FOR THE FAN DEPENDING ON THE FAN
1170      DIAMETER
C      IF(I.LE.27) A=429.08
C      IF(I.GT.27.AND.I.LE.54) A=495.95.
C      IF(I.GT.54.AND.I.LE.98) A=584.5
1175      IF(I.GT.98.AND.I.LE.111) A=658.37
C      IF(I.GT.111.AND.I.LE.135) A=1123.91
C      IF(I.GT.135) A=2580.4
C      DETERMINE THE NUMBER FANS, THE VOLUMETRIC FLOW RATE THROUGH
1180      EACH FAN, AND THE TOTAL PRESSURE DROP ACROSS EACH FAN
C      K=0
50 CONTINUE
C      K=K+1
1185      IF(K.GT.100) GO TO 59
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
1190      VELREC=0      NO VELOCITY RECOVERY
C      VELREC=1      VELOCITY RECOVERY
C      THE VELOCITY RECOVERY IS BASED ON 13 FT HIGH STACKS WITH
C      8 DEGREE SIDESAND FOR A 28 FT DIAMETER FAN THE EFFECTIVE-
1195      NESS OF THE STACK HAS BEEN TAKEN TO BE 80 PERCENT
C      AIR VELOCITY EXITING THE FAN OR STACK

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      IF (VELREC.EQ. 0.) VEL=CFM/60./A
      FAND= FANDAP(I,4)
1200  IF (VELREC.EQ.1.) VEL=CFM/60./ (FAND*2.*13./29.*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.
1205  *852)
      C
      C      TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN
      C      TP=OPT*WK*.07495*SPVOL*VP
      C
1210  C      CHECK IF PRESSURE DIFFERENTIAL AND VOLUMETRIC FLOW RATE ARE
      C      WITHIN SPECIFIED LIMITS
      C      IF (TP.GT.FANDAP(I,7)) GO TO 52
      C      IF (CFM.GT.FANDAH(I,7)) GO TO 54
      C      IF (CFM.LT.FANDAH(I,5)) GO TO 55
1215  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
1220  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
1225  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
1230  CFM=CFM*CI
      GO TO 50
      55 CFM=CFM+CINC
      GO TO 50
      54 CFM=CFM-CINC
      GO TO 50
1235  59 CONTINUE
      GO TO 700
      62 CONTINUE
      GO TO 400
1240  57 CFMPF=RCFMPF*1000000.
      C
      C      CALCULATION OF THE NUMBER OF FANS IN THE FAN SYSTEM
      C      NOF=TO*CFM/CFMPF
      C      IF (CFMPF.LT.FANDAH(I,6).OR.CFMPF.GT.FANDAH(I,7)) GO TO 400
1245  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
1250  HPPF = HPPF/GPEFF
      C
      C      CALCULATION OF THE NUMBER OF CIRCULAR TOWERS BASED ON AN
      C      ALLOWABLE FAN PACKING FACTOR

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1255      C      TOWN = (WIDTH * CDANG / (PI * FANDAP(I,9))) **2 / (NOF * PFACT)
          C      ITOWN = TOWN
          C      IF (ITOWN .LT. ITMIN) GOTO 400
          C      IF (ITOWN .GT. ITMAX) GOTO 400
1260      C      CALCULATION OF THE DIAMETER OF THE TOWERS
          C      OTOW = WIDTH * CDANG / (PI * ITOWN)
          C
          C      FAN ELECTRICAL WIRING COSTS
1265      C
          C      VM=2300.
          C      IF (HPPF .LT. 250.) VM = 480.
          C      IF (HPPF .GT. 2000.) VM = 6900.
          C      DPTWR = DIST
1270      C      DTTSG = OTOW / 4. * (ITOWN*(3./2.) + 1.)
          C      DSGTM = OTOW / 2. + DTTSG / 2.
          C      IF (HPPF .LT. 251.) TRMA = 225000./NOF + 7.88*HPPF * (115. + .159
          C      * HPPF) * HPPF
          C      IF (HPPF .GE. 251.) TRMA = 225000./NOF + 7.83*HPPF *
1275      C      870./SQRT(HPPF) * HPPF
          C      VS = 7500.
          C      IF (HPPF .LT. 2000.) VS = 13300.
          C      TRMB = (DPTWR*DTTSG-1000.) * (37. + .47*HPPF*NOF / SQRT(VS)
          C      * .5 * NOF) / NOF
1280      C      TRMC = (100. + 1.1*HPPF) * (DSGTM-250.) / SQRT(VM)
          C      CSR = HPPF * 55. + HPPF** 1.5 * 1000.
          C      FANLEC = TRMA + TRMB + TRMC
          C
          C      FAN MOTOR COSTS
1285      C
          C      FMC = 56.62
          C      IF (HPPF .GT. 300.) FMC = 24.33.
          C      BIGMC = 0.0
          C      IF (HPPF .GT. 300.) BIGMC = 9000.
1290      C      CMOT = HPPF * FMC + BIGMC
          C
          C      TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM
          C
          C      70 TOTHP=HPPF*NOF
1295      C
          C      CAPITAL COSTS OF THE FAN
          C
          C      IF (I.LT.88) FCST=FANDAP(I,9)*(22.4*FANDAP(I,8)+60.)+19.2*FANDAP(I,8
          C      *)
          C      IF (I.GE.88) FCST=FANDAP(I,9)*(51.2*FANDAP(I,8)+950.)+135.6*FANDAP(I
          C      *.8)+2700.
          C      EFCSF = 1.05
          C      FCST = FCST * EFCSF
          C      SAAFI = 1.15
1305      C      HFR = 13. / 24. * FAND
          C
          C      STACK COSTS WITH VELOCITY RECOVERY
          C      IF (VELDEC.EQ.1.) CFROS= UCS * J * S * PI * (FAND*HFR*TANB) * HFR
          C      * SQRT(1. + TANB**2)
1310      C      * UCS * UWS * PI * (FAND*HFR*TAN19) * H8
          C      * SQRT(1. + TAN19**2)

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      C
      C      STACK COSTS WITH OUT VELOCITY RECOVERY
      C      IF (VELREC .EQ. 0.) CPROS = CVM * WFM * PI * FAND**5 / 6.
1315      * UCS * UWS * PI * (FAND + HB * TAN19) * HB
      * SQR(1. + TAN19**2)
      C
      C      INCREASING THE FAN COSTS TO TAKE INTO ACCOUNT FOR SHIPPING
      C      AND ASSEMBLY OF FAN SYSTEM COMPONENTS
1320      CPROS = CPROS * SAAF * POHFAN
      FOST = POHFAN * SAAF * FOST
      CSR = POHFAN * SAAF * CSR
      CMOT = CMOT * POHFAN * SAAF
      FANLEC = FANLEC * POHLEC
1325      C
      C      TOTAL CAPITAL COST OF THE FAN SYSTEM
      TCSTF = FOST + CMOT + CSR + FANLEC + CPROS
      TCSTF = TCSTF * NOF
      C
1330      C      ANNUAL COST OF THE FAN SYSTEM
      ANFCOS = (TCSTF * TOTHP * .7457 * PLANC) * FCR * EHR * FCOS / 10 * .9 * TOTHP *
      S.7457 * CAPF * 8760.
      C
1335      C      COST OF PLENUM
      C
      CPL = CPM * WPL * (ITOWN * PI / 4. * DTOW**2 - NOF * PI / 4. * (FAND + 3.5)
      S **2)
      CPL = CPL * POHSTC
1340      C
      C      STRUCTURAL AND FOUNDATION COSTS OF THE CIRCULAR TOWER
      C
      STRUCC = .2458 * (PI * DTOW**2 / 4.) * ELENG * ITOWN
      * (.00685 * ROOFL * .725)
1345      STRUCC = STRUCC * POHSTC
      FNDC = .019 * (WHX * WATERW) * .92 * (PI / 4.) * DTOW**2 * ITOWN
      FNDC = FNDC * POHSTC
      C
      C      ANNUAL FAN, STRUCTURAL AND FOUNDATION COSTS
      C
1350      ANSEPC = (CPL + STRUCC + FNDC) * FCR
      ANSEPF = ANSEPC + ANFCOS
      C
      C      STORAGE OF DESIGN PARAMETERS FOR THE LEAST COST FAN SYSTEM TO
      C      TO BE PRINTED OUT BY THE SUBROUTINE RPTFAN
1355      C
1360      IF (ANSEPF .GT. AFC) GOTO 400
      AFC = ANSEPF
      AFCH = ANFCOS
      AC = TCSTF
      AHP = TOTHP
      ADIA = FANDAP(1.9)
      APLN = FANDAP(1.9)
      HLDANG = FANDAP(1.10)
      XNFAN = NOF
1365      NUMTOW = ITOWN
      CTOW = DTOW
      AVEL = VEL
      CPERF = CPMF

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1370      HDPPEF=HDDF
      TPC=TP
      TOTCF=TOTCFM
      FBCPF = FCST
      FMCPE = CMOT + CSR
      CPLEN=APL
1375      CYLRNG = CFROS
      HPAIR=OTHP
      FPOV=TCTHP/1.341
      DPPEL=(VP/(.07495*SPVOL))*5.2022
      DPHX = OPTINW * 5.20213 / 144.
1380      HURDIA = SQRT (ADIA**2 - 4.*A/3.14159)
      TCTPF = TCSTPF
      FDCPF = FCST
      FMTPO = CMOT
1385      ACCTP = (OPTINW + VP/(.07495*SPVOL)) * 5.2018/144.
      CFANEL = FANLEC
      ADJTP = TP * 5.20214/144.
      ACTAPD = DPHX
      ADJAPD = DPHX * .07495*SPVOL
      ACTVH = DPPEL/144.
1390      ADJVA = VP * 5.20213 / 144.
      ADJAPF = HDDF * SPVOL * .07495
      THPAIR = HPAIR
      TCTFI = AC
      AFCST = AFCH
1395      CSRD = CSR
      400 CONTINUE
      RETURN
      END

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SUBROUTINE HXPER(OD, REAIR, OFIN, PF, THFIN, HO)
 DATA PRNDTL /0.709/, CONAIR /0.01516/

THIS ROUTINE DETERMINES THE AIR SIDE HEAT TRANSFER
 COEFFICIENT USING THE CORRELATION DEVELOPED BY PFR.

DEFINITION OF VARIABLES

ARAT - RATIO OF FINNED TUBE HEAT TRANSFER AREA TO AREA OF
 BASE TUBE OF ROOT DIAMETER (DIMENSIONLESS)
 CONAIR - THERMAL CONDUCTIVITY OF AIR (BTU/HR FT DEG F)
 ODIN - OUTSIDE DIAMETER OF FINS (INCHES)
 FINHT - FIN HEIGHT (INCHES)
 HO - AIR-SIDE HEAT TRANSFER COEFFICIENT
 (BTU/HR SQ FT DEG F)
 PF - FIN PITCH (FINS/INCH)
 PRNDTL - PRANDTL NUMBER (DIMENSIONLESS)
 REAIR - REYNOLDS NUMBER OF AIR (DIMENSIONLESS)
 THFIN - FIN THICKNESS (INCHES)

FINHT = (OFIN-OD) / 2.

ARAT = 1. + 2.*PF*FINHT * (1. + (FINHT + THFIN) / OD)

HO = 0.29*(CONAIR/OD) * PRNDTL**.333 * REAIR**.633 / ARAT**.17

HO = HO * 12.

RETURN

END

SUBROUTINE FFRFR (HYDDIA, PL, GAIR, FAIR)
DATA VISAIR /0.045/

THIS ROUTINE DETERMINES THE AIR-SIDE FRICTION FACTOR USING
THE CORRELATION DEVELOPED BY PFR.

DEFINITION OF VARIABLES

FAIR - AIR-SIDE FRICTION FACTOR (DIMENSIONLESS)
GAIR - MASS VELOCITY OF AIR (LBM/HR SQ FT)
HYDDIA - HYDRAULIC DIAMETER OF FINNED TUBE (INCHES)
PL - TUBE PITCH IN THE DIRECTION OF AIR FLOW (INCHES)
REHYD - REYNOLDS NUMBER BASED ON HYDRAULIC DIAMETER
(DIMENSIONLESS)
VISAIR - VISCOSITY OF AIR (LBM/FT HR)

REHYD = HYDDIA * GAIR / (VISAIR * 12.)
IF (PL/HYDDIA .GT. 4.) FAIR = .3 * (150./REHYD + 1.8/REHYD**2)
* (PL/HYDDIA) **.35
IF (PL/HYDDIA .LE. 4.) FAIR = .5 * (13.6/REHYD**.3) *
(HYDDIA/PL) **.42
RETURN
END

SUBROUTINE FRICHO(K,FAIR,H0,OD,DFIN,PT,PL,SF,TF,GAIR)

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C
C      FRICHO CALCULATES THE FRICTION FACTOR AND HEAT TRANSFER
C      COEFFICIENT FOR AIR FLOW NORMAL TO A BANK OF FINNED HEAT
5      EXCHANGER TUBES. THESE VARIABLES CAN BE DETERMINED FOR
C      AN EQUILATERAL OR ISOSCELES TRIANGULAR ARRANGEMENT OF THE
C      TUBES.
C
C      DEFINITION OF VARIABLES
10      CONA      - THERMAL CONDUCTIVITY OF AIR (BTU/HR-FT-DEG F)
C      DFIN      - DIAMETER OF FIN (IN)
C      ENGT      - HEIGHT OF FIN (IN)
C      FAIR      - AIR SIDE FRICTION FACTOR FOR FINNED TUBES
15      F1-F4     - CORRELATION COEFFICIENTS FOR AIR SIDE FRICTION
C                  FACTOR (DIMENSIONLESS)
C      GAIR      - AIR SIDE MASS FLUX (LBM/SQ FT HR)
C      H0-H5     - CORRELATION COEFFICIENTS FOR AIR SIDE HEAT TRANSFER
20      COEFFICIENT (DIMENSIONLESS)
C      OD        - ROOT DIAMETER OF FIN (IN)
C      PL        - LONGITUDINAL TUBE PITCH (IN)
C      PR        - PRANDTL OF NUMBER OF THE AIR (DIMENSIONLESS)
C      PT        - TRANSVERSE TUBE PITCH (IN)
25      REAIR     - REYNOLDS NUMBER OF AIR (DIMENSIONLESS)
C      SF        - SPACING BETWEEN FINS (IN)
C      TF        - THICKNESS OF FINS (IN)
C
C      DATA F1,F2,F3,F4/18.93,-0.4315,-0.927,0.515/
30      DATA H1,H2,H3,H4,H5/0.1347,0.681,0.3333,0.200,0.1134/
C
C      TUBE ARRANGEMENT VARIABLE K
C      1 - EQUILATERAL CONFIGURATION
C      2 - ISOSCELES CONFIGURATION
35
C      FRICTION FACTOR
C
C      REAIR = OD*GAIR/(.0450*12.0)
C      IF(K.EQ.1) GO TO 10
40
C      ISOSCELES
C      FAIR = F1*(REAIR**F2)*((PT/OD)**F3)*(PT/PL)**F4
C      GO TO 20
C
C      EQUILATERAL
45      10 FAIR = F1*(REAIR**F2)*((PT/OD)**F3)
20      CONTINUE
C
C      HEAT TRANSFER COEFFICIENT
50
C      PR = .69
C      CONA = .01516
C      ENGT = (DFIN-OD)/2.
C      H0 = (12.*CONA/OD)*H1*(REAIR**H2)*(PR**H3)*((SF/ENGT)**H4)*(SF/TF
55      )**H5
C      RETURN
C      END

```

SUBROUTINE HEADER (GPMHDR, NBRANCH, BRCHGPM, RED, NN, J, DIA, REDCOST, STEECOST, ELCOST, UPIPCST, VELO, EJCOST, FLGCOST, DESVEL)

```

5      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)
10     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)
15     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)
20     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
25     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
30     C      PIPICST - 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
35     C      SECTIONS (INCHES). ONLY USED WHEN RED=0
      C      TEECOST - TEE COST ($1000)
      C      UPIPCST - UNIT PIPE COST ($1000/FT)
40     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)
45     C
      C      COMMON /CPIPE / APIPCST(23), DIA(23), EJCST(23), ELCST(23)
      C      $, FLGCST(23)
      C      $, ELCST(23), PIPICST(23), REDCOST(23), TEECST(23), VACST(23)
      C      COMMON /PRESS/ IPRESS
      C      DIMENSION VELO(500)
      C      DIMENSION DIA(500), REDCOST(500), TEECOST(500), UPIPCST(500)
50     C      LOGICAL CALL 1
      C      DATA DIA/12.,18.,24.,30.,36.,42.,48.,54.,60.,66.,72.,78.,84.,
      C      90.,96.,102.,108.,114.,120.,126.,132.,138.,144./
      C      DATA FLGCST/.342.,.518.,.893.,1.145.,1.298.,1.934.,2.471.,3.218.,3.966.,
      C      45.53,7.134,9.815,12.496,14.725,16.954,20.455,23.955,25.81,27.264,
55     C      28.918,30.572,32.225,33.88/
      C      DATA EJCST/.56,1.11,1.66,2.17,2.53,3.4,4.24,5.8,7.24,8.68,
      C      10.07,11.46,13.95,16.45,19.94,23.24,26.93,30.62,34.14,37.66,

```

```

541.18,44.7,48.22,51.74/
DATA REECST/.7,.8,.9,1.3,1.65,2.0,4.65,5.45,6.3,7.1,9.5,11.5,
60 $13.3,15.5,17.5,19.3,45.5,60.,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,
$29.561,37.261,42.1,46.944,51.795,65.968,71.,104.2,117.5,131.25,
$144.,158.,170.,185./
DATA PIPCST/.115,.15,.185,.225,.26,.295,.42,.465,.51,.555,.665,
65 $.71,.75,.795,.94,.99,1.25,1.235,1.39,1.445,1.505,1.555,1.61/
DATA APIPCST/.072,.100,.122,.143,.172,.198,.299,.328,.360,.390,
1.495,.525,.555,.585,.714,.745,1.028,1.070,1.11,1.15,1.19,1.23,
21.27/
DATA EECST/.536,1.34,2.04,2.60,3.15,3.71,6.03,14.2,20.4,26.5,
70 134.1,30.4,44.6,49.8,64.9,70.2,102.,116.,129.,143.,157.,171.,185./
DATA CALL 1 /.TRUE./
DATA NPS/23/, NPL/500/

C
C
75 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
80 IF (CALL 1 .AND. IPRESS .EQ. 125) CALL P125
CALL I = .FALSE.
DO 24 I=1,NPL
REDCOST(I)=0.
TEECOST(I)=0.
65 24 CONTINUE
EJCOST=0.
ELGCOST=0.

C
C
90 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.
95 CONST1=(3.1416/4.)*7.481*60.*DESVELI
CONST2=(4./3.1416)*144./(60.*7.481)

C
C
100 C      IF HN=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      SINGLE 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
105 C      BRANCH TEE COST (BRCHCST) BELOW.
C

IF (HN=.0.1) GO TO 23
BRCHDIA=SQRT(BPC+GPM/CONST1)*12.
IF (BRCHDIA.LT.DIAM(1)) BRCHDIA=DIAM(1)
DO 10 I=1,NPS
110 II = I
IF (BRCHDIA-DIAM(II)) 11,11,10
10 CONTINUE
11 BRCHDIA=DIAM(II)
23 J=1

```

```

115      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
120      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
125      C22 DIA(J)=SORT(GPMREM/CONST1)*12.
      C      DO 12 I1=1,NFS
      C      I = 11
      C      IF(DIA(J)-DIAM(I))13,13,12
      C      12 CONTINUE
130      C      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
135      C      IF(J.EQ.1 .AND. VN.NE.1) EJCOST=EJCST(1)
      C      IF(J.EQ.1 .AND. VN.NE.1) FLGCOST=3.*FLGCST(1)
      C
      C      IN THE STATEMENTS THROUGH STATEMENT 17 THE REDUCTION IN
      C      HEADER PIPE SIZE IS SPECIFIED. THE REDUCER COST IS DETER-
140      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
145      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.
150      C
      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
155      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.
160      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-
165      C      FIED AND DIAMETER J IS ASSIGNED A VALUE OF 96 INCHES. LARGE
      C      VALUES OF RED RESULT IN PIPE SIZES LARGER THAN REQUIRED BUT
      C      FEWER REDUCERS ARE REQUIRED.
      C
170      C      IF(RED.NE.0.) GO TO 14
      C      IF (ABS(DIA(J)-DIA(J-1)).LT.0.1) GO TO 15

```


C CALCULATION OF REDUCTION. RED NOT SPECIFIED.

C

175

REDUCT=DIA(J-1)-DIA(J)

M = REDUCT/6. + .01

IJ = I

GO TO 16

C

188

C

RED SPECIFIED, POSSIBLE REASSIGNMENT OF DIAMETER J.

C

14 IF (DIA(J)-0.1*G1*DIA(J-1)-RED) GO TO 17

DIA(J)=DIA(J-1)-RED

M = RED / 6. + .01

IJ = I + (DIA(J) - DIAM(I)) / 5. + .01

185

C

C

C

C

190

C

C

C

C

C

C

DETERMINE REDUCER COST. IT HAS BEEN ASSUMED FROM THE REDUCER COST DATA THAT, FOR EXAMPLE, A 96 INCH REDUCER WILL COST THE SAME WHETHER THE REDUCTION IS TO 90, 84, OR 78 INCHES. IF THE TOTAL REDUCTION BETWEEN ADJACENT HEADER SECTIONS EXCEEDS 18 INCHES THEN AN ADDITIONAL REDUCER MUST BE COSTED. IN THE EXAMPLE, THIS WOULD BE A 78 INCH REDUCER. IF THE TOTAL REDUCTION EXCEEDS 36 INCHES, SAY 96 TO 54, THEN A 96, 78, AND 60 INCH REDUCER WOULD BE COSTED, AND SO ON.

195

C

16 K=0

JJ=M

IF (JJ + IJ .GT. NFL) STOP"IN HEADER JJ+IJ EXCEEDS NFL"

18 REDCOST(J-1) = REDCOST(J-1) + REDCOST(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

IF (M+I .GT. NFL) STOP"IN HEADER M+I EXCEEDS NFL"

208

C

C

C

C

210

C

C

C

C

C

DETERMINE TEE COSTS. IF THE LAST HEADER SECTION IS BEING DESIGNED THEN USE AN ELBOW RATHER THAN A TEE. THE TEE COST IS ASSUMED TO BE .47* THE COST OF A TEE OF THE "RUN" DIAMETER PLUS .33* THE COST OF A TEE OF THE "BRANCH" DIAMETER. THE 9 INCH BRANCH DIAMETER CONNECTING THE QUADRANT HEADER TO THE BUNDLE HEADER IS NOT AN ARRAY VALUE. BRCHCST IS ASSIGNED A VALUE OF \$200.

215

C

IF (ABS(GPMREN-BRCHGPM).LT.0.01) GO TO 19

IF (NN .NE. 1) BRCHCST = TEECST(11) * .33

IF (NN .EQ. 1) BRCHCST=.2

TEECOST(J)=TEECOST(I+M)*0.67+BRCHCST

GO TO 20

220

C

19 ELCOST=ELCOST(I+M)

C

C

C

C

225

C

MAIN CIRCULATION PIPING IS UNDERGROUND. QUADRANT PIPING IS ABOVE GROUND. FITTINGS COSTS WERE NOT DEPENDENT ON ABOVE OR BELOW GROUND SPECIFICATION.

20 IF (NN .NE. 1) UPICOST(J) = PICOST(I+M)

IF (NN .EQ. 1) UPICOST(J)=APICOST(I+M)

VELD(J)=(GPMREN/DIA(J)+*2)*CONST2

SUBROUTINE HEADER

74/74 OPT=1

FTN 4.2+74351

12/21/76

```
530      C
531      C      SUBTRACT OUT THE FLOW TO ONE BRANCH FROM THE FLOW IN THE
532      C      HEADER. IF NO FLOW REMAINS THEN THE LAST HEADER SECTION HAS
533      C      BEEN DESIGNED. THERE ARE FINALLY J SECTIONS IN THE HEADER.
534      C
535      GPMREM=GPMREM-BRCHGPM
536      IF (GPMREM.LE.1.0) GO TO 21
537      J=J+1
538      IF (J.GT. NFL) STOP "IN HEADER  J EXCEEDS NFL"
539      GO TO 22
540      21 CONTINUE
541      RETURN
542      END
```

SUBROUTINE INPSUM

THIS ROUTINE REPORTS INPUT SUMMARY AND CASE DESCRIPTION

LOGICAL FIRST, EXTEMP
COMMON

5 \$ AFTR, ALPHA
 6 \$ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAF
 7 \$ CRU, CTURB, COANG, CLUVR, CHAILE, CVM
 10 \$ DANGLE, DEIN, DEEPL, DESVEL
 8 \$ EFFP

9 \$ FCR, FIRST, FIXL, FCOS, FFHX, EXTEMP
 10 \$ GREFF

11 \$ HXNP, HPCST
 15 \$ ITMAX, ITMIN

12 \$ JCOUS
 13 \$ KCONG, KALEXT
 14 \$ MXEXT

15 \$ NTUCAL(2), NTA

16 \$ NTUCAL(2), NTA
 20 COMMON

21 \$ DDZ

22 \$ PSIZE, PER, PWOS, PLANC, PFACT, POMDPL

23 \$ PCHBAF, PCHBAN, PCHLEC, PCHCIR, PCHCND, PCHSTC, PCHSCL

24 \$ PREU, PREUCE

25 \$ RRP, REDUCE, ROOFL, RFIX

26 \$ SIGMA, SAAF

27 \$ TD, TPO(4), TEFF, TLIM, TREN, TLPA, TFIX

28 \$ TCD, TW

29 \$ UCS, UWS

30 \$ VAS(5)

31 \$ WFW

32 \$ XDEPA, XW, XD

33 COMMON/FAN/ FANDAP(153,10), FANDAH(153,10), FMCPP, FRCPP, P2, R, S,

34 \$ VELREC, AFO, ELEV, EHP

35 COMMON /TIME2/ COM

126 FORMAT(//79X,"COEFFICIENTS FOR POLYNOMIAL CURVE FIT")

127 FORMAT(79X,"A0",11X,"A1",11X,"A2",11X,"A3",11X,"A4")

128 FORMAT("HEAT RATE FACTOR AS FUNCTION OF BACKPRESSURE (INCHES OF M

129 \$ RECOVERY) ",1P5E13.5//)

40 129 FORMAT(T4,"TURBINE RATING BACKPRESSURE",F6.2," INCHES OF MERCURY")

130 FORMAT(T4,"SITE ELEVATION",F7.0," FEET ABOVE SEA LEVEL")

202 FORMAT(1H,130,"INPUT SUMMARY AND CASE

203 \$ DESCRIPTION")

45 204 FORMAT(T2,3("-----"),T30,2("-----"),"-")

206 FORMAT(T2,"OPTIONS SELECTED FOR THIS RUN",T30,"STARTING CONDITIONS

207 \$")

200 FORMAT(1H3)

207 FORMAT(T4,"FRICTION FACTOR AND HT TRFR COEFF BY ",A10)

210 FORMAT(T4,"EXCHANGER DEPTH UNCONSTRAINED")

50 208 FORMAT(T6,"UPPER LIMIT ON TURBINE TEMP",F6.1," F")

215 FORMAT(T4,"EXCHANGER DEPTH CONSTRAINED TO ",A4,1X,F5.1," TUBES")

217 FORMAT(1H+,152,"PLUS OR MINUS ",F5.3)

220 FORMAT(1H+,180,"TURBINE OUTLET TEMPERATURE, T1",F10.3," F")

225 FORMAT(T4,"EXCHANGER LENGTH UNCONSTRAINED")

55 230 FORMAT(T4,"EXCHANGER LENGTH FIXED AT ",F5.0," FEET")

235 FORMAT(1H+,189,"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, AFROV",F11.0)
60 255 FORMAT(T4,"NTU CALCULATION IS BY ",2A10)
260 FORMAT(1H+.T82,"WIDTH TO LENGTH RATIO, WLRAT",F10.3)
300 FORMAT(//T51,"UNIT COSTS AND COSTING FACTORS"/T51.30(" ")/)
305 FORMAT(T2,"FUEL ",F7.3," CENTS/M3BTU"
      1.T30,"POWER PLANT CONSTRUCTION",F11.3," $/KW"
65 1.T104,"FIXED CHARGE RATE",F9.3)
310 FORMAT(T2,"LAND ",F7.3," $/SQ FT"
      1.T30,"REPLACEMENT POWER",7X,F11.3," MILLS/KWH"
      1.T106,"CAPACITY FACTOR",F9.3)
70 315 FORMAT(T2,"MOTORS",F7.3," $ / HP"
      1.T30,"STEAM SUPPLY",T54,F11.3," $/KW TURBINE OUTPUT"
      1.T99,"BASE THERMAL EFFICIENCY",F9.3)
320 FORMAT(T30,"CAPACITY CHARGE",T54,F11.3," $/KW"
      1.T93,"CONSTRUCTION COST MULTIPLIER",F9.3)
75 325 FORMAT(T95,"MAINT COSTS /CAPITAL COSTS",F9.3)
      WRITE(6,202)
      WRITE(6,204)
      WRITE(6,206)
      WRITE(6,204)
      WRITE(6,200)
80 80  WRITE(6,208) TLM
      WRITE(6,207) FFHX
      C
      LOGSYM = ".LE."
      IF (DEEPL.GT.0.0) LOGSYM = ".GE."
85 85  IF (POMDPL.GT.0.0) LOGSYM = " "
      IF (DEEPL.EQ.0.0) WRITE(6,210)
      IF (DEEPL.NE.0.0) WRITE(6,215) LOGSYM, ABS(DEEPL)
      IF (POMDPL.GT.0.0) WRITE(6,217) POMDPL
      C
90 90  WRITE(6,220) VAS(1)
      C
      IF (FIXL.EQ.0.0) WRITE(6,225)
      IF (FIXL.NE.0.0) WRITE(6,230) FIXL
      C
95 95  WRITE(6,235) VAS(3)
      C
      IF (VELDEC.EQ.0.0) WRITE(6,245)
      IF (VELDEC.NE.0.0) WRITE(6,240)
      C
100 100 WRITE(6,250) VAS(4)
      C
      WRITE(6,255) NTUCAL
      WRITE(6,260) VAS(5)
      C
105 105 C
      C
      WRITE(6,126)
      WRITE(6,127)
      WRITE(6,128) (TPO(I),I=1,4)
110 110 WRITE(6,129) BRP
      WRITE(6,130) ELEV
      C
      WRITE(6,300)
      WRITE(6,305) FCOS,PLANC,FCR

```

SUBROUTINE INPSUM 74/74 OPT=1

FTN 4.2.74351

12/21/66

```
115      WRITE(A,310) COSTL,PWCOS,CAPF  
      WRITE(A,315) HPCST,CSSPKW,TEFF  
      WRITE(A,320) CAPCHG,CCM  
      WRITE(A,325) PER  
120      RETURN  
      END
```

```

      SUBROUTINE HYDLOS(DIA,VEL,VIS,RHO,ID,HDL$)
C
C      SUBROUTINE HYDLOS FOR GIVEN VALUES OF INSIDE DIAMETER,
C      VELOCITY, VISCOSITY, AND DENSITY, DETERMINES THE FRICTION
5      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.176
10
C      DIMENSION EP(3)
C
C      INSIDE SURFACE PROTUBERANCES FOR COMMERCIAL TUBING AND PIPE
15
C      DATA EP/0.00006,0.0019,0.0102/
C
C      CALCULATE REYNOLDS NUMBER AND DETERMINE IF IN LAMINAR OR
C      TURBULENT REGION
20
C      RE=308.*RHO*VEL*DIA/VIS
C      IF(RE-2000.)100,101,101
C
C      CALCULATE LAMINAR FLOW FRICTION FACTOR
25
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.
30
101  RF=DIA/EP(ID)
      RF=4.*ALOG10(RF)+2.23
C
C      CHECK TO DETERMINE IF TURBULENT FLOW IS FULLY DEVELOPED
35
      CF=RF/RE
      IF(CF-0.01)104,103,103
C
C      DETERMINE RECIPROCAL OF SQUARE ROOT OF FRICTION FACTOR
40
C      FOR TRANSITION FLOW INITIALLY ASSUMING IT TO BE THE SAME AS
C      FOR FULLY TURBULENT FLOW
C
103  TRF=RF
107  TRFC=RF-4.*ALOG10(1.+4.67*RF-TRF/RE)
45
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
50
C      CALCULATION
C
      IF((ABS(TRFC-TRF)/TRF)-0.001)105,105,106
106  TRF=TRFC
      GO TO 107
55
C
C      CALCULATE FULLY DEVELOPED TURBULENT FLOW OR TRANSITION FLOW
C      FRICTION FACTOR

```

SUBROUTINE HYDLOS

74/74 OPT=1

FTN 4.2+74351

12/21/76

```

      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)

SUBROUTINE NOVART CALCULATES THE PERFORMANCE OF THE POWER PLANT AND DRY COOLING TOWER UNDER THE ASSUMPTION THAT THE AIR SIDE HEAT TRANSFER COEFFICIENTS AND AIR VELOCITY THROUGH THE HEAT EXCHANGER TUBES ARE UNCHANGED

DEFINITION OF VARIABLES

CAPCHG - GAS TURBINE CAPITAL COST (\$/MW)
 CIPRST - COST OF GAS TURBINE (\$)
 CAPE - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER (PERCENT)
 CCOO - COST OF THE DRY COOLING TOWERS (\$)
 CLAND - COST OF LAND TAKEN UP BY THE DRY COOLING TOWERS (\$)
 CONBAS - COST OF SURFACE CONDENSER (\$)
 CDSM - COST OF MAINTAINING THE DRY COOLING TOWERS (\$)
 CPIP - COST OF PIPING AND PUMPING SYSTEMS (\$)
 CATCH - COST OF MAKE-UP POWER BY GAS TURBINES AT EACH AMBIENT AIR TEMPERATURE (MILLS/KW-HR)
 DFLFC - INCREMENTAL FUEL COST FOR STEAM SUPPLY SYSTEM (MILLS/KW HR)
 EFF - HEAT EXCHANGER EFFECTIVENESS OF DRY COOLING TOWERS (DIMENSIONLESS)
 EFFC - CONDENSER EFFECTIVENESS
 FPOS - FUEL COST FOR THE STEAM SUPPLY SYSTEM (MILLS/BTU)
 FAP - FIXED CHARGE RATE ON CAPITAL PER YEAR (PERCENT)
 FPOW - POWER REQUIREMENTS OF FAN SYSTEM (KW)
 HRFAC1 - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK PRESSURE (DIMENSIONLESS)
 HRFAC2 - HEAT RATE FACTOR OF STEAM TURBINE AT DESIGN CONDITIONS OF POWER PLANT (DIMENSIONLESS)
 HRFAC4 - HEAT RATE FACTOR OF STEAM TURBINE AT A PARTICULAR AMBIENT AIR TEMPERATURE (DIMENSIONLESS)
 P - BACK PRESSURE OF STEAM TURBINE (IN. HG.)
 PARCOS - INCREMENTAL POWER PRODUCTION COST OF THE DRY COOLED POWER PLANT FOR A PARTICULAR AMBIENT AIR TEMPERATURE (MILLS/KW-HR)
 PGEN - POWER OUTPUT OF PLANT AT A PARTICULAR AMBIENT AIR TEMPERATURE (MW)
 PPOW - POWER REQUIREMENTS OF THE PIPING SYSTEM (KW)
 PISZ13 - POWER OUTPUT OF STEAM TURBINE AT RATED BACK PRESSURE TO PRODUCE REQUIRED OUTPUT OF PLANT AT DESIGN CONDITIONS (MW)
 PIOT - POWER OUTPUT OF PLANT AT SPECIFIED AMBIENT AIR TEMPERATURE (MW)
 PFCOS - COST OF FUEL FOR GAS TURBINE (MILLS/KW-HR)
 QINI - THERMAL ENERGY OUTPUT OF STEAM SUPPLY SYSTEM AT RATED BACK PRESSURE OF TURBINE (BTU/HR)
 QREJCT - HEAT REJECTED AT A SPECIFIED AMBIENT AIR TEMPERATURE (BTU/HR)
 RANGE - TEMPERATURE RANGE OF WATER PASSING THROUGH THE HEAT EXCHANGER (DEG F)
 SCOD - INCREMENTAL COST OF PLANT DUE TO SCALE UP OF STEAM SUPPLY SYSTEM AND THE SCALE UP OF THE PLANT TO TAKE INTO ACCOUNT FOR FAN AND PUMP POWER REQUIREMENTS (\$)


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C      TA      - AMBIENT AIR TEMPERATURE (DEG F)
C      TEFF    - THERMAL EFFICIENCY OF CONVENTIONAL STEAM TURBINE
60      C      AT RATED BACK PRESSURE (DIMENSIONLESS)
C      TEFF1   - THERMAL EFFICIENCY OF STEAM TURBINE AT RATED
C      C      BACK PRESSURE (DIMENSIONLESS)
C      TEFF3   - THERMAL EFFICIENCY OF STEAM TURBINE AT POWER
C      C      PLANT DESIGN CONDITIONS (DIMENSIONLESS)
65      C      TEFF4   - THERMAL EFFICIENCY OF STEAM TURBINE ASSOCIATED
C      C      WITH A PARTICULAR AMBIENT AIR TEMPERATURE
C      C      (DIMENSIONLESS)
C      TLIM    - LIMIT ON THE TEMPERATURE EXITING THE STEAM
C      C      TURBINE (DEG F)
70      C      TPER   - PERCENT OF TIME AN AMBIENT TEMPERATURE OCCURS
C      C      DURING THE YEAR (PERCENT)
C      TPO     - COEFFICIENTS FOR THIRD ORDER CURVE FIT OF STEAM
C      C      TURBINE HEAT RATE FACTOR (DIMENSIONLESS)
C      TTDPR   - TERMINAL TEMPERATURE DIFFERENCE OF SURFACE
75      C      CONDENSER FOR A PARTICULAR AMBIENT AIR TEMPERATURE
C      TVAL3   - THERMAL CAPACITY RATIO OF THE WATER TO THE AIR
C      C      PASSING THROUGH THE HEAT EXCHANGER (DIMENSIONLESS)
C      TT      - EXIT TEMPERATURE OF STEAM TURBINE (DEG F)
C      VCOST   - TOTAL INCREMENTAL COST OF DRY COOLING (MILLS/KW-HR)
80      C      WTA    - MASS FLOW RATE OF WATER THROUGH THE HEAT EXCHANGER
C      C      (LBM/HR)
C      XCOST   - INCREMENTAL COST OF DRY COOLING FOR EACH AMBIENT
C      C      AIR TEMPERATURE (MILLS/KW-HR)
85      C      YEP    - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR
C      C      FAN AND PUMP POWER (DIMENSIONLESS)
C
      REAL XCOST(9)
      COMMON /VAPVAR/ VTPER(16),VTA(16)
      LOGICAL FIRST, FXTMP
90      COMMON
      $ AFTR, ALPHA
      $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
      $ ,CRU, CTUR3, COANG, CLUVR, CHALS, CVM
      $ ,DANGLE, DFIN, DEEPL, DESVEL
95      $ ,TEFF
      $ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
      $ ,GREFF
      $ ,HXNP, HPCST
      $ ,ITMAX, ITMIN
100      $ ,JCONC
      $ ,KCONC, KALEXT
      $ ,MXCOST
      $ ,NTUCCL(2), NTA
      COMMON
105      $ ,QDR
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      $ ,POHRAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCD
      $ ,PREU, PREUCE
      $ ,RAP, REDUCE, ROOFL, RFIX
110      $ ,SIGMA, SAAF
      $ ,TD, TPO(4), TEFF, TLIM, TFIN, TLPRA, TFIX
      $ ,TCD, TW
      $ ,UCS, UWS
      $ ,VAS(7)

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115      S ,WFM
      S ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W2, COSM, EFF,
      S QIN, CLAND, REAIR, Z,HRFAC2, W4, U, DELPW, PPW,
120      S FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HT, HO, T4,
      S REWAT, NW, NT, NP,PLANC2,PSIZ12, SPSS, SW4, SW3,
      S SPC,TOTAL,PLANC3,SAFROV, AAIR, YFP, SPCD,PSIZ13, WT2,
      S RPP, NW2, TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      S , TL,X, UCON, FMCST, FMCST, FRACC, EFFC, CH, CA, CS
125      S , CLIC, CFC, CPOC, FITC, CSC,CEPREP,DELPD, AST,OLDCST
      S ,CARCST, XNFAN,BLOANG, CPLEN, DPFL, WHX, ATTUR, ADIA, ABLN
      S , ATTHR, WTERF,STRJCC,CPREF,HPREF, TOTCF, TPC, EFFIN, ANTU
      S , ATREF, WATER, XNM00, TOTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      S , ACTRD, ADJRPD, ACTVH, ADJVV, ADJPPF, THPAIR, TCTF, AFCST
130      S , CSRH, WATERH, WSTRCT, CFJND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S ,ATURH, CSTLV9, CSTHS, CYLRNG, CFANEL
      COMMON /SCALER/HRFAC1, ATUR, CPERA, SSCD,PLANC1,CASSS1,
      S GAIR, FAIR, HPAIR, HPWAT, PLAVCT1
      DIMENSION VLIST(9)
      DATA NTRIP/0/
135      DATA VLIST /"CCOS","SPCD","CLAND","CPIP","CONBAS","COSM"
      S , "WTERF","CARCOS","VOST"/

      C
      C      THERMAL EFFICIENCY OF TURBINE AT THE DESIGN POINT OF THE
      C      PLANT.
140      C
      C      TEFF3=TEFF/HRFAC2
      C
      C      THERMAL EFFICIENCY OF TURBINE AT THE RATED BACK PRESSURE
      C
145      C
      C      TEFF1=TEFF/HRFAC1
      C      QIN1=3413.2*B * PSIZ13/TEFF1
      C      VOST=0.0
      C
      C      START OF LOOP FOR CALCULATING THE INCREMENTAL COST OF DRY
150      C      COOLING FOR EACH TEMPERATURE RANGE
      C
      C      DO 800 I=1,NTA
      C
      C      AMBIENT AIR TEMPERATURE AND PERCENTAGE OF YEAR OVER WHICH
155      C      TEMPERATURE OCCURS.
      C
      C      TA=VTA(I)
      C      TPER=V+PER(I)
      C
160      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
165      C
      C      T1=140.
      C      1 P=EXP((17.169-9240./(T1+460.))
      C      HRFAC4=TPD(1) + TPD(2)*P + TPD(3)*P**2 + TPD(4)*P**3
      C      TEFF4=TEFF/HRFAC4
      C
170      C
      C      TEMPERATURE RANGE OF WATER FLOWING THROUGH THE HEAT EXCHANGER
      C      PREJCT=QIN1*(1.-TEFF4)

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      RANGE=PREJCT/(WB*(1.+YFP))
      C
      C      TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND THE
775  C      STEAM OF THE SURFACE CONDENSER
      C      TTDP=RANGE/EFFC-RANGE
      C
      C      EXIT TEMPERATURE OF THE STEAM TURBINE ON PREVIOUS ESTIMATE
      C      IF(TVAL3.GT.1.) GOTO 2
780  C      T11=RANGE/EFF + TA + TTDP
      C      GOTO 3
      C      2 T11=RANGE+TVAL3/EFF + TA + TTDP
      C
      C      CONVERGENCE CRITERION FOR EXIT TEMPERATURE OF TURBINE
785  C      3 IF(.NOT. EXTEMP .AND. (T11-T1)**2 .LT. .001) GOTO 4
      C      CVT = ABS( (T11-T1) / T11 )
      C      IF (EXTEMP .AND. CVT .LT. 0.0001) GOTO 4
      C      T1=T11
      C      GOTO 1
790  C
      C      C      TOTAL POWER OUTPUT OF TURBINE AT THE PARTICULAR AMBIENT
      C      C      AIR TEMPERATURE
      C
795  C      4 PTOT = QIN1 + TEFF4 / 3413.E+3
      C
      C      C      POWER OUTPUT FROM PLANT AT THE PARTICULAR AMBIENT AIR
      C      C      TEMPERATURE
      C
      C      PGEN=PTOT-PPOW/1000.-EPOW/1000.
800  C      TEFFD=TEFF4
      C      IF(PGEN.GE.PSIZE) GOTO 5
      C
      C      C      COST OF FUEL FOR GAS TURBINE MAKE UP POWER
      C
805  C      CSTOL=(PSIZE-PGEN)/PSIZE*PWCOS
      C      TEFFD=TEFF3
      C      GOTO 6
      C      5 CSTOL=.0
      C
810  C      C      INCREMENTAL COST OF FUEL FOR STEAM SUPPLY SYSTEM DUE TO STEAM
      C      C      TURBINE OPERATING AT OFF DESIGN CONDITIONS
      C
      C      6 DELFC=PWCOS*3413.E+3 * ((1.+YFP)/TEFFD-1./TEFF)
815  C      IF(I.NE.1) GO TO 10
      C      CAPCST = 0.0
      C
      C      C      TEMPERATURE LIMITATION ON MAXIMUM YEARLY EXIT, TEMPERATURE OF
      C      C      THE STEAM TURBINE
      C
820  C      IF(T11 .GT. TLIM) VCST = T11 * 100.
      C      IF (T11 .GT. TLIM) RETURN
      C
      C      C      CAPITAL COST OF GAS TURBINE USED FOR MAKE-UP POWER OF STEAM
      C      C      PLANT
825  C
      C      IF(PSIZE.LE.PGEN) GO TO 10
      C      CAPCST=CAPCHG*(PSIZE-PGEN)
830  C      10 CONTINUE

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530      C      COST OF PRODUCING POWER WITH DRY COOLED PLANT AT SPECIFIED
      C      AMBIENT AIR TEMPERATURE
      C
      C      PARCOS = (CCOS + SPCD + CLAND + CPIP + CONBAS + CAPCST) * FCR /
535      S (PSIZE * CAPE + 8750.) + COSM + DELFC + CSTCL
      XCOST(I) = TPER * PARCOS
800      CONTINUE
      C
      C      SUMMATION OF INCREMENTAL POWER PRODUCTION COSTS
      C
540      DO 820 I=1,NTA
      VCST = VCST + XCOST(I)
820      CONTINUE
      C
      C      DEBUG PRINT OUT STATEMENTS
545      C
      NDBG=A
      IF(NDBG.EQ.0) RETURN
      NTRIP=NTRIP+1
      WRITE(4,992) NTRIP
550      WRITE(4,900) CCOS,SPCD,CLAND,CPIP,CONBAS,COSM,TPER,PARCOS,VCST
      WRITE(4,901) VLIST
800      FORMAT(1H,9G14.6)
901      FORMAT(1H,9(4X,A6.4X))
902      FORMAT("NOVART CALL NO.",I10)
555      RETURN
      END

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SUBROUTINE NUN02P(T1, TD, TTD, CWARA, RANGE, W3, W4, ANTU)

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C      THIS ROUTINE DETERMINES THE NUMBER OF TRANSFER UNITS
C      FOR A TRUE COUNTER-FLOW HEAT EXCHANGER.
5      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
10     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 - INITIAL TEMPERATURE DIFFERENCE OF HEAT
15     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)
20     C
C      REAL ITD
1 FORMAT('0IN S.P. NUN02P EFF IS GREATER THAN OR EQUAL TO 1.0')
$ T2, 'EFF=', 1PE12.6, T20, 'T1, TD, TTD, CWARA, RANGE=',
$ 1P5E15.6)
25     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
30     GOTO 300
C
200 EFF = CWARA * RANGE / ITD
     IF (EFF.GE. 1.0) GOTO 700
35     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.-
40     ZCAP)
     RETURN
300 ANTU = (-ALOG( (1.-EFF)/(1.-EFF*ZCAP) ) ) / (1.-ZCAP)
     RETURN
700 WRITE(4,1) EFF, T1, TD, TTD, CWARA, RANGE
45     STOP
     END

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1      SUBROUTINE NTU1P (CP, F, 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
5      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.
13     C
      C      DEFINITION OF VARIABLES
      C
      C      CR      - RATIO OF CAPACITY OF WATER TO CAPACITY OF AIR
      C                (DIMENSIONLESS)
15     C      E      - HEAT EXCHANGER EFFECTIVENESS (DIMENSIONLESS)
      C      Y      - NUMBER OF TRANSFER UNITS (DIMENSIONLESS)
      C
      C      CR AND E ARE INPUT ARGUMENTS, Y IS RETURNED.
23     C
      C      DIMENSION VE(16,11), VC(11), VY(16), PCOL(16)
      C
      C      DATA VC / 0.0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1. /
      C
      C      DATA VY / 0.0, .25, .5, .85, 1.00, 1.25, 1.5, 1.75, 2.0, 2.5, 3.0,
25     C      3.5, 4., 5., 6., 7. /
      C
      C      DATA (VE(I,I),I=1,11) /
      C      $ 11 * 0. /
      C      DATA (VE( 2,I),I=1,11) /
30     C      $ .2212, .2188, .2164, .2141, .2117, .2095, .2072, .2050, .2028,
      C      $ .2007, .1985 /
      C      DATA (VE( 3,I),I=1,11) /
      C      $ .3935, .3863, .3787, .3716, .3646, .3578, .3512, .3448, .3385,
45     C      $ .3323, .3263 /
      C
      C      DATA (VE( 4,I),I=1,11) /
      C      $ .5728, .5574, .5427, .5285, .5147, .5014, .4885, .4760, .4640,
      C      $ .4523, .4410 /
      C      DATA (VE( 5,I),I=1,11) /
40     C      $ .6321, .6141, .5966, .5797, .5633, .5475, .5323, .5175, .5033,
      C      $ .4896, .4763 /
      C      DATA (VE( 6,I),I=1,11) /
      C      $ .7134, .6916, .6702, .6496, .6296, .6103, .5917, .5737, .5563,
45     C      $ .5396, .5243 /
      C
      C      DATA (VE( 7,I),I=1,11) /
      C      $ .7769, .7522, .7281, .7046, .6819, .6598, .6385, .6179, .5980,
      C      $ .5788, .5603 /
      C      DATA (VE( 8,I),I=1,11) /
50     C      $ .8259, .8000, .7741, .7487, .7239, .6998, .6763, .6536, .6316,
      C      $ .6104, .5899 /
      C      DATA (VE( 9,I),I=1,11) /
      C      $ .8647, .8379, .8124, .7873, .7627, .7385, .7147, .6911, .6684,
55     C      $ .6465, .6243 /
      C
      C      DATA (VE(10,I),I=1,11) /
      C      $ .9179, .8920, .8662, .8407, .8156, .7909, .7665, .7421, .7180,

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      60      5 .6774, .6526/
        DATA (VE(11,I),I=1,11) /
      65      5 .9507, .9270, .9018, .8753, .8479, .8199, .7917, .7635, .7357,
        DATA (VE(12,I),I=1,11) /
      70      5 .7082, .6814/
        DATA (VE(13,I),I=1,11) /
      75      5 .9817, .9654, .9454, .9225, .8971, .8699, .8414, .8120, .7821,
        DATA (VE(14,I),I=1,11) /
      80      5 .7522, .7226/
        DATA (VE(15,I),I=1,11) /
      85      5 .9933, .9830, .9693, .9495, .9273, .9019, .8742, .8447, .8140,
        DATA (VE(16,I),I=1,11) /
      90      5 .7826, .7511/
        DATA (VE(17,I),I=1,11) /
      95      5 .9975, .9914, .9809, .9661, .9470, .9239, .8975, .8685, .8375,
        DATA (VE(18,I),I=1,11) /
      100     5 .8052, .7723/
        DATA (VE(19,I),I=1,11) /
      105     5 .9991, .9955, .9883, .9767, .9605, .9397, .9149, .8866, .8557,
        DATA (VE(20,I),I=1,11) /
      110     5 .8229, .7889/

      C = CR
      IF (CR .GT. 1.) C = 1./C

      C
      C
      C
      85      C FIND COLUMNS WHICH ROUND C.
      C
      C
      C
      90      KL = 0
      DO 400 K=1,11
        IF (C.LT.VC(K)) GOTO 410
        KL = K
      400 CONTINUE

      C
      C
      C
      95      C GENERATE ARRAY PCOL BY INTERPOLATING BETWEEN VE VALUES IN
      C COLUMNS KL AND KL+1
      C
      410 IF (KL.GT.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)
      100      5 PCOL(I) = (VE(I,KL) - VE(I,KL+1) ) * FACTOR + VE(I,KL+1)
      500 CONTINUE

      C
      C
      105     C FIND THE POSITION OF PCOL VALUES BOUNDING E
      C
      C
      C
      110     IA = 1
      DO 600 I=1,16
        IF (E .LT. PCOL(I) ) GOTO 610
        IA = I
      600 CONTINUE
      C
      C

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115      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) )
120      Y = VY(IA) + (VY(IA+1)-VY(IA)) * FACTOR
      RETURN
      END
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1      SUBROUTINE NTU2P (CR, E, Y)
2
3      THIS ROUTINE DETERMINES THE NUMBER OF TRANSFER UNITS FOR A
4      TWO-PASS COUNTER-CROSS-FLOW HEAT EXCHANGER WITH THE WATER
5      SIDE MIXED BETWEEN PASSES.
6      THE TABULATED DATA OF NTU VERSUS EFFECTIVENESS AND CAPACITY
7      RATIO WAS TAKEN FROM "MEAN TEMPERATURE DIFFERENCE IN COUNTER-
8      CROSS-FLOW HEAT EXCHANGERS", RA STEVENS, MS THESIS,
9      SOUTHERN METHODIST UNIVERSITY, 1956. THE DATA WERE
10     DETERMINED ANALYTICALLY.
11
12     DEFINITION OF VARIABLES
13
14     CR      - RATIO OF CAPACITY OF WATER TO CAPACITY OF AIR
15              (DIMENSIONLESS)
16     E      - HEAT EXCHANGER EFFECTIVENESS (DIMENSIONLESS)
17     Y      - NUMBER OF TRANSFER UNITS (DIMENSIONLESS)
18
19     CR AND E ARE INPUT ARGUMENTS, Y IS RETURNED.
20
21     DIMENSION VE(15,11), VC(11), VY(15), PCOL(15)
22     DATA (VE( 1,I), I=1,11) /
23     * 11 * 0.0 /
24     DATA (VE( 2,I), I=1,11) /
25     * .2212, .2189, .2167, .2145, .2122, .2100, .2079, .2058, .2038,
26     * .2017, .1996 /
27     DATA (VE( 3,I), I=1,11) /
28     * .3935, .3868, .3801, .3736, .3673, .3610, .3548, .3487, .3428,
29     * .3369, .3312 /
30
31     DATA (VE( 4,I), I=1,11) /
32     * .5034, .4930, .4829, .4729, .4629, .4532, .4437, .4343, .4252,
33     * .4162, .4074 /
34     DATA (VE( 5,I), I=1,11) /
35     * .6321, .6172, .6024, .5877, .5732, .5590, .5449, .5311, .5176,
36     * .5043, .4914 /
37     DATA (VE( 6,I), I=1,11) /
38     * .7275, .7095, .6914, .6734, .6554, .6375, .6194, .6023, .5852,
39     * .5683, .5518 /
40
41     DATA (VE( 7,I), I=1,11) /
42     * .8173, .7975, .7772, .7564, .7353, .7141, .6929, .6717, .6507,
43     * .6300, .6097 /
44     DATA (VE( 8,I), I=1,11) /
45     * .8647, .8448, .8239, .8022, .7800, .7571, .7340, .7108, .6877,
46     * .6648, .6421 /
47     DATA (VE( 9,I), I=1,11) /
48     * .9179, .8946, .8704, .8456, .8204, .7955, .7699, .7443,
49     * .7185, .6928 /
50
51     DATA (VE(10,I), I=1,11) /
52     * .9522, .9344, .9160, .8964, .8724, .8445, .8227, .7959, .7684,
53     * .7406, .7127 /
54     DATA (VE(11,I), I=1,11) /
55     * .9594, .9567, .9487, .9425, .9365, .9240, .9023, .8821, .8625,
56     * .8437, .8274 /
57     DATA (VE(12,I), I=1,11) /

```

```

      * .9817, .9712, .9575, .9456, .9286, .8977, .8721, .8445, .8152,
      * .7849, .7539/
60      C      DATA (VE(13,I), I=1,11) /
      * .9933, .9879, .9775, .9645, .9477, .9271, .9030, .8758, .8460,
      * .8142, .7813/
      C      DATA (VE(14,I), I=1,11) /
65      * .9975, .9939, .9876, .9773, .9642, .9462, .9239, .8976, .8679,
      * .8355, .8013/
      C      DATA (VE(15,I), I=1,11) /
      * .9991, .9971, .9939, .9858, .9747, .9592, .9383, .9138, .8845,
      * .8518, .8166/
70      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 / 3.3, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1. /
75      C      C = CR
      C      IF( CR .GT. 1.) C = 1./C
      C
      C      FIND COLUMNS WHICH BOUND C.
80      C      KL = 0
      C      DO 400 K=1,11
      C      IF(C.LT.VC(K)) GOTO 410
      C      KL = K
85      C      400 CONTINUE
      C
      C      GENERATE ARRAY PCOL BY INTERPOLATING BETWEEN VE VALUES IN
      C      COLUMNS KL AND KL+1
90      C      410 IF(KL.GT.0.AND. KL.LT.11) FACTOR=(C-VC(KL+1))/(VC(KL)-VC(KL+1))
      C      DO 500 I=1,15
      C      IF(KL.EQ.0) PCOL(I) = VE(I,1)
95      C      IF(KL.EQ. 11) PCOL(I) = VE(I,KL)
      C      IF(KL.GT.0 .AND. KL .LT. 11)
      C      * PCOL(I) = (VE(I,KL) - VE(I,KL+1) ) * FACTOR + VE(I,KL+1)
      C      500 CONTINUE
100      C      FIND THE POSITION OF PCOL VALUES BOUNDING E
      C
      C      IA = 1
      C      DO 600 I=1,15
      C      IF(E .LT. PCOL(I) ) GOTO 610
105      C      IA = I
      C      600 CONTINUE
      C
      C      THE VY VALUES BOUNDING Y ARE VY(IA) AND VY(IA+1)
110      C      INTERPOLATE BETWEEN VY VALUES TO GET Y
      C      610 FACTOR = (E-PCOL(IA))/(PCOL(IA+1)-PCOL(IA) )

```

SUBROUTINE NTU2P

74/74 OPT=1

FTN 4.5+414

05/02/77

115

Y = VY(IA) + (JY(IA+1)-VY(IA)) * FACTOR
RETURN
END

SUBROUTINE OUT2(RBP,HRFAC1,SSCD,CASSS1,PLANCT1,PLANC1,CTURB,TCO)

C
C
C
C

THIS ROUTINE REPORTS STEAM SUPPLY COSTS DUE TO INCREASED HEAT RATE
AT RATING BACKPRESSURE.

5

1 FORMAT(1H0,T3,"STEAM SUPPLY SCALING TO COMPENSATE FOR INCREASED ",
\$ "HEAT RATE AT RATING BACKPRESSURE. RBP=",F5.2,T67,"IN. HG",

\$ T113,"HRFAC1=",F11.6)

10

2 FORMAT(T17,"STEAM SUPPLY COST DIFFERENTIAL \$",F12.0

\$,T91,"TURBINE COST DIFFERENTIAL",F11.0,T129,"\$/KW")

3 FORMAT(T2,"PLANT COST INCLUDING STEAM SUPPLY AND TURBINE \$",F12.0

\$,T55,"PLANT UNIT COST INCLUDING STEAM SUPPLY AND TURBINE",F11.0

\$,T128,"\$")

15

WRITE(4,1) RBP,HRFAC1

WRITE(4,2) SSCD, TCO

WRITE(4,3) PLANCT1,PLANC1

RETURN

END

SUBROUTINE OUT4(KWHICH)

WHEN CALLED WITH KWHICH = 1 THIS ROUTINE REPORTS CONDITIONS AFTER
SCALING PLANT AND STEAM SUPPLY BUT BEFORE SCALING FOR FANS AND PUMPS

WHEN CALLED WITH KWHICH NOT 1 THE ROUTINE REPORTS CONDITIONS AFTER
SCALING FOR FANS AND PUMPS

LOGICAL FXTLNG

LOGICAL FIRST, FXTMP

COMMON

* AFTR, ALPHA

* CAPF, CDSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP

* C3U, CTURB, CDANG, CLUVR, CHAHS, CVM

* DANGLE, DFIN, DEEPL, DESVEL

* EFFP

* FOR, FIRST, FIXL, FCOS, FFHX, FXTMP

* GREFF

* HXNP, HPCST

* ITMAY, ITMIN

* JCOND

* KCOND, KALEXT

* MXEXT

* NTUCAL(2), NTA

COMMON

* ORR

* PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL

* POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCS

* QRED, QREDUCE

* REP, REDUCE, RCOFL, RFIX

* SIGMA, SAAF

* TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX

* TCD, TW

* UCS, UNS

* VAS(3)

* WFFV

* XDEP, XW, XD

COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,

* QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPW,

* FPOV, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,

* REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,

* SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPC3, PSIZ13, WT2,

* SPP, NWS, TCOS, DELPA, DELPAT, DELPWC, CONBAS, XNTSX, VELOX

* TLX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS

* CLTC, CTC, UPOC, FITCO, CSC, CEPREP, DELPIB, AST, OLUCST

* CAPCST, XNFAN, QLOANO, CPLEN, DEEL, WHX, ATTUR, ADIA, ABLN

* WTHP, WATERM, STRUCC, CEPEP, HPRERF, TOTCF, TPC, EFFIN, ANTU

* AIRCF, WATER, XVMOD, TOTPR, FDCPF, FMTRC, ACCTP, ADJTP

* ACTBND, ADURPD, ACTVH, ADUVH, ADUPPF, THAIR, TCF, AFCST

* CSR, WATERM, WSTROT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD

* ATUBO, CST-VR, CSTHS, CYLNG, CFANEL

COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,

* QIN1, CLAN1, REA11, Z1, HRFAC2S, W41, U1, DEPW1, PPW1,

* FPO1, DEFC1, WID1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,

* REW1, NW1, NT1, NP1, PLNC2, ZSIZ12, ZSPBP, SW41, SW31,

* SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,

* BP2MIN, NW2MIN, TCOS1, DEPA1, DPAT1, DPWC1, CONBAS1, XNTS1, VELO1

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60      S, TL1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CHI, CA1, CS1
      S, CLT1, CFCL, CPCL, FITCL, CSC1, CEPRE1, DEPI1, AST1, OLOCS1
      S, CAPCS1, XFAN1, BLDA1, CPLE1, DPEL1, WH1, WTU1, ADI1, ABL1
      S, WTH1, WTR1, STRUC1, CFMPF1, HPP1, TOTCF1, TP1, EFFIN1, ANTU1
      S, AIRF1, WATER1, XNMOD1, TCTP1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
      S, ACTB1, ADJBP1, ACTVH1, ADJUH1, ADJRP1, THPA1, ICTF1, AFCS1
65      S, CSRT, WATER1, WSTRC1, CFJUN1, HJBD1, TOWLE1, NUMT01, CTOWD1
      S, ATUBC1, CSTLM1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/HRFAC1, ATUB, CPRA, SSCD, PLANC1, CASSS1,
70      S, GAIR, FAIR, HPAIR, HPWAT, PLANC1
      COMMON /DUA/ DI, XOS, SF
      COMMON /FLSW/ FXTLNG
901  FORMAT(' CONDITIONS AFTER SCALING PLANT AND STEAM SUPPLY (BEFORE)
      *SCALING FOR FANS AND PUMPS)', T88, 'HRFAC2=', G15.7)
906  FORMAT(1X, T88, 'PSIZ12=', G15.7, ' M")
911  FORMAT(1X, T88, 'PLANC2=', G15.7, ' $/KW")
916  FORMAT(1X, T88, 'SPRP=', G15.9, ' $")
75  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")
80  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 ", T45, ' TUBES")
65  961  FORMAT(1X, T15, 'WIDTH ", G15.9, ' FEET")
962  FORMAT(1X, T9, 'NO. CONDENSER TUBES ", G15.9)
963  FORMAT(1X, T6, '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")
90  1001 FORMAT(1X, 'SCALING FOR FAN AND PUMP POWER REQUIREMENTS',
      * T83, 'SCALING FACTOR ", G15.9)
1005  FORMAT(1X, T88, 'PSIZE ", G15.9, ' M")
1006  FORMAT(1X, T88, 'PSI713 ", G15.9, ' M")
1011  FORMAT(1X, T88, 'PTOTAL ", G15.9, ' M")
65  1016  FORMAT(1X, T88, 'PLANC3 ", G15.9, ' $/KW")
1021  FORMAT(1X, T88, 'SPC ", G15.9, ' $")
1026  FORMAT(1X, T88, 'SSCD ", G15.9, ' $")
8888  FORMAT(1X, T12, ' ** ** ** ")//)
      WRITE(4, 8888)
700  WLRTP = WIDT1/LENL
      IF (WLRTP.NE.1) GO TO 2000
      WRITE(4, 901) HRFAC2
      WRITE(4, 906) ZSIZ12
      WRITE(4, 911) ZPLNC2
705  WRITE(4, 916) ZSPRP
      WRITE(4, 917) BP2*IN
      WRITE(4, 919) VAR(1)
      WRITE(4, 921) W31
      WRITE(4, 926) W41
715  WRITE(4, 931) (FPOW1/(1.+YFPMIN))
      WRITE(4, 936) (FPOW1/(1.+YFPMIN))
      WRITE(4, 941) (AIR1/(1.+YFPMIN))
      WRITE(4, 946) (AFR2/(1.+YFPMIN))
      WRITE(4, 951) WLRTP/(1.+YFPMIN)

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115      WRITE(A,956) NW2MIN
        WRITE(A,961) WT2MIN
        WRITE(A,965) AST1
        WRITE(A,962) XN1S1
120      WRITE(A,963) TLA1
        WRITE(A,964) VELD1
        RETJRN
2000 CONTINUE
        WRITE(A,1001) (1.+YFPMIN)
125      WRITE(A,1005) PSIZE
        WRITE(A,1006) SPS13
        WRITE(A,1011) OTOT1
        WRITE(A,1016) PLN1C31
        WRITE(A,1021) SPC1
130      WRITE(A,1026) SPCD1
        WRITE(A,921) SW31
        WRITE(A,926) SW41
        WRITE(A,931) PPOW1
        WRITE(A,936) FPOW1
        WRITE(A,941) AAIR1
135      WRITE(A,946) AFR01
        WRITE(A,951) WLPT
        WRITE(A,956) NW1
        WRITE(A,961) WT1
        WRITE(A,965) AST1 * (1. + YFPMIN)
140      WRITE(A,962) XN1S1 * (1. + YFPMIN)
        WRITE(A,963) TLA1
        WRITE(A,964) VELD1
        RETJRN
END

```

SUBROUTINE PIPCRT (TS, W3, TTD, TR, TOWERD, DELHX, DELCON, DIST,
 \$ DESVEL, REDUCE, DREDUCE, BUNWIDT, TUBDEP,
 \$ TRANPIT, COST, NCTOW, PDP, EPDP, HPWAT,
 \$ RHO, CDANG, PCHCIR, PCHLEC, EFPF)

5 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
 10 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
 15 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
 20 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
 25 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 CCGP - PIPING COST PER TOWER GROUP (\$1000)
 30 C CTTOW - 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)
 35 C DELPMP - 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)
 40 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 DIAO - DIAMETER OF DISTRIBUTION PIPING (INCHES)
 45 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)
 50 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
 55 C DYNHEAD - DYNAMIC HEAD SEEN BY PUMPS (FT OF WATER)
 C EFPF - PUMP EFFICIENCY (DECIMAL FRACTION)
 C EJICST - EXPANSION JOINT COST (\$1000)

60	C	ELCST	- 90 DEGREE ELBOW COST (\$1000)
	C	EL45	- 45 DEGREE ELBOW COST (\$1000)
	C	ELEN	- EQUIVALENT LENGTH (FT)
	C	ELENL	- EQUIVALENT LENGTH OF DISTRIBUTION PIPING (FT)
	C	ELENL	- EQUIVALENT LENGTH OF TOWER PIPING (FT)
	C	ELFIT	- EQUIVALENT LENGTH OF BUNDLE FITTINGS (FT)
65	C	ELPUMP	- EQUIVALENT LENGTH OF PIPE IN PUMP STATION (FT)
	C	FLGCST	- FLANGE COST (\$1000)
	C	FG	- FLOW TO COMPLETE TOWER GROUPS (LBM/HR)
	C	GCST	- COST OF PIPING FOR MAIN CIRCULATION HEADERS (\$1000)
	C	QSGPM	- FLOW RATE TO COMPLETE TOWER GROUPS (GPM)
70	C	QSMCIRC	- FLOW RATE TO EACH CIRCULAR TOWER (GPM)
	C	QSMAX	- MAXIMUM FLOW RATE THAT CAN BE TRANSPORTED THROUGH LARGEST DIAMETER PIPE AVAILABLE AT THE GIVEN DESIGN VELOCITY (GPM)
	C	QMTOT	- TOTAL WATER FLOW RATE (GPM)
75	C	HEAD	- HEAD LOSS (FT OF WATER/100 FT OF EQUIVALENT LENGTH)
	C	HEAD1,2	- HEAD LOSS FOR ELENL, SUPPLY (1) AND RETURN (2), (FT/100 FT)
	C	HEAD1,2	- HEAD LOSS FOR ELENL, SUPPLY (1) AND RETURN (2), (FT/100 FT)
80	C	HEDR	- LENGTH OF MAIN CIRCULATION HEADER SECTIONS (FT)
	C	HPPMP	- HORSE POWER PER PUMP (HP)
	C	HPWAT	- REQUIRED PUMP HORSE POWER (HP)
	C	IPRESS	- PIPING COMPONENT DESIGN PRESSURE (PSI)
	C	NUNPQD	- TUBE BUNDLES PER QUADRANT
85	C	NCTOW	- CTOW
	C	NEL	- UPPER LIMIT FOR NUMBER OF TOWERS OR TUBE BUNDLES PER QUADRANT
	C	NES	- NUMBER OF POSITIONS IN UNIT COST ARRAYS
	C	NMP	- TOTAL NUMBER OF PUMPS
	C	NMX	- NUMBER OF PUMPS SERVING EXTRA TOWER GROUP
90	C	NTOWGPS	- NUMBER OF COMPLETE TOWER GROUPS
	C	NTOWGRP	- NUMBER OF TOWERS PER GROUP
	C	NTURBU	- NUMBER OF TUBES PER BUNDLE
	C	PIA	- DIAMETER OF PUMP STATION PIPING COMPONENTS (INCHES)
95	C	PP	- PRESSURE DROP IN PIPING SYSTEM (PSF)
	C	PIPCOST	- COST OF STRAIGHT PIPE FOR ONE HEADER SECTION OF MAIN CIRCULATION PIPING (\$1000)
	C	PISCOS	- TOTAL PIPING SYSTEM COST (\$1000)
	C	P-ELEC	- PUMP MOTOR ELECTRIC COST (\$)
100	C	PAHCIR	- INDIRECT COST FACTOR FOR CIRCULATION PIPING
	C	PAHLEC	- INDIRECT COST FACTOR FOR ELECTRICAL REQUIREMENTS
	C	PROP	- WATER PROPERTIES ARRAY
	C	PSTACST	- COST OF PUMP STATION FOR COMPLETE TOWER GROUP- PIPING AND PUMPS (\$1000)
105	C	PUPITS	- COST OF PIPING COMPONENTS IN PUMP STATION OF COMPLETE TOWER GROUP (\$1000)
	C	PUMPST	- PUMP COSTS FOR COMPLETE TOWER GROUP (\$1000)
	C	Q-ELR,S,SP	- PRESSURE DROP IN QUADRANT HEADER RETURN (R), SUPPLY (S), SUPPLY AND RETURN (SR) (PSF)
110	C	Q-ELCST	- COST OF ELBOW ON LAST QUADRANT HEADER SECTION (\$1000)
	C	Q-QCST	- TOTAL COST OF QUADRANT HEADER PIPING COMPONENTS (\$1000)
	C	Q-HEDR	- LENGTH OF SECTION OF QUADRANT HEADER (FT)
	C	Q-IPICST	- COST OF STRAIGHT PIPE FOR ONE QUADRANT HEADER

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115      C      SECTION ($1000)
      C      QRCOST - 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)
120      C      QTECOST - QUADRANT TEE COST ($1000)
      C      QTPCOST - PIPE COMPONENTS COST FOR ONE QUADRANT
      C      HEADER ($1000)
      C      QUADGPM - FLOW RATE TO ONE QUADRANT (GPM)
      C      REDCOST - REDUCER COST ($1000)
125      C      RREDUCE - 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      RDH,1,2 - DENSITY OF WATER AVERAGE, SUPPLY (1), RETURN (2)
130      C      (LBM/CU FT)
      C      TDCOST - DISTRIBUTION AND TOWER PIPING COSTS ($1000)
      C      TW - WATER TEMPERATURE LEAVING CONDENSER (DEG F)
      C      TTECOST - TEE COST ($1000)
      C      TTPCOST - TOTAL COST OF MAIN CIRCULATION HEADERS ($1000)
135      C      TW20 - WATER TEMPERATURE (DEG F)
      C      TW - WATER TEMPERATURE ENTERING CONDENSER (DEG F)
      C      TWDIA - TOWER DIAMETER (FT)
      C      TDCOST - TOTAL COST OF PUMP STATIONS ($1000)
      C      TQDCOST - TOTAL COST OF QUADRANT HEADERS ($1000)
140      C      TR - TEMPERATURE RANGE OF WATER (DEG F)
      C      TRANPIT - TRANSVERSE TUBE PITCH (INCHES)
      C      TTRMA, - TERMS IN PUMP ELECTRIC CHARGES DETERMINED BY
      C      TMR, EMPIRICAL COST CORRELATIONS
      C      TMR,
145      C      TMR - STEAM SATURATION TEMPERATURE (DEG F)
      C      TTD - CONDENSER TERMINAL TEMPERATURE DIFFERENCE (DEG F)
      C      TTDOST - TOTAL COST OF TOWER DISTRIBUTION PIPING ($1000)
      C      TUDRER - HEAT EXCHANGER TUBE ROWS IN DIRECTION OF AIR FLOW
      C      URPCOST - UNIT COST OF STRAIGHT PIPE ($/FT)
150      C      VACOST - VALVE COST ($1000)
      C      VELO - ACTUAL WATER VELOCITY (FT/SEC)
      C      VFLOCIT - ACTUAL VELOCITY IN BUNDLE FITTINGS OR PUMP STATION
      C      PIPING (FT/SEC)
      C      VFLOD - ACTUAL VELOCITY IN DISTRIBUTION PIPING (FT/SEC)
155      C      VELOT - ACTUAL VELOCITY IN TOWER PIPING (FT/SEC)
      C      VFS,1,2 - WATER VISCOSITY AVERAGE, SUPPLY(1), RETURN(2),
      C      (CBM/FT HR)
      C      VM - PUMP MOTOR VOLTAGE (VOLTS)
      C      VS - PUMP SYSTEM VOLTAGE (VOLTS)
160      C      WR - CIRCULATION WATER FLOW RATE (LBM/HR)
      C      XTDW - CTOW
      C
      C      VARIABLES APPLYING TO EXTRA TOWER GROUP WITH COUNTERPARTS
      C      FOR COMPLETE TOWER GROUPS
165      C
      C      EDELPRP - DELPRP
      C      EDELSR - DELSR
      C      EDYNHD - DYNHD
      C
170      C      EJCOST - EJCOST
      C      EFLGOST - FLGOST
      C      EPCOST - GPCOST

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C      EDOJA - PDIA
C      EODP - POP
C      EOPCST - PUMPCST
175 C      ELCST - PSTACST
C      E-UFITS - PUFITS
C      EYOST - CPGP
C      EVFLO - FPG
C      EXGPM - GPGPM
180 C      NEXTOW - NTOWPGP
C
      DIMENSION VELO(500), UPIPCST(500)
      COMMON /CPIPE / APIPCST(23), DIAM(23), EUCST(23), ELCST(23)
      S, ELGCST(23)
      S, ELAS(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
185 C      COMMON /PRESS/ IPRESS
      COMMON /PH2O/ TH2O(16), PROP(16.2)
      LOGICAL CALL 1
      COMMON /RPRT1/
190 C      S, QJNGPM
      S, DYNHEAD, DIAD, DIAT, DIAH(500), DIAQ(500)
      S, EPSCST, EGPCST, EOPCST, EPUFITS, EDYNHD, EXGPM, EUCST, ELCST
      S, ELGCST
      S, GPMCTRC, GPGPM, GPCST
195 C      S, HEDR(500)
      S, USAVE
      S, LSAVE
      S, NTUBRBU, NBUNPOD, NTOWGPS, NTOWPGP, NEXTOW
      S, PSTACST, PUFITS, PUMPCST, PIPCST(500), PISCOS
200 C      S, QHDCST, QUADGPM, QPIPCST(500), QHEDR(500), QTECST(500)
      S, QREDCST(500), QELCST
      S, QREDCST(500), QETPL
      S, TEECST(500), TPCST, TDCST, ITDCST, TGPCST, TOWDIA, TQDCST
205 C      S, XTOW
      COMMON /PME/ PVELEC
C
      DATA CALL 1 /TRUE./
      DATA DCGTM /100./
      DATA NES /23/, NFL/500/
210 C
C      CALL THE APPROPRIATE SUBROUTINE TO ESTABLISH UNIT COST DATA
C      FOR THE PIPING SYSTEM COMPONENTS.
C
      IF(IPRESS.LT.50. OR. IPRESS.GT. 125) STOP "CHECK VALUE OF IPRESS"
215 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
220 C      CTOW = NCTOW
      TOWDIA = TOWERD
      DO 1 I=1,NFL
1      REDCST(I)=0.
      TE=TS-TTD
225 C
C      USE WATER TEMPERATURES TO DETERMINE WATER PROPERTIES.
C
      TI=TE-TR

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535 VIS1=T(U(TE,TH20,PROP(1,2),15)
    RH01=T(U(TE,TH20,PROP(1,6)
    VIS2=T(U(TI,TH20,PROP(1,2),15)
    RH02=T(U(TI,TH20,PROP(1,6)
    RHO=(RHO1+RHO2)/2.
    VIS=(VIS1+VIS2)/2.
535 GPMTOT = 48/(60.*RHO/7.481)
    NTOWPGP=12.*BUNWIDT*TURDEP/TRANPIT
    CONST1=(3.1416/4.)*7.481*60.*DESVEL
    CONST2=(4./3.1416)*144./(60.*7.481)
    GPMCIRC=GPMTOT/CTOW
540 GPMVAX = (DIAM(VFS)**2/144.) * CONST1
    NTOWPGP=GPMVAX/GPMCIRC

C
C     IF THE FLOW TO ONE TOWER EXCEEDS THE FLOW THAT CAN BE
C     TRANSPORTED THROUGH THE LARGEST DIAMETER PIPE THEN REJECT
545 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
550 THE LARGEST PIPE DIAMETER DIVIDED BY THE FLOW PER TOWER
C     (GPMCIRC).

C
C     IF ( NTOWPGP .LT. 1) COST = 1.E+40
C     IF (NTOWPGP .LT. 1) WRITE(6,5757)
555 5757 FORMAT("01N PIPING ROUTINE NUMBER OF TOWERS PER GROUP = 0 WAS
C     REJECTED")
C     IF ( NTOWPGP .LT. 1) RETURN
C     IF (NTOWPGP.GT.CTOW) NTOWPGP=CTOW +1.E-40
C     NTOWPGP=CTOW/NTOWPGP
560

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
565 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
570 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
575 DIAMETER OF THE EXTRA GROUP MAIN CIRCULATION HEADER IS
C     SMALLER AND THE PUMP STATION REQUIREMENTS ARE REDUCED.

C
C     NEXTOW=NCTOW-NTOWPGP*NTOWGPS
C     EXGPM=NEXTOW*GPMCIRC
C     GPGPM=NTOWPGP*GPMCIRC
580 QUADGPM=GPMCIRC/4.
C     NBUNPQD = (TOWDIA*3.14159)/(4. * BUNWIDT * CDANG) +1.
C     BUNGPM=QUADGPM/NBUNPQD

C
C     SIZE THE DISTRIBUTION PIPING.
585

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      DIAD=SQRT(GPM/CIRC/CONST1)*12.
      DO 10 NT = 1,NFS
      ID = NT
      IF (DIAD-DIAM(ID))11,11,10
290 10 CONTINUE
      C
      C      SIZE THE TOWER PIPING.
      C
      11 DIAD=DIAM(ID)
      DIAT=SQRT(QUADGPM/CONST1)*12.
      DO 12 IT = 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
      305 EQLEND=.2*TOWDIA+200.*DIAD/12.
      VELOD=(GPM/CIRC/DIAD**2)*CONST2
      EQLENT=TOWDIA+.40.*DIAT/12.
      VELOT=(QUADGPM/DIAT**2)*CONST2
      310 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*
      315 RHO2))/100.
      C
      C      DETERMINE THE COST OF THE DISTRIBUTION AND TOWER PIPING.
      C
      C      THE DISTRIBUTION AND TOWER PIPING COST (TDCST) INCLUDES THE
      320 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 DISTRIBUTION
      C      HEADER IS COSTED AS FOUR PIPE TEES. THE TEE IS COSTED
      325 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))
      330 +3.25*TOWDIA*PIPCST(IT)+10.*ELCOST(IT)+2.*EL45(IT)+4.*VACST(IT)
      TDCST=.2*TDCST
      C
      C      DESIGN AND COST THE QUADRANT PIPING.
      C
      335 CALL HEADER(QUADGPM,NBUNPQO,BUNGPM,QREDUCE,1,L,DIAD,QRDCST,QTECST,
      340 SQELCST,UPIPCST,VELO,GEUCST,QFLCST,DESVEL)
      LSAVE = L
      QDEL5=.
      QDEL2=.
      QIPICST=.
      IF (L.GT.NFL) STOP"PIPCST I TOO BIG IN DO 20"

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      DO 20 KK=1,L
      I = KK
445      IF(I.GT.1) GO TO 21
      QHEDR(I)=0.
      GO TO 22
      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.
450      21 QHEDR(I) = BUNWIDT * CDANG - DIAQ(I) * 1.75 / 12.
      C
      C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE QUADRANT
      C      PIPING.
      C
460      22 EQLEN=QHEDR(I)+20.*DIAQ(I)/12.
      CALL HYDLOS(DIAQ(I),VELO(I),VIS1,RH01,2,HEAD1)
      CALL HYDLOS(DIAQ(I),VELO(I),VIS2,RH02,2,HEAD2)
      QDELS=QDELS+HEAD1*RH01*EQLEN/100.
      QDELR=QDELR+HEAD2*RH02*EQLEN/100.
      QPIPCST(I)=QHEDR(I)*UPIPCST(I)
465      IF(I.LT.L) QTPCST=QTPCST+QPIPCST(I)+QROCST(I)+QTECST(I)
      IF(I.EQ.L) QTPCST=QTPCST+QPIPCST(I)+QROCST(I)+QELCST
      20 CONTINUE
      QDELSR=(QDELS+QDELR)/2.
      C
470      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
475      QHDCST=QTPCST*2.+1.75*N8UNPQD
      TQDCST=QHDCST*CTOW**3.
      C
      C      DESIGN AND COST THE MAIN CIRCULATION PIPING FOR THE
      C      EXTRA TOWER GROUP.
      C
480      C      VARIABLES DEFINING CONDITIONS IN THE EXTRA TOWER GROUP ARE
      C      GENERALLY RESET TO A ZERO VALUE EACH TIME PIPORT 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.
485      C
      50 PIPCL.155,PIPC.157
      C
      C
490      EDELSR=0.
      EPOTA=0.
      EQPCST=0.
      EEUCST=0.
      EFLGCST=0.
495      IF(NEXTOW.EQ.0) GO TO 35
      CALL HTADR(EXGPM,NEXTOW,GPMCIRC,REDUCE,0,JEX,DIAH,REDCOST,TEECOST
      *,EELCST,UPIPCST,VELO,EEUCST,EFLGCST,DESVEL)
      DELSUP=0.
      DELRET=0.

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400      EGPCST=0.
      IF(JEX.GT.NFL) STOP "PIPC L JEX TOO BIG IN DO 30"
      DO 30 I2=1,JEX
      I = I2

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
410      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
      GO TO 32
31 HEDR(I)=DIST*.5*TOWDIA

415      C
C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE MAIN CIRC-
C      ULATION PIPING TO THE EXTRA TOWER GROUP.
C
32 EOLEN=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*EOLEN/100.
      IF(I.GT.1) GO TO 33
      DELRET=DELRET+HEAD2*RHO2*(EOLEN-50.)/100.
      GO TO 34
33 DELRET=DELRET+HEAD2*RHO2*EOLEN/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
430      30 CONTINUE
      EOSP=DELSUP+DELRET
      EPDIA=.7*DIAH(1)
      EGPCST=EGPCST*2.-50.*UPIPCST(1)+(EEUCST*EFLBCST)*5
435      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
440      CALL HEADER(GRAPH,NTOWPSP,GRMCIRC,REDUCE,0,J,DIAH,REDCOST,TEECOST,
      SELCOST,UPIPCST,VELO,EJPCST,FLBCOST,DESVEL)
      USAVE = J
      DELSUP=0.
      DELRET=0.
      GPCST=0.
445      IF(J.GT.NFL) STOP "PIPC L J TOO BIG IN DO 40"
      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 EOLEN=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)

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      DELSUP=DELSUP+HEAD1*RHO1*EQLN/100.
      IF(I.GT.1) GO TO 43
      DELRET=DELRET+HEAD2*RHO2*(EQLN-50.)/100.
460  GO TO 44
      43 DELRET=DELRET+HEAD2*RHO2*EQLN/100.
      44 PIPCOST(I)=UPIPCOST(I)*WFDR(I)
      IF(I.LT.J) GPCST=GPCST+PIPCOST(I)+REDCOST(I)+TEECOST(I)
      IF(I.EQ.J) GPCST=GPCST+PIPCOST(I)+REDCOST(I)+ELCOST
465  40 CONTINUE
      DELSURF=DELSUP+DELRET
      GPCST=GPCST*2.-50.*UPIPCOST(I)+(ELCOST+FLGCOST)*2
C
C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE BUNDLE
470  C FITTINGS CONNECTING THE QUADRANT HEADER TO THE TUBE BUNDLE
C      HEADER.
C
      EQLFIT=350.
      VELOCIT=(300GPM/3.**2)*CONST2
475  CALL HYDLOS(Y,VELOCIT,VIS,RHO,2,HEAD)
      DELFIT=HEAD*RHO*EQLFIT/100.
C
C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE PIPING FOR
480  C THE PUMP STATION SERVING THE COMPLETE TOWER GROUP.
C
      EQLPUMP=200.
      PDIA=.7*DIAH(1)
      VELOCIT=(300GPM/PDIA**2)*CONST2
485  CALL HYDLOS(PDIA,VELOCIT,VIS2,RHO2,2,HEAD)
      DELPUMP=HEAD*RHO2*EQLPUMP/100.
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.
490  C TWO PUMPS SERVE EACH TOWER GROUP. NO AUXILIARY PUMP
C      CAPACITY IS PROVIDED.
C
      PDP=DELSURF+DELSR+DELFIT+DELPUMP+DELTD
      DYNHEAD=(PDP+DELHX+DELCON)/RHO
      PUMPCOST=(.0129+DYNHEAD+1.065)*300GPM/1000.
      PUFITS=(2.5*300GPM/1000.)*7./DESVEL
      PSTACST=PUMPCOST+PUFITS
      COTOW=HDCOST*4.+TDCST
C
C      TOTAL COST OF PIPE, FITTINGS, AND PUMPS PER COMPLETE TOWER
500  C GROUP.
C
      CGRP=COTOW*NTOWGRP+GPCST+PSTACST
C
C      DESIGN AND COST THE PUMP STATION SERVING THE EXTRA TOWER
505  C GROUP. THE METHOD IS IDENTICAL TO THAT FOR THE COMPLETE
C      TOWER GROUP.
C
      EDELPMP=0.
      EPDP=0.
      EDYNHD=0.
      EPUMPCOST=0.
      EPUFITS=0.
510

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      EPSGST=0.
      EXGST=0.
      IF (NEXTOW.EQ.0) GO TO 50
      VELOCIT=(EXGPM/EPDIA**2)*CONST2
      CALL HYDLOS(EPDIA,VELOCIT,VIS2,RHO2,2,HEAD)
      EDELPM=HEAD+RHO2*EQLPUMP/100.
      EDP=EDLSR+QDELRS+DELFIT+EDELPM*DELTO
      EDYNHD=(EDP+DELHX+DELCON)/RHO
      EDPGST=(0.012*EDYNHD+1.065)*EXGPM/1000.
      EPUFITS=(2.5*EXGPM/1000.)*7./DESVEL
      EPSGST=EDPGST+EPUFITS
      EXGST=OPTOW*NEXTOW+EGPGST+EPSGST
50    CONTINUE

      C
      C
      C      DETERMINE TOTAL COSTS.
      C
      COST=CGGP*NTOWGPS      +EXGST
      COST = COST + POWCIR
      TTGST=TTGST*CTOW
      TGPGST=GGPGST+NTOWGPS+EGPGST
      TPGST=TTGST*NTOWGPS+EPSGST
      FRG = CGGP * (60.0*RHO/7.481) * NTOWGPS
      EXFLO =EXGPM * (60.*RHO/7.481)
      HPWAT = (FRG * (PDJ + DELHX + DELCON) +
3      EXFLO*(EDP+ DELHX + DELCON)) / (62.*3600.*550.)
      NPX = 1
      IF (NEXTOW .GT. 0) NPX = 2
      NPMP = 2 * NTOWGPS + NPX
      HPPMP = HPWAT/(NPMP*EFFP)
      IF (HPPMP .LT. 251.) TRMA = 112500./NPMP + 7.88 * HPPMP
3      + (116.-.159*HPPMP)*HPPMP
      IF (HPPMP .GE. 251. .AND. HPPMP .LE. 4000.) TRMA = 112500./NPMP
5      + 7.88*HPPMP + 870./SQRT(HPPMP)*HPPMP
      IF (HPPMP .GT. 2000.) TRMA = 112500./NPMP + 7.88 * HPPMP
      VS = 7000.
      IF (HPPMP .LT. 2000.) VS = 13000.
      VM = 6000.
      IF (HPPMP .LT. 2000.) VM = 2300.
      IF (HPPMP .LT. 251) VM = 480.
      TRM3 = (DIST/2. - 1000.)*(37. + .47*HPPMP*NPMP/SQRT(VS)
5      + .5 *NPMP) / NPMP
      TRM4 = (100. + 1.1 * HPPMP) * (DSGTM -250.) / SQRT(VM)
      PMELEC = (TRMA + TRM3 + TRM4) * POWLEC
      COST = COST + PMELEC/1000. * NPMP
      PISGOS = COST
      RTPL = PMELEC/1000. * NPMP
      RETURN
      END

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SUBROUTINE P50
COMMON /PIP50 / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
$, EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
COMMON /CPIPE/ X(230)

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THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
PIPCST FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
50 PSI. THIS DATA IS CALLED BY USING A VALUE OF
DPRESS= 50 (DPRESS=PIPING DESIGN PRESSURE) ON CARD G1
OF THE INPUT. THUS, ANY COST DATA CAN BE SUBSTITUTED HERE
FOR STUDY PURPOSES.

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DEFINITION OF VARIABLES

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APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
DIAM - COMPONENT DIAMETER (INCHES)
EJCST - EXPANSION JOINT COST ($1000)
ELCST - 90 DEGREE ELBOW COST ($1000)
EL45 - 45 DEGREE ELBOW COST ($1000)
ELGCST - FLANGE COST ($1000)
PIPCST - BELOW GROUND PIPE COST ($1000/FT)
REDCST - REDUCER COST ($1000)
TEECST - TEE COST ($1000)
VACST - VALVE COST ($1000), VALVES ARE MOTOR OPERATED
BUTTERFLY VALVES

```

50 PSI

DATA APIPCST /

\$		.055,	.074,	.092,	.112,	.132,
\$	.152,	.240,	.265,	.290,	.322,	.353,
\$	.375,	.396,	.423,	.449,	.470,	.490,
\$	.511,	.691,	.727,	.772,	.812,	.852

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 EJCST/

\$		.560,	1.11,	1.56,	2.17,	2.69,
\$	4.24,	5.90,	7.24,	8.60,	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 ELGCST/

\$		.437,	.999,	1.56,	2.12,	2.68,
\$	3.24,	7.05,	12.0,	16.9,	20.3,	23.5,
\$	27.4,	31.1,	34.9,	38.7,	43.1,	47.4,
\$	51.7,	74.8,	77.9,	80.9,	89.0,	95.1

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,	27.5,	30.6,	33.6,

```

      C      $ 35.5 , 51.2 , 56.4 , 60.9 , 65.0 , 69.0 /
60      DATA F1GCST/
      $      .342, .518, .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 ,
      $ 25.5 , 27.3 , 28.9 , 30.5 , 32.2 , 33.9 /
65      C      DATA P1PCST/
      $      .096, .127, .157, .189, .221,
      $ .253, .353, .402, .441, .472, .503,
      $ .548, .593, .634, .675, .697, .719,
70      $ .741, .933, 1.03 , 1.09 , 1.17 , 1.24 /
      C      DATA R1DCST/
      $      .365, .455, .545, .798, 1.05 ,
75      $ 1.35 , 1.55 , 2.91 , 4.25 , 4.99 , 5.71 ,
      $ 5.95 , 8.19 , 8.37 , 9.55 , 12.7 , 16.8 ,
      $ 20.9 , 35.9 , 42.9 , 49.9 , 55.9 , 63.8 /
      C      DATA T1ECST/
      $      .494, 1.29 , 2.09 , 2.59 , 3.03 ,
80      $ 3.57 , 7.37 , 12.1 , 16.8 , 20.1 , 23.3 ,
      $ 25.1 , 26.8 , 31.0 , 35.2 , 39.1 , 43.0 ,
      $ 45.9 , 68.5 , 74.9 , 81.2 , 87.8 , 94.4 /
      C      DATA V1ACST/
85      $      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. /
90      C      DO 40 I=1,230
      X(I) = A1PCST(I)
40      CONTINUE
      RETURN
      END

```

```

SUBROUTINE P75
COMMON /PI75 / APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
$ , FLGCST(23)
$ , EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
COMMON /CPIPE/ X(230)

```

```

      THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
      REPORT FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
      75 PSI. THIS DATA IS CALLED BY USING A VALUE OF
      DPRESS= 75 (DPRESS=PIPING DESIGN PRESSURE) ON CARD 61
      OF THE INPUT. THUS, ANY COST DATA CAN BE SUBSTITUTED HERE!
      FOR STUDY PURPOSES.

```

DEFINITION OF VARIABLES

```

APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
DIAM     - COMPONENT DIAMETER (INCHES)
EJCST    - EXPANSION JOINT COST ($1000)
ELCST    - 90 DEGREE ELBOW COST ($1000)
EL45     - 45 DEGREE ELBOW COST ($1000)
FLGCST   - FLANGE COST ($1000)
PIPCST   - BELOW GROUND PIPE COST ($1000/FT)
REDCST   - REDUCER COST ($1000)
TEECST   - TEE COST ($1000)
VACST    - VALVE COST ($1000), VALVES ARE MOTOR OPERATED
          BUTTERFLY VALVES

```

75 PSI

DATA DIAM/

\$	12.	18.	24.	30.	36.
\$ 42.	48.	54.	60.	66.	72.
\$ 75.	84.	90.	96.	102.	108.
\$ 114.	120.	126.	132.	138.	144.

DATA FLGCST/

\$	.362,	.618,	.893,	1.15,	1.40,
\$ 1.92,	2.47,	3.22,	3.97,	5.55,	7.13,
\$ 9.82,	12.5,	14.7,	17.0,	20.5,	24.0,
\$ 25.5,	27.3,	29.9,	30.5,	32.2,	33.9,

DATA EJCST/

\$	.530,	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 VACST/

\$	3.64,	5.16,	8.67,	11.2,	13.8,
\$ 17.4,	21.0,	27.7,	34.3,	37.4,	40.4,
\$ 45.0,	51.7,	58.6,	65.5,	70.5,	75.5,
\$ 80.5,	85.5,	90.6,	95.5,	101.	106.

DATA APIPCST/

\$	.055,	.074,	.092,	.112,	.132,
\$.152,	.240,	.265,	.290,	.322,	.353,
\$.325,	.471,	.501,	.530,	.575,	.622,

```

      S .652, .681, .711, .879, .922, .965 /
C
60 DATA PIPCST/
   S .096, .127, .157, .189, .221,
   S .253, .353, .402, .441, .472, .503,
   S .534, .659, .713, .757, .816, .874,
   S .919, .963, 1.08, 1.19, 1.28, 1.36 /
C
65 DATA EL45/
   S .300, .665, 1.03, 1.37, 1.71,
   S 2.05, 4.77, 8.94, 13.1, 15.4, 17.6,
   S 19.9, 28.8, 32.1, 35.3, 38.9, 42.5,
   S 47.2, 51.9, 56.6, 74.3, 79.3, 84.3 /
C
70 DATA EDCST/
   S .437, 1.00, 1.56, 2.12, 2.68,
   S 3.24, 7.05, 12.0, 16.9, 20.3, 23.6,
   S 27.0, 39.2, 43.9, 48.6, 53.7, 58.7,
   S 65.3, 74.8, 82.9, 97.0, 106, 114, /
C
80 DATA TEECST/
   S .494, 1.29, 2.09, 2.59, 3.08,
   S 3.57, 7.37, 12.1, 16.8, 20.1, 23.3,
   S 25.1, 38.0, 41.5, 45.0, 49.7, 54.3,
   S 61.5, 68.6, 76.8, 99.1, 107, 115, /
C
85 DATA REECST/
   S .355, .455, .545, .798, 1.05,
   S 1.31, 1.55, 2.91, 4.26, 4.99, 5.71,
   S 5.95, 10.9, 11.1, 11.3, 16.3, 21.2,
   S 23.6, 35.9, 43.3, 62.5, 71.2, 79.9 /
90 DO 40 I=1,230
   X(I) = AIPCST(I)
40 CONTINUE
RETURN
END

```

```

SUBROUTINE P125
COMMON /P125/ APIPCST(23), DIAM(23), EJCST(23), ELCST(23)
$, FLGCST(23)
$, EL45(23), PIPCST(23), REDCST(23), TEECST(23), VACST(23)
COMMON /CPIPE/ X(230)

```

THIS SUBROUTINE SUPPLIES UNIT COST DATA TO SUBROUTINE
 PIPORT FOR PIPING SYSTEM COMPONENTS DESIGNED FOR
 125 PSI. THIS DATA IS CALLED BY USING A VALUE OF
 DPRESS= 125 (DPRESS=PIPING DESIGN PRESSURE) ON CARD G1
 OF THE INPUT. THUS, ANY COST DATA CAN BE SUBSTITUTED HERE
 FOR STUDY PURPOSES.

DEFINITION OF VARIABLES

APIPCST - ABOVE GROUND PIPE COST (\$1000/FT)
 DIAM - COMPONENT DIAMETER (INCHES)
 EJCST - EXPANSION JOINT COST (\$1000)
 ELCST - 90 DEGREE ELBOW COST (\$1000)
 EL45 - 45 DEGREE ELBOW COST (\$1000)
 FLGCST - FLANGE COST (\$1000)
 PIPCST - BELOW GROUND PIPE COST (\$1000/FT)
 REDCST - REDUCER COST (\$1000)
 TEECST - TEE COST (\$1000)
 VACST - VALVE COST (\$1000), VALVES ARE MOTOR OPERATED
 BUTTERFLY VALVES

125 PSI

DATA DIAM/

\$	42.	48.	54.	60.	66.	72.
\$	78.	84.	90.	96.	102.	108.
\$	114.	120.	126.	132.	138.	144.

DATA FLGCST/

\$	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	30.5	32.2	33.9

DATA EJCST/

\$	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 VACST/

\$	17.4	21.0	27.7	34.3	37.4	40.4
\$	45.0	51.7	58.6	65.5	70.5	75.5
\$	80.5	85.5	90.6	95.6	101.	106.

DATA APIPCST/

\$	.056	.074	.092	.110	.168
\$	.204	.240	.275	.350	.421
\$	.457	.555	.653	.718	.787

```

      $ .858, .893, .928, 1.11, 1.16, 1.21 /
60      C      DATA PIIPCST/
      $ .096, .127, .157, .188, .257,
      $ .310, .353, .416, .501, .537, .572,
      $ .607, .753, .894, .946, 1.01, 1.07,
85      C      $ 1.13, 1.19, 1.23, 1.43, 1.52, 1.60 /
      DATA EL45/
      $ .300, .665, 1.03, 1.40, 2.33,
      $ 3.55, 4.77, 5.99, 15.0, 19.9, 22.7,
70      C      $ 25.6, 35.5, 45.7, 51.7, 56.7, 61.7,
      $ 65.0, 68.3, 71.6, 102., 109., 116., /
      DATA ELCST/
      $ .437, .999, 1.56, 2.12, 3.47,
75      C      $ 5.24, 7.05, 8.84, 21.5, 25.7, 29.9,
      $ 34.1, 47.6, 62.8, 69.4, 75.1, 82.7,
      $ 93.9, 105., 116., 130., 141., 152., /
      DATA TEFCST/
80      C      $ .494, 1.29, 2.09, 2.89, 4.22,
      $ 5.80, 7.37, 5.95, 21.8, 26.0, 30.1,
      $ 34.2, 47.0, 59.8, 66.2, 72.7, 79.1,
      $ 89.4, 99.7, 110., 135., 147., 157., /
85      C      DATA REFCST/
      $ .365, .455, .545, .635, 1.55,
      $ 2.44, 3.33, 4.22, 5.63, 6.61, 7.58,
      $ 9.54, 13.9, 15.9, 17.8, 24.3, 30.8,
90      C      $ 45.5, 62.1, 77.7, 88.5, 101., 113., /
      DO 40 I=1,230
      X(I) = APIPCST(I)
40      CONTINUE
      RETURN
      END

```

SUBROUTINE ROOT(TFIX,RFIX,TTD,TD,CWARL)

GIVEN THE EFFECTIVENESS THIS ROUTINE CALCULATES THE
CAPACITY RATIO LIMIT FOR THE HEAT EXCHANGER USING A
SINGLE PASS CROSSFLOW CORRELATION

DEFINITION OF VARIABLES

CWARA - THERMAL CAPACITY RATIO OF WATER TO AIR FLOWING
THROUGH THE HEAT EXCHANGER (DIMENSIONLESS)
EFF - EFFECTIVENESS OF HEAT EXCHANGER (DIMENSIONLESS)
RFIX - TEMPERATURE RANGE OF WATER FLOWING THROUGH THE
HEAT EXCHANGER (DEG F)
TD - HEAT EXCHANGER AMBIENT AIR DESIGN TEMPERATURE
(DEG F)
TFIX - EXIT TEMPERATURE OF THE TURBINE AT WHICH THE
SYSTEM IS TO BE DESIGNED FOR (DEG F)
TTD - TERMINAL TEMPERATURE DIFFERENCE OF THE SURFACE
CONDENSER (DEG F)

EFF = RFIX/(TFIX - TTD - TD)
CWARA = (1.00 - EFF)/EFF

NEWTON-RAPHSON ROOT FINDING ROUTINE

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, DIST, PF)

C THIS ROUTINE PRINTS PIPING COST REPORT

C

COMMON /KPRT1/

S DUNGS1

S DYNH1, DIAD1, DIAT1, DIAH1(500), DIAQ1(500)

S EPSC1, EGPC1, EPMP1, EPUF1, EDYNH1, EXSPM1, EUC0S1, ELC0S1

S FLGC1

S GPMCI1, GPGRM1, GPCST1

S HEDR1(500)

S JSAV1

S LSAV1

S NTUB1, NBUNP1, NTOWG1, NTOWP1, NEXTO1

S PSTAC1, PUFIT1, PUMPC1, PIPCOS1(500), PISCO1

S QDCS1, QUADG1, QPIPC1(500), QHEDR1(500), QTECS1(500)

S QROCS1(500), RELCS1

S REDCS1(500), RPTPL1

S TEECS1(500), TPCS1, TDCS1, TTDCS1, TGPCS1, TOWD11, TQOCS1

S XTOW1

COMMON /PRESS/ IPRESS

180 FORMAT(T31,16("-"))//T36,"PIPING",T55,I3," PSI DESIGN PRESSURE"

S //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

S PIPE TEES REDUCERS EXPANSION FLANGES"/12X,"SECTION (I

SNCHES) (FEET)",33X,"JOINT(1 (3)"/)

203 FORMAT(1H,14X,12,1X,7F10.0)

204 FORMAT(//10X,"CIRCULAR TOWERS",I6,14X,"TOWER GROUPS",I4X,I6,/10X,

S "TOWERS PER GROUP",I5,14X,"TOWERS IN INCOMPLETE GROUP",I6)

1204 FORMAT(//10X,

S "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//47X)

205 FORMAT(//25X,"QUADRANT PIPING"//42X,"COST IN 10**3 DOLLARS FOR"/40X

S "-----"/12X,"HEADER DIAMETER LENGTH"

S PIPE TEES REDUCERS"/12X,"SECTION (INCHES) (FEET)"/)

208 FORMAT(//10X,"TUBES PER BUNDLE",I10,/10X,"BUNDLES PER QUADRANT",I6

S,/10X,"COST OF HEADERS PER QUADRANT \$",F5.0," *10**3"//49X,"TOTAL

\$L COST OF QUADRANT HEADERS \$",F5.0," *10**3"//49X)

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

\$ISTRIBUTION PIPING PER TOWER \$",F5.0," *10**3"//40X,"TOTAL COST O

\$F TOWER DISTRIBUTION PIPING \$",F5.0," *10**3"//40X)

211 FORMAT(//25X,"PUMP STATION"//10X,"DESIGN VELOCITY",15X,F3.0," FPS"/

\$10X,"FLOW PER BUNDLE",10X,F3.0," GPM"/

\$10X,"FLOW PER QUADRANT",8X,F3.0," GPM"/10X,"FLOW PER TOWER",11X,

\$F3.0," GPM"/10X,"FLOW PER TOWER GROUP",F3.0," GPM"/10X,

\$FLOW TO INCOMPLETE GROUP",F3.0," 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 \$"

```

      5,F5.0," *10**3",7X,"PUMP STATION COST  $",F5.0," *10**3")
2120  FORMAT(//T58,"PUMP ELECTRICAL COSTS $",F5.0," *10**3"//)
65  2125  FORMAT(T58,"COST OF PUMP STATIONS $",F5.0," *10**3"////,
      5      .T54,"TOTAL PIPING SYSTEM COSTS $",F6.0," *10**3"//)
213  FORMAT(1H1)
214  FORMAT(14,13X,I2,1X,7F10.1)
      WRITE(A,213)
65  75  WRITE(A,190) IPRESS
      WRITE(A,204) IFIX(XTOW1+1.E-30),NTOWG1,NTOWP1,NEXT01
      WRITE(A,200)
      DO 201 I = 1, JSAV1
      IF(I.GT.1) GO TO 202
      WRITE(A,203) I,DIAH1(I),HEDR1(I),PIPCOS1(I)*PF,TEECOL1(I)*PF,
75  $ REDCOL1(I)*PF,EJCS1*PF,FLGCOL*PF
      GO TO 201
202  IF (I.EQ. JSAV1) GOTO 210
      WRITE(A,203) I, DIAH1(I), HEDR1(I), PIPCOS1(I)*PF, TEECOL1(I)*PF,
75  $ REDCOL1(I)*PF
      GO TO 201
210  WRITE(A,203) I, DIAH1(I), HEDR1(I), PIPCOS1(I)*PF, ELCCS1*PF,
      $ REDCOL1(I)*PF
80  201  CONTINUE
      WRITE(A,1204) GPCST1*PF,EGPCST1*PF,TGPCST1*PF
      WRITE(A,209) TOWD11,DIAD1,DIAT1,TDCS1*PF,TTDCS1*PF
      WRITE(A,205)
      DO 206 I = 1, LSAV1
      IF (I.EQ. LSAV1) GOTO 207
85  WRITE(A,214) I, DIAQ1(I), QHEDR1(I), QPIPC1(I)*PF, QTECS1(I)*PF,
      $ QROCS1(I)*PF
      GO TO 206
207  WRITE(A,214) I, DIAQ1(I), QHEDR1(I), QPIPC1(I)*PF, QELCS1*PF,
      $ QROCS1(I)*PF
90  206  CONTINUE
      WRITE(A,208) NTURP1, NEUNP1, QHDCS1*PF, TQDCS1*PF
      WRITE(A,211) DESVEL, BUNSP1, QUADG1, GPMCI1, GPGPM1, EXGPM1
      WRITE(A,212) DYNH01, EDYNH1, PUMPC1*PF, EPMP1*PF, PUFIT1*PF,
95  $ EPJFI1*PF, PSTAC1*PF, EPSCS1*PF
      WRITE(A,2100) OPTPL1
      WRITE(A,2125) TPCS1*PF, PISC01
      RETURN
      END

```

```

      SUBROUTINE RPRT2 (EFFC, TUBEM, TUBEM2)
      C
      C   THIS ROUTINE REPORTS CONDENSER DESIGN AND COSTS
      C
5      COMMON /KPRT2/ UCON, TI, TE, TOLM, XNP
      S, VELD, DELPWC, ARPS, TLA, XNTS, XNS, TS
      COMMON /KPRT3/ TUBCST, SHLCST, FETCST, CHX
6100  FORMAT(1H1,
10      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 T16, "STEAM TEMPERATURE", F6.1, " F"
15      R T50, "OVERALL HEAT TRANSFER COEFFICIENT ", F8.2, " BTU/HRI SQ FT DEG
      RE")
6115  FORMAT(
      L T10, "INLET WATER TEMPERATURE", F6.1, " F"
      R T60, "AVERAGE WATER VELOCITY THRU COND ", F8.1, " FT/SEC")
20      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"
25      R T70, "CONDENSED EFFECTIVENESS ", F8.3)
6130  FORMAT(
      L T06, " --- CONDENSER DESCRIPTION ---"
      R T75, " --- CONDENSER COSTS ---" //)
6135  FORMAT(
30      L T17, "NUMBER OF SHELLS", I6,
      R T76, "TUBING MATERIAL $", F14.2X(" ", 2A10, " "))
6140  FORMAT(
      L T05, "HEAT TRANSFER AREA PER SHELL", G11.5, " SQ FT"
      R T85, "SHELLS $", F14.2)
35      6145  FORMAT(
      L T07, "NUMBER OF PASSES PER SHELL", I6,
      R T77, "FIELD ERECTION $", F14.2)
6150  FORMAT(
40      L T22, "TUBE LENGTH", I6, T45, " FEET")
6155  FORMAT(
      L T08, "NUMBER OF TUBES PER SHELL", I6
      R T43, "TOTAL COST OF CONDENSER $", F14.0)
      C
45      WRITE(6,6100)
      WRITE(6,6105)
      WRITE(6,6110) TS, UCON
      WRITE(6,6115) TI, VELD
      WRITE(6,6120) TE, DELPWC
      WRITE(6,6125) TOLM, EFFC
50      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)
65      RETURN
      END

```

SUBROUTINE PPTFAN

THIS ROUTINE REPORTS FAN DESCRIPTION AND COSTS

COMMON/FAN/ FANDAP(153,10),FANDAH(153,10),FMOPF,FBCPF,P2,R,S,
SVELREC,APC,ELEV,EHR
LOGICAL FIRST, FXTMP

COMMON

\$ AFTR, ALPHA
\$ CAPF, CSEPKW, CONF, CONL, COSTL, CAPCHS, CONMAT, CONMA2, CAFI
\$ CBU, CTURB, CDANG, CLUVR, CHAILS, CVM
\$ DANGLE, DFIN, DEEPL, DESVEL
\$ EFFF
\$ FOR, FIRST, FIXL, FCOS, FFHX, FXTMP
\$ GBEFF
\$ HXNP, HPCST
\$ ITMAX, ITMIN
\$ JCONS
\$ KCONQ, KALEXT
\$ MXEXT
\$ NTUCAL(2), NTA

COMMON

\$ ODR
\$ PSIZE, PER, PWCOS, PLANC, PEACT, POMDPL
\$ POMBAF, POMFAN, POMLEC, POMCIR, POMCND, POMSTC, POMSCL
\$ PREU, PREDUCE
\$ PRP, REDUCE, ROOFL, RFIX
\$ SIGMA, SAAF
\$ TD, TPO(4), TEFF, TLIM, THEIN, TLPRA, TFIX
\$ TCD, TW
\$ UCS, UWS
\$ VAS(7)
\$ WFFV
\$ XDEPA, XW, XD

COMMON /SINK/ VAR(5), CHLN1, CPIP1, CCOS1, W31, COSH1, EFF1,
\$ DIN1, CLAN1, REA11, Z1, HRF12S, J41, UI, DEPW1, PPW1,
\$ FROM1, DEFC1, WIOT1, ELENI, VAIR1, VWAT1, HI1, H01, T41,
\$ REW1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSP6P, SW41, SW31,
\$ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
\$ BRPMIN, NWPMIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
\$, TL41, UCON1, PMOS1, FMOS1, FBAC1, EFFC1, CH1, CA1, CS1
\$, CLT1, CFC1, CPCC1, FITC1, CS1, CEPRE1, DEPI1, AST1, OLOCS1
\$, CAPCS1, XNFAN1, RLDAN1, CPLEN1, DPFE1, WH1, WTTU1, ADI1, ARL1
\$, WTH1, WTER1, STRUC1, CFMPF1, HPPF1, TOTCF1, TPT, CFFIN1, ANTU1
\$, AIRFE1, WATER1, XNMOT1, TCTP1, FDCPF1, FMTRC1, ACTTP1, ADUTP1
\$, ACTP1, ADJBP1, ACTVH1, ADJWH1, ADJPP1, THPA11, TCTF1, AFCST1
\$, CSP1, WATER1, WSTRC1, CFJUN1, HJBD11, TOWLE1, NUMT01, CTOWD1
\$, ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
REAL MOTOR(4,3), DRIVE(3,2), PITCH(3,2), RECOVY(5,2)

DATA ((MOTOR(I,K), I=1,4), K=1,3) /
* "TOTALLY EN", "CLOSED SQU", "IRREL CASE", " MOTOR ",
* "EXPLOSION ", "PROOF SQU", "IRREL CASE ", " MOTOR ",
* "TWO SPEED ", "SQUIREL C", "AGE ", " "
DATA ((DRIVE(I,K), I=1,3), K=1,2) /
* "SPIRAL BEV", "HEL GEAR DR", "IVE ",

```

      * "V-BELT DRI","VE      ","      "/"
      DATA ((PITCH(I,K),I=1,3),K=1,2)/
60      * "MANUAL PIT","CH BLADES ","      "/"
      * "AUTO-VARIA","BLE PITCH ","      "/"
      DATA ((RECOVY(I,K), I=1,5),K=1,2)/
      * "FANS NOT EQ","QUIPPOD WT","TH VELOCIT","Y RECOVERY";
      * "DIFFUSERS";
65      * "FANS EQUIP","PED WITH V","ELOCIITY RE","COVERY DIF";
      * "FUSERS      "/"

C
1000 FORMAT(1H )
1005 FORMAT(141)
70 1010 FORMAT(T52,"FAN S")
1020 FORMAT(T51,"-----")
1030 FORMAT(T15,"--- DRIVE SYSTEM ---",T82,"--- FAN GEOMETRY ---")
1040 FORMAT(T84,"BLADE DIAMETER ",F6.2," FEET")
1050 FORMAT(T87,"BLADE ANGLE ",F6.2," DEGREES")
75 1060 FORMAT(T79,"NUMBER OF BLADES/FAN ",F5.2)
1070 FORMAT(T84,"NUMBER OF FANS ",F5.0)
1080 FORMAT(T17,"--- FAN COSTS ---",T78,"--- DESIGN CONDITIONS ---")

C
1085 FORMAT (T100,"(ACTUAL)",T122,"(ADJUSTED)")
80 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. ",F9.5," PSI",T120,F8.5)
85 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 ",F9.5," PSI",T120,F8.5)
90 1145 FORMAT(T13,"ELECTRICAL COST/FAN $",F10.0,
      * "T33,"HORSEPOWER/FAN",F13.0," HP",T116,F12.0)
1150 FORMAT(T79,
      * "FAN POWER REQUIREMENTS ",F8.0," HP")
1160 FORMAT(T2,"***ANNUAL OPERATIONAL COSTS $",F10.0)
1200 FORMAT(T37,5A10)
35 1210 FORMAT(
      * "R T86,"HUB DIAMETER ",F6.2," FEET")
      WRITE(4,1005)
      WRITE(4,1000)
      WRITE(4,1000)
100 1010 WRITE(4,1020)
      WRITE(4,1010)
      WRITE(4,1020)
      WRITE(4,1000)
105 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(4,1000)
      WRITE(4,1030)
      WRITE(4,1000)
110 1010 WRITE(4,1210) HUBDI1
      WRITE(4,1040) ADI1
      WRITE(4,1050) RLDAN1
      WRITE(4,1060) ADI1
      WRITE(4,1070) XNFAN1
      WRITE(4,1000)

```

```
115      WRITE(4,1000)
        WRITE(4,1000)
        WRITE(4,1000)
        WRITE(4,1005)
        WRITE(4,1020) CFMPF1
120      WRITE(4,1100) FDCPF1, TOTCF1
        WRITE(4,1120) FMTRC1, ACTTP1, ADJTP1
        WRITE(4,1130) CSP1, ACTB1, ADJB1
        WRITE(4,1140) CYLRN1, ACTVH1, ADJVH1
125      WRITE(4,1145) CFANE1, HPPF1, ADJPP1
        WRITE(4,1150) THPA11
        WRITE(4,1190) AFCST1
        RETURN
      *END
```

SUBROUTINE RPTHXC(AFR0N)

THIS ROUTINE REPORTS HEAT EXCHANGER DESIGN, OPERATING CONDITIONS
AND COST

LOGICAL FIRST, FXTMP
COMMON

\$ AFR0, ALPHA
\$,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
\$,CRJ, CTURB, CDANG, CLUVR, CHAHS, CVM
\$,DANGLE, DFIN, DEEPL, DESVEL
\$,EFFP

\$,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP

\$,GBEFF

\$,HXND, HPCST

\$,ITMAX, ITMIN

\$,JCONS

\$,KCONV, KALEXT

\$,MXEXT

\$,NFUCAL(2), NTA

COMMON

\$,DRI

\$,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL

\$,POHRAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCC

\$,OREJ, OREUCE

\$,RRS, REDUCE, ROOFL, RFIX

\$,SIGMA, SAAF

\$,TD, TPO(4), TEF, TLIM, THFIN, TLPRA, TFIX

\$,TOD, TW

\$,UIC, UWS

\$,VAS(4)

\$,WFW

\$,XDEP, XW, XD

COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOST, W3I, COSM1, EFF1,

\$,CIN1, CLAN1, REAT1, Z1, HRFAS, W4I, U1, DEPW1, PPW1,

\$,EPW1, DEFC1, WIDT1, ELENI, VAIR1, VWAT1, HI1, HO1, T41,

\$,REW1, MW1, NT1, VPI, ZPLNC2, ZSIZ12, ZSPBP, SW41, SW31,

\$,SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCO1, SPS13, WT2MIN,

\$,RP2MIN, NN2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XN1S1, VELD1

\$,TLA1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CAL, CSI

\$,CLT1, CFC1, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLOCS1

\$,CAPCS1, XNEFAN1, ALDANI, CPLEN1, DPFE1, WH1, WTTU1, ADI1, ABL1

\$,WTH1, WTER1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1

\$,AIRFE1, WATER1, XNMOD1, TCTP1, FOCPE1, FMTRC1, ACTTP1, ADJTP1

\$,ACTRN1, ADJRP1, ACTVH1, ADJVV1, ADJPP1, THPA1, TCTF1, AFCST1

\$,CSSE, WATER1, WSTRC1, CFOUN1, HUBD1, TOWLE1, NUMTOL, CTOWD1

\$,ATUBC1, CSTLV1, CSTHS1, CYLRN1, CFANE1

COMMON /TIME/ XNS, TTD, TLA, XN1S, ARPS

COMMON /HXD/ AI, ATOT

COMMON /ESCAL/ BSECF

5390 FORMAT

\$,T71, "WT OF WATER ", F14.0, " LB"

6400 FORMAT

\$,T9, "AFR0", G14.8

\$,T71, "WT OF TUBES ", F14.0, " LB"

6410 FORMAT

```

      L T8,"ALPHA", G14.8
      R,T71,"WT OF FRAME ",F14.0," LB")
60      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")
65      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 (I40,2A10,T15,"NTU EFFECTIVENESS CORRELATION USED")
      6500 FORMAT(I40)
      6505 FORMAT(T35,30(" "))
      6510 FORMAT(T35,"H E A T   E X C H A N G E R")
75      6512 FORMAT(I4,T90,F5.1," FANS",T110,F4.1," PASS")
      6515 FORMAT(
      L T2," WATER FLOW RATE",I11," LBM/HR"
      R,T71," COOLING SURFACE S",F10.0)
      6520 FORMAT(
      L T2," AIR FLOW RATE",I11," LBM/HR"
      R,T71," HEADER AND NOZZEL S",F10.0)
      6525 FORMAT(
      L T2," TUBES IN DEPTH",F11.2," TUBES  ("F7.1," FT DEEP)"
      R,T71,"BUNDLE ASSEMBLE AND FRAME S",F10.0)
85      6530 FORMAT(
      L T2,"TUBES ACROSS FRONT",I11," TUBES  ("F7.1," FT WIDE)"
      R,T71," PLENUM S",F10.0)
      6532 FORMAT(I4
      R, T71," LOUVERS S",F10.0)
90      6533 FORMAT (I4
      R, T71," HAIL SCREENS S",F10.0)
      6535 FORMAT(
      L T2," LENGTH",F11.0," FEET"
      R,T71," STRUCTURE S",F10.0)
95      6537 FORMAT(
      R T71," FOUNDATION S",F10.0)
      6540 FORMAT(
      L T2," FRONTAL AREA",I11," SQ FEET"
      R,T71," HEAT XCHR SHIP AND ERECT S",F10.0)
100      6550 FORMAT(T40,2("FOR",F5.0," DEGREE F AMBIENT  "))
      6541 FORMAT(T4,"SURFACE AREA",I11," SQ FT")
      6555 FORMAT(T70,11(" "),2X,11(" "))
      6560 FORMAT(T70,"AIR",T37,"WATER")
      6565 FORMAT(T70,25(" "))
105      6570 FORMAT(T50,"REYNOLDS NUMBER"
      S .2(1PE13.5,E14.5,3X))
      6575 FORMAT(T40,"VELOCITY (FT/SEC)"
      S .2(1PE13.5,E14.5,3X))
      6580 FORMAT(T34,"PRESSURE DROP (LBS FORCE/SQ IN)"
      S .2(1PE13.5,E14.5,3X))
110      6581 FORMAT(T44,"INLET TEMPERATURE (F)",1PE13.5,E14.5)
      6582 FORMAT(T45,"EXIT TEMPERATURE (F)",1PE13.5,E14.5)
      6583 FORMAT(T26,"RANGE (F)",1PE13.5,E14.5)
      6584 FORMAT(T60,"CWARA",7X,1PE13.5)

```



```

115      6585 FORMAT(T29,"HEAT TRFR COEFF (BTU/HR SQ FT DEG F)"
          $ ,2(1P=13.5,E14.5,3X))
      6586 FORMAT(T62,"NTU",7X,1P=13.5)
      6587 FORMAT(T50,"FRICTION FACTOR"
          $ ,2(1P=13.5,E14.5,3X))
120      6590 FORMAT(T35,"HEAT TRFR SURFACE AREA (SQ FT)"
          $ ,1P=13.5,E14.5)
      6592 FORMAT(T35,"EXIT TEMPERATURE (F)"
          $ ,2(1P=13.5,E14.5,3X))
      6595 FORMAT(T35,"OVERALL U (BTU/HR SQ FT DEG F)"
          $ ,7X,1P=13.5,E14.5)
125      6600 FORMAT(T62,"EFFECTIVENESS"
          $ ,T76,F7.4)
      6610 FORMAT(T61,"FIN EFFICIENCY"
          $ ,T76,F7.4)
130      6620 FORMAT(T07,"LOG MEAN TEMPERATURE DIFFERENCE"
          $ ,T46,F7.2,T76,F7.2)

```

C

```

      WRITE(4,6500)
      WRITE(4,6505)
135      WRITE(4,6510)
      WRITE(4,6512) XNFAN1, HXNP
      WRITE(4,6515)
      WRITE(4,6520)
      WRITE(4,6525)
140      WRITE(4,6530)
      WRITE(4,6535)
      WRITE(4,6540)
      WRITE(4,6545)
      WRITE(4,6550)
      WRITE(4,6555)
      WRITE(4,6560) REA11, REWA1
      WRITE(4,6565) VAIR1, VWAT1
      WRITE(4,6570) DEPA1/144., DPWT1/144.
145      WRITE(4,6575) HO1, HI1
      WRITE(4,6580) AIRFF1, WATERF1
      WRITE(4,6585) TD, VAR(1)-TTD
      WRITE(4,6590) T41, VAR(1)-VAR(2)-TTD
      WRITE(4,6595) T41-TD, VAR(2)
150      WRITE(4,6600) VAR(3)
      WRITE(4,6605) ANTU1
      WRITE(4,6610) UI
      WRITE(4,6615) EFF1
      WRITE(4,6620) EFFIN1
155      WRITE(4,6625)
      WRITE(4,6630) WATER1
      WRITE(4,6635) AFTR, WTTU1
      WRITE(4,6640) ALPH4, WTRF1
      WRITE(4,6645) SIGMA, WTHD1
160      WRITE(4,6650) WSTR1
      WRITE(4,6655) AFROV, ROOFL, ROOFL1
      WRITE(4,6660) FITCO1/ATOT
      WRITE(4,6665) NTJCAL
      WRITE(4,6670)

```

C

```

165      WRITE(4,6515) IFIX(SW31), CS1
      WRITE(4,6520) IFIX(SW41), CH1
      WRITE(4,6525) Z1, Z1*XD/12., CAL
      WRITE(4,6530) NW1, WIDT1, CPLEN1
170      WRITE(4,6532) CST-V1
      WRITE(4,6533) CSTHS1

```

SUBROUTINE RPTHXC

74/74 OPT=1

FTN 4.2-74351

12/21/68

775 WRITE(4,6535) ELEN1, STRUC1
 WRITE(4,6537) CFOUN1
 WRITE(4,6540) IFIX(AFRO1), (3SECF-1.)*(CA1 + CH1 + CSI)
 WRITE(4,6541) IFIX(AAIR1)
 PETJPN
 END

SUBROUTINE RPTHXD

THIS ROUTINE REPORTS HEAT EXCHANGER DESCRIPTION AND UNIT COST DATA

LOGICAL FIRST, FXTMP
COMMON

```

$ AFTR, ALPHA
$ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAF
$ ,CRJ, CTURB, COANG, CLUVR, CHAHS, CVM
$ ,DANGIE, DFIN, DEEPL, DESVEL
$ ,EFFP

```

```

$ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
$ ,GHEFF

```

```

$ ,HXNP, HPCST
$ ,ITMAX, ITMIN
$ ,JCONV
$ ,KCONV, KALEXT
$ ,KXEXT

```

```

$ ,NTUC, L(2), NTA
COMMON

```

```

$ ,DDR
$ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
$ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCLE
$ ,PREJ, PREJUCE

```

```

$ ,RBP, REDUCE, ROOFL, RFX
$ ,RSIGN, SAAF
$ ,TL, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX

```

```

$ ,TCD, TW
$ ,UCS, UWS
$ ,VAS(7)

```

```

$ ,WFW
$ ,XDEP, XW, XD
COMMON /HEADX/ CHH, CV, CHM, CMW, CRJ, CWJ, CST
$ , CJO, CSR, CSM, PITCHF, CPM, PRESS, HEDMAT, HEOTYP, NPASS
$ ,

```

```

COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W3, COSM1, EFF1,
$ , Q1N1, CLAN1, REA11, Z1, HRFAPS, W41, UT, DEPW1, PPOW1,
$ , FPOW1, DEFC1, WIDT1, ELENG1, VAIR1, VWAT1, HT, HO1, T41,
$ , REWAT, NW, NT, NP1, ZPLNC2, ZSIZ12, ZSPB, SW41, SW31,
$ , SPAL, PTOT1, PLNC31, AFRO1, AAIR1, YERMIN, SPCO1, SPS13, WT2MIN,
$ , B2MIN, VW2MIN, TCOS1, DEPA1, DPWT1, DPAC1, CONBAT, XNTS1, VELD1
$ , TL1, JCON1, FMCS1, FMCS1, FBAC1, EFFC1, CH1, CA1, CS1

```

```

$ , CLT1, CFC1, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLOCS1
$ , CAPCS1, XNFAN1, BLOAN1, CPLEN1, DPEL1, W41, WTTU1, AD11, ABL1
$ , WTH1, WTH1, STRUC1, CAPPE1, TPEF1, TUTCF1, TPI, EFF11, ANTJ1
$ , AIPPE1, WATPE1, XNWD1, TCTPE1, FOCPE1, EMTRC1, ACTIP1, ADJTP1
$ , ACTBP1, ADJBP1, ACTVH1, ADJUH1, ADJUP1, THPA1, TCTF1, AFCST1
$ , CSRI, WATER1, WSTRC1, CFJUN1, HUBD1, FOWLE1, NUMT1, CTOWD1
$ , ATUHC1, CSTLV1, CSTHS1, CYLRN1, CFANE1

```

```

COMMON /TIME/ XNS, ITD, TLA, XNTS, ARPS
COMMON /SUPPEX/ ODL, GAGLIN, NTUB, TURMAT, FINTYP, FINMAT, CFB
$ , APLATE, COATC, ZINCC, CASTC, SS, EPREPC, XTUMM, XHEDTY, XFINTY

```

```

COMMON /OUR/ DI, XDG, SF
COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
$ , Q1N, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
$ , FPAW, DELEC, WIDTH, ELENG, VAIR, VWAT, HT, HO, T4,
$ , REWAT, NW, NT, NP, PLANC2, PSIZ12, SPB, SW4, SW3,

```

```

      S SPC,PTOTAL,PLANC3,SAFRON, AAIR, YFP, SPCN,PSIZ13, WT2,
      S S22, NWR, TCOS, DELPA,DELPNT,DELPWC,CONBAS, XNTSX, VELDX
60      S , TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
      S , CLAC, CFC, CCCC, FITCO, CSC,CEPREP,DELPPI, AST,OLDGST
      S,CAPOST, XNFAN,RDANG, CPLEN, DPFL, WHX, WTTUB, ADIA, ABLV
      S, WTHR, WTRM,STRUCO,CFPERF,HPERF, TOTCF, TPC, EFFIN, ANTU
65      S, AIRFF, WATERF, XNMOO, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      S, ACTHRO, ADURPD, ACTVH, ADJUH, ADJPPF, THPAIR, TCTF, AFCST
      S, CSRD, WATERM, WSTRT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S, ATUBO, CSTLVR, CSTHS, CYLRNG, CFANEL
6600 FORMAT(1H1)
6601 FORMAT(1H1)
70 6602 FORMAT(1H+,T10," V O N - D E L I T A   H E A T   E X C H A N G E I
      S R   D E S C R I P T I O N",T5,F5.1," DEGREEI  ")
6603 FORMAT(
      L T22,"SUPPORT SPACING ",F7.3,T47,"FEET"
      R,T60,"ROOT DIAMETER",F8.4,T82,"INCH")
75 6605 FORMAT(
      L T8,"TUBE PITCH NORMAL TO AIR FLOW ",F7.3,T47,"INCH"
      R,T60,"FIN THICKNESS",F8.4,T82,"INCH")
6610 FORMAT(
      L T2,"TUBE PITCH IN DIRECTION OF AIR FLOW ",F7.3,T47,"INCH"
80 6615 FORMAT(
      L T8,"FIN DIAMETER ",F8.4,T82,"INCH")
      L T10,"TUBE DIAGONAL PITCH ",F7.3,T47,"INCH"
      R,T60,"FIN SPACING",F8.4,T82,"INCH")
6620 FORMAT(
      L T23,"LINER MATERIAL ",Z410
85 6625 FORMAT(
      R,T61,"FIN MATERIAL ",Z410)
      L T11,"LINER THERMAL CONDUCTIVITY",F7.3
      R,T55,"FIN THERMAL COND. ",G11.4,T83,"BTU/(HR SQ FT DEG F)/FT")
90 6630 FORMAT(
      L T8,"LINER TUBING OUTSIDE DIAMETER ",F7.4,T47,"INCH"
      R,T62,"HEADER TYPE ",Z410)
6635 FORMAT(1H+
      L T8,"--- U N I T   C O S T S ---")
95 6640 FORMAT(
      L T13,"FIN BONDING $",G10.4,"/SQ FT"
      R,T55,"HEADER MATERIAL (" ,Z410," ) $",F8.3,"/LB")
6645 FORMAT(
      L T8,"PROTECTIVE COATING $",G10.4,"/SQ FT"
100 6650 FORMAT(
      R,T55,"WELDED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
      L T8,"GALV FOR SPACERS $",G10.4,"/LB"
      R,T55,"WELDED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
105 6655 FORMAT(
      L T10,"SPACER CASTING $",G10.4,"/EA"
      R,T55,"TUBE AND PLUG HOLE PREPARATION $",F8.3,"/HOLE")
6660 FORMAT(
      L T8,"HOLE PREPARATION $",G10.4,"/TUBE"
      R,T66,"NOZZEL AND ATTACHING $",F8.3,"/HOLE")
110 6662 FORMAT(
      R,T47,"WELDED HEADER JOINT $",F8.3,"/FT")
6665 FORMAT(
      R,T55,"HEADER MACHINING AND WELDING $",F8.3,"/FT")
6670 FORMAT(

```

```

115      LT09,"LINER TUBING   S",G11.5,"/FT",
      RT79,"STRUCTURAL STEEL  S",F8.3,"/LB")
6675 FORMAT(
      LT03,"PROTECTIVE COATING   S",G11.5,"/FT"
      )
120      6680 FORMAT(
      LT14,"FINNING           S",G11.5,"/FT"
      )
6685 FORMAT(
      LT09,"FINNED TUBE   S",G11.5,"/FT"
      )
125      6695 FORMAT(
      LT03,"TUBE SPACERS   S",G11.5,"/FT"
      )
C
130      6617 FORMAT(
      LT27,"LINER GAGE ",F5.1
      R ,T55,"FIN TYPE ",Z410)
6700 FORMAT(
      LT19,"TUBES THRU EACH FIN",F8.0,T47,"TUBES"
      R,T56,"AREA OF PLATE FIN ",F11.1," SQ IN.")
135      6710 FORMAT(
      LT0,"LINER TUBING INSIDE DIAMETER ",F7.4,T47,"INCH"
      R,T60,"HEADER LENGTH",F11.3," FEET")
      WRITE(4,6600)
      DO 20 I=1,3
140      20 IF (DANGLE .LT. 1.E-30) WRITE(6,6602)
      IF (DANGLE .GT. 0.0) WRITE(6,6602) DANGLE*180. / 3.14159
      WRITE(4,6601)
      WRITE(4,6603) SS      ,ODR
      WRITE(4,6605) XW      ,TDFIN
      WRITE(4,6610) XO      ,DFIN
      WRITE(4,6615) XDG      ,SF
      WRITE(4,6617) GAGLIN,FIN TYP,XFIN TYP
      IF (FIN TYP .EQ. "PLATE ") WRITE(6,6700) NTUB,APLATE
150      WRITE(4,6620) TUB MAT,XTUB MA,FIN MAT
      WRITE(4,6625) CONL,CONF
      WRITE(4,6630) ODL,HEDTYP,XHEDTY
      WRITE(4,6710) DI, 48
      WRITE(4,6601)
155      WRITE(4,6601)
C
      DO 30 I=1,3
160      30 WRITE(6,6635)
      WRITE(4,6601)
      WRITE(4,6640) CFB,HEDMAT,CHM
      WRITE(4,6645) COATC,CPJ
      WRITE(4,6650) ZINCC,CNJ
      WRITE(4,6655) CASTC,CHM
      WRITE(4,6660) EPREPC,CN
165      WRITE(4,6662) CBJ
      WRITE(4,6665) CMW
      WRITE(4,6670) CLIC1, CST
      WRITE(4,6675) CPC1
      WRITE(4,6680) CFC1
170      WRITE(4,6685) FITC1
      WRITE(4,6695) CSC1

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SUBROUTINE RPTHXD 74/74 OPT=1

FTN 4,2+74351

12/21/76

C
RETURN
END

SUBROUTINE SCALP (RANGE, CWARA, AFRON, WLRAT, TCWFCS, ITOWN)

SUBROUTINE SCALP SCALES THE PLANT AND DRY COOLING TOWER
DESIGNS AND COSTS LINEARLY UPWARD OR DOWNWARD TO ACCOUNT
FOR THE FOLLOWING FACTORS-

1. THE DESIGN TEMPERATURE OF THE POWER PLANT DOES
NOT CORRESPOND TO THE RATED BACK PRESSURE OF THE
STEAM TURBINE.
2. PART OF THE TOTAL POWER OUTPUT OF THE PLANT IS
USED IN SUPPLYING POWER TO THE FAN AND PUMPING
SYSTEMS.

THE FOLLOWING ARE POINTS ON THE HEAT RATE FACTOR CURVE WHICH
ARE USED IN DESCRIBING THE SCALING OF THE PLANT AND DRY COOL-
ING TOWERS. AT EACH OF THESE POINTS THE HEAT RATE FACTOR,
PLANT SIZE AND PLANT COSTS ARE DETERMINED.

POINT 0 - CONVENTIONAL TURBINE OPERATING AT RATED BACK
PRESSURE

POINT 1 - STEAM TURBINE OPERATING AT RATED BACK PRESSURE

POINT 2 - STEAM TURBINE OPERATING AT SYSTEM DESIGN EXIT
TEMPERATURE WITH OUTPUT OF TURBINE GENERATOR EQUAL
TO THE DESIGN POWER OUTPUT

POINT 3 - STEAM TURBINE OPERATING AT SYSTEM DESIGN EXIT
TEMPERATURE WITH THE POWER OUTPUT OF PLANT EQUAL
TO THE DESIGN POWER OUTPUT

THE DIFFERENCE BETWEEN POINT TWO AND THREE IS THE PLANT HAS
BEEN SCALED UP TO ACCOUNT FOR THE POWER CONSUMPTION OF THE
FANS AND PUMPS. BETWEEN POINT ONE AND TWO THE POWER PLANT
HAS BEEN SCALED UP OR DOWN TO ACCOUNT FOR AN INCREASE OR
DECREASE IN THE HEAT RATE FACTOR.

DEFINITION OF VARIABLES

AIR - AIR SIDE HEAT TRANSFER AREA OF HEAT EXCHANGER
(SQ FT)

APTA - FAN BLADE DIAMETER (FT)

AFRON - FRONTAL AREA OF THE HEAT EXCHANGER NORMAL TO AIR
FLOW (SQ FT)

ATUBC - HEAT EXCHANGER TUBE COST (\$)

BRECF - BUNDLE SHIPPING AND ERECTION COST FACTOR (DIMEN-
SIONLESS)

CA - BUNDLE ASSEMBLY COST (\$)

CAPE - PERCENT OF TIME PLANT IS GENERATING POWER DURING
THE YEAR (PERCENT)

CCOS - TOTAL COST OF THE DRY COOLING TOWER (\$)

CFANEC - COST OF THE ELECTRICAL WIRING FOR THE FAN SYSTEM
(\$)

CFOUND - COST OF THE FOUNDATION FOR THE DRY COOLING TOWERS
(\$)

CH - BUNDLE COSTS FOR THE HEAT EXCHANGER (\$)

CHALS - COST OF HAIL SCREENS PER UNIT AREA (\$/SQ FT)

CHAND - COST OF LAND COVERED BY THE DRY COOLING TOWERS (\$)

CHUVR - COST OF LOUVERS PER UNIT AREA (\$/SQ FT)

CONRAS - COST OF THE SURFACE CONDENSER (\$)

COSM - INCREMENTAL MAINTENANCE COSTS OF DRY COOLING (\$)

CRIP - COST OF THE PIPING SYSTEM (\$)

CPLEN - COST OF THE PLENUM ON TOP OF THE COOLING TOWERS (\$)

	C	CDM	- COST OF PLENUM MATERIAL PER POUND (\$/LBM)
	C	CC	- COOLING SURFACE COST (\$)
60	C	CSE	- COST OF HEADER SEALANT FOR CONNECTING PLASTIC TUBES TO THE HEADER (\$)
	C	CSTHS	- COST OF THE HAIL SCREENS FOR THE ENTIRE FRONTAL AREA OF THE HEAT EXCHANGER (\$)
	C	CSTLVR	- COST OF THE LOUVERS FOR CONTROLLING THE AIR FLOW TO THE HEAT EXCHANGERS (\$)
65	C	CWARA	- RATIO OF HEAT CAPACITY OF THE WATER TO THE AIR (DIMENSIONLESS)
	C	CVLRNG	- COST OF THE FAN RING AND THE VELOCITY RECOVERY STACK IF THEY ARE USED (\$/FAN)
70	C	DELFC	- INCREMENTAL FUEL COST FOR THE SCALED UP PLANT (MILLS/KW HR)
	C	ELENG	- LENGTH OF HEAT EXCHANGER TUBES (FT)
	C	FAACC	- COST OF FAN BLADES AFTER SCALING UP THE NUMBER OF FANS (\$)
75	C	FACPF	- COST OF FAN BLADES PER FAN (\$/FAN)
	C	FCBZ	- FUEL COST FOR THE BASE PLANT WITH A ZERO COST ONCE THROUGH COOLING SYSTEM (MILLS/KW HR)
	C	FCB3	- FUEL COST FOR THE SCALED UP PLANT (MILLS /KW HR)
	C	FCOS	- COST OF FUEL FOR POWER PLANT (CENTS/8TU)
80	C	FCR	- FIXED CHARGE RATE FOR CAPITAL PER YEAR (PERCENT/YR)
	C	FIXL	- THE FIXED LENGTH OF HEAT EXCHANGER TUBES SPECIFIED BY THE INPUT TO THE CODE (FT)
	C	FMCPE	- FAN MOTOR COST PER FAN (\$/FNA)
	C	FMCST	- TOTAL FAN MOTOR COST FOR THE FAN SYSTEM AFTER SCALE UP (\$)
85	C	FPDOW	- POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
	C	HFAIR	- HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
	C	HWAT	- HORSEPOWER REQUIREMENTS OF THE WATER PUMPING SYSTEM (HP)
90	C	HRAFC1	- HEAT RATE FACTOR AT POINT ONE (DIMENSIONLESS)
	C	HRAFC2	- HEAT RATE FACTOR AT POINT TWO (DIMENSIONLESS)
	C	HRR21	- RATIO OF HRAFC2 TO HRAFC1 USED FOR SCALING UP PLANT TO S
	C		PLANT TO DESIGN CONDITIONS (DIMENSIONLESS)
95	C	HCLA	
	C	HCLVA	- SURFACE AREA COVERED BY HAIL SCREENS OR LOUVERS (SQ FT)
	C	ICUR	
	C	ITOWN	- NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
100	C	KADNV	- INTERNAL VARIABLE FOR SPECIFYING THAT THE SET OF INPUT VARIABLES LEAD TO UNREASONABLE VALUES (DIMENSIONLESS)
	C		
	C	KCA1	- VARIABLE FOR SPECIFYING GAGE OF TUBES USED IN THE CONDENSER (DIMENSIONLESS)
105	C	LD	- VARIABLE FOR SPECIFYING THE DIAMETER OF THE CONDENSER TUBING (DIMENSIONLESS)
	C	NEGV	- STOPS THE PROGRAM IF THE SCALED UP FRONTAL AREA, MASS FLOW OF AIR AND SPECIFIC VOLUME OF AIR IS LESS THAN ZERO (DIMENSIONLESS)
110	C	NMTOW	- NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
	C	NV	- NUMBER OF HEAT EXCHANGER TUBES IN WIDTH (DIMENSIONLESS)
	C	PER	- PERCENTAGE OF TOTAL CAPITAL COSTS OF DRY COOLING TOWER ALLOWED FOR MAINTENANCE COST (PERCENT)

115	C	PLANC	- BASE PLANT COSTS (\$/KW)
	C	PLANC1	- PLANT COSTS AT POINT ONE (\$/KW)
	C	PLANC2	- PLANT COST AT POINT TWO (\$/KW)
	C	PLANC3	- PLANT COSTS AT POINT THREE
120	C	PWELEC	- COST OF ELECTRICAL WIRING FOR WATER PUMPING SYSTEM (\$)
	C	POHCOND	- INDIRECT COSTS FOR SURFACE CONDENSER AS A PERCENTAGE OF BASE COSTS (PERCENT)
	C	POHSCU	- INDIRECT COSTS FOR WHIL SCREENS AND LOUVERS AS A PERCENTAGE OF BASE COSTS (PERCENT)
125	C	POHSTC	- INDIRECT COSTS FOR THE STRUCTURES AND FOUNDATION FOR THE CIRCULAR TOWER AS A PERCENTAGE OF BASE COSTS (PERCENT)
	C	PPOW	- POWER REQUIREMENTS OF THE WATER PUMPING SYSTEM (KW)
130	C	PRIZE	- SPECIFIED POWER OUTPUT OF THE PLANT AND MAKE UP SYSTEM TO THE POWER GRID (MW)
	C	PSIZ12	- POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK PRESSURE FOR A POWER OUTPUT OF THE TURBINE OF PSIZE AT DESIGN CONDITIONS (MW)
	C	PSIZ13	- POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK PRESSURE FOR A POWER OUTPUT OF THE PLANT OF PIZSE AT DESIGN CONDITIONS (MW)
135	C	PTOTAL	- TOTAL POWER OUTPUT OF THE TURBINE AT DESIGN CONDITIONS (MW)
	C	PINGE	- TEMPERATURE DIFFERENCE OF THE WATER ENTERING AND LEAVING THE HEAT EXCHANGER (DEG F)
140	C	ROOFL	- ROOF LOAD DESIGN CONDITIONS FOR STRUCTURAL COSTS OF CIRCULAR TOWERS (LBF/SQ FT)
	C	SAFROF	- SCALED UP FRONTAL AREA OF THE HEAT EXCHANGER NORMAL TO AIR FLOW (SQ FT)
145	C	SEAP	- INCREMENTAL PLANT COST BETWEEN PLANT DESIGNED AT RATED CONDITIONS (POINT 1) AND AT DESIGN CONDITIONS (POINT 2) (\$)
	C	SPC	- COST OF PLANT AT DESIGN CONDITIONS (POINT 3)
	C	SPCD	- INCREMENTAL COST OF PLANT USING DRY COOLING TOWERS AT DESIGN CONDITIONS (POINT 3) OVER PLANT AT RATED CONDITIONS (POINT 1) (\$)
150	C	STRUCC	- STRUCTURAL COST OF THE CIRCULAR TOWERS (\$)
	C	SALRAT	- SCALED UP WIDTH TO LENGTH RATIO OF THE HEAT EXCHANGER (DIMENSIONLESS)
155	C	SM3	- SCALED UP MASS FLOW RATE OF WATER THROUGH THE HEAT EXCHANGER (LBM/HR)
	C	SM4	- SCALED UP MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER (LBM/HR)
	C	TOWFCS	- TOTAL COST OF THE PIPING SYSTEM (K\$)
160	C	T _D	- DESIGN TEMPERATURE OF THE DRY COOLING TOWER (DEG F)
	C	T _{EFF}	- RATED BACK PRESSURE EFFICIENCY OF THE STEAM TURBINE (PERCENT)
	C	T _{LA}	- LENGTH OF CONDENSER TUBING (FT)
	C	T _A	- EXIT TEMPERATURE OF THE AIR FROM THE HEAT EXCHANGER (DEG F)
165	C	V _A	- SPECIFIC VOLUME OF THE AIR (CU FT/LBM)
	C	WATERW	- WEIGHT OF WATER IN THE HEAT EXCHANGER BUNDLES (LBM)
	C	W _{HX}	- TOTAL WEIGHT OF THE HEAT EXCHANGER EXCLUDING WATER (LBM)
170	C	WIDTH	- TOTAL HEAT EXCHANGER WIDTH (FT)
	C	W _{RAT}	- RATIO OF THE WIDTH TO THE LENGTH OF THE HEAT

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C          EXCHANGER (DIMENSIONLESS)
C          WBL - WEIGHT OF THE PLENUM PER UNIT AREA (LBF/SQ FT)
C          WSTRUCT - TOTAL WEIGHT OF THE COOLING TOWER STRUCTURES (LBF)
175 C          WTRM - TOTAL WEIGHT OF THE HEAT EXCHANGER FRAM (LBF)
C          WTHDR - TOTAL WEIGHT OF THE HEAT EXCHANGER HEADERS (LBF)
C          WTTUR - TOTAL WEIGHT OF THE HEAT EXCHANGER TUBES (LBF)
C          W2 - MASS FLOW RATE OF THE WATER THROUGH THE HEAT
180 C          W2 - 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)
185 C          XNP - TRANSVERS PITCH BETWEEN ADJACENT TUBES IN THE SAME
C          TUBE ROW OF THE HEAT EXCHANGER FROM CENTERLINE TO
C          CENTERLINE (IN)
C          YEPPI - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR PUMP
190 C          AND FAN POWER

LOGICAL EXTLNG
LOGICAL NEGV
LOGICAL FIRST, EXTEMP
COMMON
195 $ AFTR, ALPHA
$ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP
$ CSU, CIURS, COANG, CLUVR, CHALS, CVM
$ DANGLE, DFIN, DEEPL, DESVEL
$ DEFF
200 $ FOR, FIRST, FIXL, FCOS, FFHX, EXTEMP
$ GREFF
$ HXNP, HPCST
$ ITMAX, ITMIN
$ JCONV
205 $ KCONV, KALEXT
$ MXEXT
$ INTUCL(2), NTA
COMMON
$ ORP
210 $ PSIZE, PER, PWCOS, PLANC, PFACT, POMPPL
$ POHAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
$ PREU, PREUCE
$ REP, REDUCE, ROOFL, WFIX
$ SIGMA, SAAF
215 $ TD, TPO(4), TEF, TLIM, THFIN, TLPRA, TFIX
$ TCO, TW
$ UOS, UWS
$ VAS(4)
$ WFFV
220 $ XREP, XW, XN
COMMON /SUPPLY/ VAL(5), CPLV, CPIP, CCOs, W3, COSM, EFF,
$ DIN, CLAND, REAIR, ZHRFAC2, W4, U, DELPW, PPOW,
$ FRAY, DELFC, WIDTH, ELENG, VAIR, VWAT, HT, HQ, T4,
$ REWAT, NW, NT, NP, PLANC2, PSI712, SPBP, SW4, SW3,
225 $ SPC, PTOTAL, PLANC3, SAFFON, AAIR, YFP, SPC2, PSI713, WT2,
$ Q2, NW2, TCO2, DELPA, DELPAT, DELPWC, CONBAS, XNTSX, VELOX
$ TLX, UCON, PNCST, FNCST, FHACC, EFFC, CH, CA, CS
$ CLIC, CFC, CPCC, FITC, CSC, CEPREP, DELPIP, AST, OLDOST

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530      S,CAPOST,XNFAN,BLOANG,CPLEN,DPFEL,WHX,WTUB,ADIA,ABLN
      S,ATHAR,WTFRM,STPUCC,CPPERF,HPPERF,TOTCF,TPC,EFFIN,ANTU
      S,AIRFF,WATFF,XNMOD,TCTPF,FDCPF,FMTRC,ACCTP,ADUTP
      S,ACTRAD,ADURPD,ACTVH,ADUVH,ADUPPF,THPAIR,TCTF,AFCST
      S,CSRH,WATERH,WSTPCT,CFOUND,HUBDIA,TOWLEN,NUMTON,CTOWD
      S,ATUBC,CSTLVR,CSTHS,CYLRNG,CFANEL
535      COMMON /SINK/ VAR(5),CPLN1,CPIP1,CCOS1,W31,COSM1,EFF1,
      S,GIM1,CLAN1,REAIL,Z1,HFA2S,W41,U1,DEW1,PPOW1,
      S,FROM1,DEFC1,WIDT1,ELEN1,VAIR1,VWAT1,H11,H01,T41,
      S,REWA1,NW1,NT1,NP1,ZPLNC2,ZSIZ12,ZSPBP,S41,SW31,
      S,SPC1,PTOT1,PLNC1,AFR01,AAIR1,YEPMIN,SPCD1,SPS13,WT2MIN,
540      S,PPMIN,NR2MIN,TCOS1,DEPA1,DPWT1,DPWC1,CONBA1,XNTS1,VELD1
      S,TLA1,UCON1,PMCS1,FMCS1,FHAC1,FFEC1,CH1,CA1,CS1
      S,CLT1,CFC1,CPC1,FITC1,CSC1,CEPR1,DEPIP1,AST1,OLDCSI
      S,CAPOST,XNFAN1,BLOAN1,CPLEN1,DPFEL1,W41,WTU1,ARL1
      S,ATH01,WTFR1,STRU1,CPPER1,HPPER1,TOTCF1,TP1,EFFIN1,ANTU1
545      S,AIRF1,WATF1,XNMOD1,TCTPF1,FDCPF1,FMTRC1,ACTP1,ADUT1
      S,ACTH1,ADUR1,ACTV1,ADUV1,ADUP1,THPA1,TCTF1,AFCST1
      S,CSR1,WATER1,WSTRC1,CFOUN1,HUBD1,TOWL1,NUMT1,CTOWD1
      S,ATUB1,CSTLV1,CSTHS1,CYLR1,CFANEL
      COMMON /SCALER/HFAC1,ATUB,CPERA,SSCD,PLANC1,CASSS1,
550      S,GAIR,FAIR,HPAIR,HPWAT,PLANC1
      COMMON /LACALL/ SRM
      COMMON /ESCAL/ RSECF
      COMMON /TINE/ XNS,TID,TLA,XNTS,ARPS
      COMMON /TURE/KGA,FGA(7),LD,ESA(6),TID(7.6),FTF(7.6)
555      COMMON /PLCOST/ WPL
      COMMON /FLSW/ FXTUNG
      COMMON /PVE/ PVELEC
      COMMON /HEADEX/ CHH,CN,CHM,CW,CWJ,CST,CMO,CSR,CSM,PITCHF,CPM4
      IMPRESS,HEDMAT,HEDTYP,NPASS,WB
560      COMMON /FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF,FACPF,P2,R,S,
      SVELREC,AFC,ELEV,EHR
      DATA NEGV,FALSE,/
901 FORMAT(1X,A10,"T1,RANGE,CWARA,AFR0N,HLRAT",5314.4)
      NAMELIST /DBNL/ AFRON,VA,W4,TD,T4,CWARA,RANGE
565      XTOW = ITOWN
      C
      C      SCALING FACTOR FROM POINT 1 TO POINT 2 TO ACCOUNT FOR CHANGE
      C      IN HEAT RATE FACTOR
      C
570      HFR21=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
575      PSIZ12=PSIZE*HFR21
      C
      C      PLANT COSTS AT DESIGN CONDITIONS (POINT 2) WHICH INCLUDE
      C      STEAM SUPPLY AND BACK PRESSURE SCALING TO POINT 2
580      PLANC2=PLANC1 + HFR21
      C
      C      INCREMENTAL COST OF SCALING UP PLANT DUE TO INCREASED HEAT
      C      RATE FACTOR
      C
585      C
      C      RATE FACTOR.

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      C
      C      SRPZ=(PLANC2-PLANC)*PSIZE*1.E+3
      C
      C      SCALING FACTOR FOR SCALING PLANT SIZE TO MEET PUMP AND FAN
290  C      POWER REQUIREMENTS
      C
      C      IF(PSITE*1000.-PPOW-FPOW*LE*0.0) KCONV=1
      C      IF(KCONV.EQ.1) RETURN
      C      YFP=(PSIZE*1.E+3)/(PSIZE*1.E+3-PPOW-FPOW)-1.0
295  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)
300  C
      C      PSIZ13=(1.+YFP)*PSIZ12
      C
      C      TOTAL POWER OUTPUT OF THE PLANT AT POINT 3
      C
305  C      PTOTAL = PSIZE * (1.+YFP)
      C
      C      PLANT COST AT POINT 3 EXCLUDING THE DRY COOLING TOWER COST
      C
310  C      PLANC3=PLANC2*(1.+YFP)
      C      SPC=PLANC3*PSIZE*1.E+3
      C
      C      INCREMENTAL COST OF PLANT DUE TO DRY COOLING TOWERS
      C
315  C      SPCD=(PLANC3-PLANC) * PSIZE * 1.E+3
      C
      C
      C      SCALING UP THE DRY COOLING TOWER DIMENSIONS AND THE COSTS
      C      ASSOCIATED WITH IT
320  C
      C      INDEPENDENT PARAMETERS OF THE DRY COOLING TOWER
      C
      C      YFPD1=YFP + 1.
      C      SW3=WB*YFPD1
      C      SW4=WB*YFPD1
325  C      SAFRON=AFRON*YFPD1
      C      SWLRAT=WLRT * YFPD1
      C
      C      SURFACE CONDENSER DIMENSIONS AND COSTS
      C
330  C      ISUR = 1
      C      CALL SPCON(ISUR, KGA, LO, TLA, XNTS, ARPS, XNS, CONBAS, CONMAT
      C      ,POHCND)
      C      XNTS = XNTS*YFPD1
      C      CONBAS = CONBAS*YFPD1
335  C
      C      SCALE THE NUMBER OF TUBES IN WIDTH AND THE WIDTH OF THE
      C      HEAT EXCHANGER
      C
      C      IF(EXTLNG) WIDTH=SAFRON/FIXL
      C      IF(.NOT.EXTLNG) WIDTH=SQRT(SWLRAT*SAFRON)
340  C      TOWLEN = WIDTH / (XTOW*2.)
      C      NW=WIDTH/XW*12.

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      C
      C      CHECK ON THE EXIT TEMPERATURE OF THE AIR LEAVING THE HEAT
445      C      EXCHANGER
      C
      T4=QWADA*RANGE+TD
      VA=53.25*(TD+460.)/(15.*144.)
      IF(SAFCON.LT.0.0) NEGV=.TRUE.
450      IF(VA.LT.0.0) NEGV=.TRUE.
      IF(SW4.LT.0.0) NEGV=.TRUE.
      IF(NEGV) WRITE(6,ORN1)
      IF(NEGV) STOP
41      CONTINUE
455      C
      C      FAN AND PUMP POWER
      C
      FPOW=FPOW + YFPP1
      PPOW=PPOW + YFPP1
460      HPWAT=HPWAT + YFPP1
      HPAIR=HPAIR + YFPP1
      FPHW=FPHW + HPAIR
      C
      C      THE NUMBER OF FANS AND THE MOTOR, BLADE, AND ELECTRICAL
465      C      WIRING COSTS OF THE FAN SYSTEM
      C
      XNFAN=XNFAN+YFPP1
      FMCST=XNFAN*FMCPE
      FRACC=FRACC+XNFAN
      CFANEL = CFANEL + YFPP1
470      C
      C      ELECTRICAL WIRING OF THE PIPING SYSTEM
      C
      PWELEC = PWELEC + YFPP1
475      C
      C      DIMENSIONS AND WEIGHT OF THE HEAT EXCHANGER
      C
      ATUBC = (CA + CH + CS) * BSCEP
      ATUBC = ATUBC*YFPP1
480      AAIR=AAIR + YFPP1
      WHX=WHX*YFPP1
      WTTUB=TTUB*YFPP1
      WTHOR=THOR*YFPP1
      WTERM=TERM*YFPP1
485      WATERW = WATERW + YFPP1
      C
      C
      C      INCREASED FUEL COST OF THE PLANT
      C
      C      FUEL COST, FOR THE BASE PLANT WITH A CONVENTIONAL TURBINE
490      C      OPERATING AT RATED BACK PRESSURE
      C
      FORZ=FCOS + 3413.E-5 / TEFF
      C
495      C      INCREASED FUEL COST FOR THE SCALED UP PLANT
      C
      FOR3 = FCOS + 3413.E-5*(HRFAC2/TEFF) * (1.+YEP)
      DELFO=FOR3-FORZ
      C

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400      C      LAND AND PIPING COSTS
      C
      CLAND = COSTL*SAFROV
      CPIP = TCWFCS * YFPP1 * 1000.

405      C      PLENUM SIZE AND COSTS
      C
      CTOWD = CTOWD * YFPP1
      CPLEN = CPM * MPL * (ITOWN * 3.14159/4. * CTOWD**2
      S = XNFAN * 3.14159/4. * (ADIA*3.5)**2)
410      CPLEN = CPLEN * POHSTC

      C      STRUCTURE AND FOUNDATION COSTS
      C
      CALL STRUCT(CTOWD, WHX, WATERW, ROOFL, STRUCC, CFOUND, WSTRUCT,
      C      NUNTON, ELENG, POHSTC)
415      CFOUND = POHSTC * CFOUND

      C      LOUVER AND HAIL SCREEN COSTS
      C
420      HSLVA = CTOWD * NUNTON * 3.14159 * ELENG
      CSTLVR = CLUVR * HSLVA * POHSCV
      CSTHS = CHAHS * HSLVA * POHSCV

      C      TOTAL COST OF DRY COOLING TOWER
425      C
      CCOS = FRACC + ATUBC + FMCST + CPLEN + STRUCC + CFOUND
      S + CSTLVR + CSTHS + CFANEL*XNFAN/YFPP1 + CYLANG*XNFAN

      C      ANNUAL INCREMENTAL COST DUE TO MAINTENANCE OF DRY COOLING
430      C      TOWERS
      C
      COSM = PER * (CCOS + CPIP + CONBAS) / (PSIZE*CAPF*8760.)

      C      INCREMENTAL COST OF DRY COOLING TOWER
435      C
      OLOCST = (CCOS+SPCD+CLAND+CPIC+CONBAS)*FCR/(PSIZE*CAPF*8760.)
      S + COSM* DELEC
      RETURN
440      END

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SUBROUTINE SERCH

THIS ROUTINE SEEKS MINIMUM BY SINGLE VARIABLE SEARCH METHOD

LOGICAL EXTNG

COMMON /LACALL/ SRN

DIMENSION C(5)

COMMON /SUPPLY/ VAL(5), CPLN, CP1P, CCOS, W4, COSM, EFF,

\$ QIN, CLAND, REAIR, Z,HRFAC2, W4, U, DELPW, PPOW,

\$ EPC4, DELEC, WIDTH, ELEN3, VAIR, VWAT, HI, HO, T4,

\$ REAIT, NW, NT, N2, PLANC2, PSIZ12, SPBP, SW4, SW3,

\$ SSC,PTOTAL,PLANC3,SAFRON, AAIR, YFP, SPCD,PSIZ13, WT2,

\$ BPD, MW2, TCOS, DELPA,DELPNT,DELPWC,CONBAS, XN1SX, VELDX

\$, TLX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS

\$, CLTC, CFC, CPCC, FITC, CSC,CEPREP,DELP1P, AST,OLDCST

\$,CAPOST, XNFAN,BLDANG, CPLEN, DPFE1, WHX, ATTUS, ADIA, ABLN

\$, WTHP, WTER,STRUC,CFPERF,HPERF, TOTCF, TPC, EFFIN, ANTU

\$, AIRF, WATER, XNMOD, TOTPF, FDCPF, FMTRC, ACCTP, ADJTP

\$, ACTB1, ADJBP1, ACTV1, ADJV1, ADJPP1, THPA1, TCTF, AFCST

\$, CSRT, WATERW, WSTRCT, CFOJN1, HURD1, TOWLE, NUMTO, CTOWD

\$,ATUB1, CSTLVR, CSTHS, CYLRN1, CFANEL

COMMON /SINK/ VAR(5), CPLN1, CP1P1, CCOS1, W31, COSM1, EFF1,

\$ QIN1, CLAN1, REAI1, Z1,HRFA2S, W41, U1, DEPW1, PPOW1,

\$ EPC1, DEFC1, WIDTH1, ELEN1, VAIR1, VWAT1, HI1, HO1, T41,

\$ REAI1, NW1, NT1, N1,ZPLNC2,ZS1712, ZSPRO, SW41, SW31,

\$ SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN, SPCD1, SPS13,WT2MIN,

\$ BPD1,MW21,TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XN1S1, VELD1

\$, TL1, UCON1, PMOS1, FMOS1, FBAC1, EFFC1, CH1, CA1, CS1

\$, CLTC1, CFC1, CPCC1,FITC1, CSC1,CEPRE1,DEPI1, AST1,OLDCS1

\$,CAPOST,XNFAN1,BLDAN1,CPLEN1,DPFE1, WH1, ATTU1, ADI1, ABL1

\$, WTH1, WTER1,STRUC1,CFMPE1, HPPF1,TOTCF1, TPC1,EFFIN1, ANTU1

\$, AIRF1, WATER1, XNMOD1, TOTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1

\$, ACTB1, ADJBP1, ACTV1, ADJV1, ADJPP1, THPA1, TCTF1, AFCST1

\$, CSRT, WATER1, WSTRCT, CFOJN1, HURD1, TOWLE1, NUMTO1, CTOWD1

\$,ATUB1, CSTLVR1, CSTHS1, CYLRN1, CFANEL

COMMON /SCALER/HRFAC1, ATUB, OPERA, SSCD,PLANC1,CASSS1,

\$ GAIR, PAIR, HPAIR, HPWAT, PLANC1

LOGICAL FIRST, EXTEND

COMMON

\$ AFTR,ALB44

\$,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAP

\$,CRU, CTURB, CDANG, CLUVR, CHA1LS, CVM

\$,DANG1, DFIN, DEEPL, DESVEL

\$,EFFP

\$,FCS, FIRST, FIAL, FPOS, FFAK, EXTEND

\$,GHEP

\$,HXNP, HPOST

\$,ITMAX, ITMIN

\$,JCONC

\$,KCONV, KALEXT

\$,KEYX

\$,NTUCAL(2), NTA

COMMON

\$ QDP

\$,PSIZ1, PER, PMCOS, PLANC, PFACT, POMDPL

\$,POHGF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCD

\$,PREU, PREDUCE

```

      S ,PBP, REDUCE, ROOFL, RFIX
      S ,SIGMA, SAAF
55      S ,TD, TPO(4), TEFF, TLIM, THEIN, TLPRA, TFIX
      S ,TCD, TW
      S ,UCS, UWS
      S ,VAS(4)
      S ,WTV
65      S ,XDEP, XW, XD
      COMMON /FLSW/ FXTLNG
      COMMON /TINE/ XNS,TTD,TLA,XNTS,ARPS
      CWARL = 0.0
      IF (FXTEMP) CALL ROOT (TFIX, RFIX, TTD, TD, CWARL)
70      IF (FXTEMP .AND. VAR(3) .GT. .90*CWARL) VAR(3) = .9 * 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)
75      CALL STORE
      C(1)=5.
      C(2)=1.
      C(3)=1.
      C(4)=CAF
80      C(5)=50.
      IR=1
      IF (FXTLNG) IR=2
      DO 8 I=14,5
      M=6-I
85      K=3
      DO 9 I=1,5
9      VAL(IK)=VAR(IK)
      KC=0
      1 J=0
90      2 VAL(M)=VAR(M)+C(M)
      IF (FXTEMP) VAL(1) = TFIX
      IF (FXTEMP) VAL(2) = RFIX
      IF (FXTEMP .AND. VAL(3) .GT. .90 * CWARL) GOTO 7
      IF (M.GT.3) GO TO 10
      IF (VAL(1).GT.170.) GO TO 4
      H = VAL(3)+VAL(2)/(VAL(1)-TTD-TD)
16      IF (H.GT.1.) GO TO 4
      IF (ALOG(1.-H)/VAL(3).LE.-1.) GO TO 4
10      SRN="/SERCH-2/"
100      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
      IF (KC.EQ.1) GO TO 4
      IF (DELTA.LT.XDEP) GO TO 3
      IF (DELTA.LE.XDEP) GO TO 3
      IF (TCD.GE.TCOS1) GO TO 4
105      J=1
      CALL STORE
      GO TO 2
      3 IF (K.EQ.1) KC=1
      4 IF (J.EQ.1) GO TO 7
110      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)

```



```
115      18 IF(H.G-1.) GO TO 7
        IF(ALOG(1.-H)/VAL(3).LE.-1.) GO TO 7
        SPN="/SERCH-3/ "
        CALL CALO(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
        IF(KC.EQ.1) GO TO 7
120      C  IF(DEPHA.LT.XDEPA) GO TO 6
        IF(DEPHA.LE.XDEPA) GO TO 6
        IF(TCOS.GE.TCOS1) GO TO 7
        CALL STORE
        KC=0
125      GO TO 8
        6 IF(K.EQ.1) KC=1
        7 IF(KC.EQ.1) CALL CHNGE(M)
        K=K-1
        IF(K.EQ.0) GO TO 8
130      C(M)=C(M)/5.
        GO TO 1
        8 CONTINUE
        RETURN
        END
```

SUBROUTINE SETUP(TSTAR,TEND)

INPUT DESCRIPTION
FOR GNL METAL FIN ROUND OCT

DECEMBER 10 1976

IN THE DESCRIPTIONS BELOW THE SYMBOL (OF) MEANS
DECIMAL FRACTION

CARD TYPE	COLUMNS	FORMAT	NAME OF VARIABLE	UNIT	DESCRIPTION AND (UNITS)
A1	1-95	(3410)	DESCR(1)	R	COMMENTS OR CASE DESCRIPTION TO BE PRINTED AT TOP OF FIRST OUTPUT PAGE. ANY NUMBER OF TYPE A1 CARDS MAY BE USED BUT A BLANK A1 CARD IS NOT ALLOWED.
A2	1-95				BLANK IN ALL COLUMNS. ONE TYPE A2 CARD ONLY
B1	1-15	(E10.0,	TSTAR	R	LOWEST DESIGN TEMPERATURE TO USE (DEGREES F)
	11-25	E10.0,	TEND	R	HIGHEST DESIGN TEMPERATURE TO USE (DEGREES F)
	21-35	E10.0,	VAS(1)	R	INITIAL VALUE FOR TURBINE OUTLET TEMPERATURE (DEGREES F)
	31-45	E10.0,	VAS(3)	R	INITIAL VALUE FOR CHARG. RATIO OF MCP WATER / MCP AIR (OF)
	41-55	E10.0,	VAS(4)	R	INITIAL VALUE FOR APRON, AIR SIDE FRONTAL AREA (SQ FT)
	51-65	E10.0,	VAS(5)	R	INITIAL VALUE FOR WLRAT, RATIO OF HEAT EXCHANGER WIDTH/LENGTH (OF)
	61-75	E10.0,	FIXL	R	LENGTH OF HEAT EXCHANGER (FT). IF THE ABSOLUTE VALUE OF FIXL=0. THEN THE PROGRAM WILL CALCULATE THE LENGTH.
	71-75	F5.0,	DEEPL	R	LIMITING VALUE FOR NUMBER OF TUBES IN DEPTH FOR HEAT EXCHANGER. (NUMBER OF TUBES)

```

60      C
        C
        C IF THE ABSOLUTE VALUE OF DEEPL = 0.0
        C THEN THE PROGRAM WILL COMPUTE THE
        C DEPTH WITH NO CONSTRAINTS
        C
        C
        C IF POMDPL IS BLANK OR ZERO THEN A
        C POSITIVE VALUE FOR DEEPL IMPLIES A
        C CONSTRAINT OF EQUAL TO OR GREATER
        C THAN DEEPL, WHILE A NEGATIVE VALUE
        C FOR DEEPL IMPLIES A CONSTRAINT OF
        C EQUAL TO OR LESS THAN DEEPL.
        C
        C
        C 75-85 F5.0) POMDPL R TOLERANCE ON DEEPL. NOTE THAT A ZERO
        C OR BLANK IS NOT INTERPRETED AS ZERO
        C TOLERANCE. (SEE DEFINITION OF DEEPL)
        C
        C
        C .....
        C .....
        C
        C C1 1-45 (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
        C 41-85 8F5.0) TPER(I) R FRACTION OF YEAR OVER WHICH TEMPERA-
        C TURE TA(I) IS TYPICAL. (OF)
        C
        C
        C .....
        C .....
        C
        C C2 1-45 (8F5.0, TA(I) R CONTINUATION OF TA(I) FOR I= 9 TO 16.
        C
        C 41-85 8F5.0) TPER(I) R CONTINUATION OF TPER(I)
        C
        C NOTE - A TYPE C2 CARD IS REQUIRED EVEN IF BLANK.
        C
        C
        C .....
        C .....
        C
        C D1 4-15 (E10.0, PSIZE R BASE PLANT SIZE (MEGAWATTS)
        C
        C 11-25 E10.0, TEFF R BASE THERMAL EFFICIENCY (OF)
        C
        C 21-35 E10.0, CAPF R CAPACITY FACTOR (OF)
        C
        C 31-45 E10.0, FCR R FIXED CHARGE RATE (OF)
        C
        C 41-55 E10.0, PER R RATIO MAINTENANCE COST TO CAPITAL
        C COST (OF)
        C
        C 51-65 E10.0, CCM R CONSTRUCTION COST MULTIPLIER (OF)
        C
        C 61-75 E10.0, ELEV R SITE ELEVATION ABOVE SEA LEVEL (FT)
        C
        C 71-85 E10.0) ROOFL R ROOF LOAD (LB/SQ FT)
        C
        C .....
        C .....

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115      C
      C      E1      1-10      (E10.0, PCOS      R      FUEL COST (CENTS/MMBTU)
      C
      C      11-20      E10.0, PACOS      R      REPLACEMENT POWER COST (MILLS/KWH)
      C
120      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 ($/KW)
125      C
      C      51-60      E10.0, CAPCHG      R      CAPACITY CHARGE ($/MEGAWATT)
      C
      C      61-70      E10.0, HPCST      R      COST OF ELECTRIC MOTORS ($/HP)
      C
130      C      71-80      E10.0) CTURB      R      EXTRA TURBINE COST BECAUSE OF
      C      NUCLEAR POWER PLANT ($/KW)
      C
      C.....
      C      INDIRECT COST FACTORS FOR -
135      C      E2      1-10      (E10.0, POHBAF      R      BUNDLE ASSEMBLY AND FRAME
      C
      C      11-20      E10.0, POHFAN      R      FANS
      C
      C      21-30      E10.0, POHLFC      R      ELECTRICAL
140      C
      C      31-40      E10.0, POHCIR      R      CIRCULATION PIPING
      C
      C      41-50      E10.0, POHCND      R      CONDENSER
      C
145      C      51-60      E10.0, POHSTC      R      STRUCTURE
      C
      C      61-70      E10.0) POHSCL      R      SCREENS AND LOUVERS
      C
      C.....
150      C.....
      C      F1      1-10      (E10.0, RBP      R      TURBINE RATING BACK PRESSURE (INCHES
      C      OF MERCURY)
      C
155      C      11-20      (F15.8) TPO(I)      R      COEFFICIENTS FOR THIRD ORDER POLY-
      C      NOMIAL FOR HEAT RATE AS A FUNCTION
      C      OF TURBINE BACK PRESSURE.
      C
      C.....
160      C.....
      C      G1      1-10      (E10.0, EFFP      R      EFFICIENCY OF PUMPS (OF)
      C
      C      11-20      E10.0) DPRESS      R      PIPING DESIGN PRESSURE (PSI)
165      C
      C      MAY BE
      C      50.
      C      75.
      C      125.
170      C
      C.....

```

```

C.....
C
775      H1      1-15      (E10.0, VELREC      R  CONTROL VARIABLE.
C                                     =1 FOR VELOCITY RECOVERY
C                                     =0  FOR NO VELOCITY RECOVERY
C
C      11-25      E10.0, XDEPA      R  MINIMUM AIR SIDE PRESSURE DROP THRU
C      HEAT EXCHANGER (LB FORCE/SQ FT)
180      C
C      21-35      E10.0, TLIM      R  MAXIMUM STEAM TEMPERATURE FOR THE
C      TURBINE (DEGREES F).
C      ASSUMED 190 IF FIELD IS BLANK OR 0.
C
195      C      31-45      E10.0, TOWMIN      R  THE MINIMUM ALLOWABLE NUMBER OF
C      TOWERS PER GROUP.
C      ASSUMED 1 IF NOT SPECIFIED
C
196      C      41-55      E10.0, PFACT      R  PACKING FACTOR, RATIO OF CIRCULAR
C      TOWER ROOF AREA TO FAN SHEET AREA
C      (CF)
C
195      C      51-65      E10.0, TFIX      R  FIXED TURBINE OUTLET TEMPERATURE (F)
C
C      ENTRY IS IGNORED IF BLANK OR ZERO
C
C      61-75      E10.0, RFIX      R  FIXED RANGE (F). ENTRY IS IGNORED
C      IF BLANK OR ZERO
500      C
C      71-85      E10.0, TOWMAX      R  MAXIMUM ALLOWABLE NUMBER OF TOWERS.
C      ASSUMED 9999 IF BLANK OR ZERO
C
C.....
505      C      H2      1-15      E10.0  GBEFF      R  FAN GEARBOX EFFICIENCY
C
C.....
C.....
510      C      I1      1-15      (E10.0, CPM      R  PLENUM COST ($/LB)
C
C      11-25      E10.0, WPL      R  WEIGHT OF PLENUM MATERIAL (LB/SQ FT)
C
515      C      21-35      E10.0, CLUVR      R  COST OF LOUVERS ($/SQ FT)
C
C      31-45      E10.0, CHAILS      R  COST OF HAIL SCREENS ($/SQ FT)
C
C      41-55      E10.0, UCS      R  UNIT COST OF STACK $/LB
520      C
C      51-65      E10.0, UWS      R  UNIT WT OF STACK LB/CU FT
C
C      61-75      E10.0, CVM      R  FAN RING MATERIAL UNIT COST $/LB
C
525      C      71-85      E10.0, WFFV      R  UNIT WT OF STRAIGHT CYLINDER LB/SQ FT
C
C.....
C.....

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530      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
535      C          '          '          '  TABLE
      C          '          '          '  CROSS FLOW OR COUNTER FLOW CAUSES
      C          '          '          '  CALCULATION OF NTU BY EQUATIONS.
      C          '          '          '  TABLE CAUSES TABLE LOOKUP OF NTU.
540      C          21-30  F10.0,  HXNP      R  NUMBER OF PASSES THRU HEAT EXCHANGER
      C          31-40  F10.0,  WB          R  HEADER LENGTH (FEET)
      C          41-50  F10.0,  NTUB      R  NUMBER OF TUBES THRU PLATE FINS
545      C          61-60  F10.0,  SS          R  SUPPORT SPACING (FT)
      C          C.....
550      C  J2      1-10  (E10.0,  DESVEL  R  DESIGN WATER VELOCITY FOR PIPING
      C          '          '          '  (FT/SEC)
      C          11-20  E10.0,  REDUCE      R  MINIMUM STEP CHANGE IN PIPE DIAMETER
555      C          '          '          '  FOR TOWER PIPING (INCHES)
      C          '          '          '  MAY BE 6, 12, OR 18
      C          21-30  E10.0,  QREDUCE      R  MINIMUM STEP CHANGE IN PIPE DIAMETER
560      C          '          '          '  FOR QUADRANT HEADERING (INCHES)
      C          '          '          '  MAY BE 6, 12, OR 18
      C          31-40  E10.0,  DIST          R  DISTANCE FROM TOWER TO CONDENSER
      C          '          '          '  ROOM (FT)
      C          C.....
565      C          C.....
      C  K1      1-10  (E10.0,  XW          R  TUBE TRANSVERSE PITCH (NORMAL TO AIR
570      C          '          '          '  FLOW) (INCHES)
      C          11-20  E10.0,  XD          R  TUBE PITCH IN DIRECTION OF AIR FLOW
      C          '          '          '  (INCHES)
      C          21-30  E10.0,  XDG          R  TUBE DIAGONAL PITCH (INCHES)
575      C          31-40  E10.0,  SF          R  FIN SPACING (INCHES)
      C          41-50  E10.0,  DFIN          R  FIN DIAMETER (INCHES)
      C          51-60  E10.0,  THFIN          R  FIN THICKNESS (INCHES)
580      C          61-70  E10.0,  DANGLE      R  BASE ANGLE FOR DELTA HEAT EXCHANGER
      C          '          '          '  (DEGREES)
585      C

```

```

C.....
C.....
C
C  L1  1-18  (F10.0,  OOL  R  HX LINER OUTSIDE DIAMETER (INCHES)
390 C
C      11-28  F10.0,  DI  R  HX LINER INSIDE DIAMETER (INCHES;
C
C      21-38  F10.0,  GAGLIN  R  GAGE OF HX LINER TUBE (MAY BE
395 C      22. 20. 19. 18. 17. 16. 15.
C      14.5 14. 13. 12. 11. 10. )
C
C      31-58  2A10,  TUBMAT,  R  LINER MATERIAL. MUST BEGIN IN COL 31
C      XTUBMA  R
C
C      MAY BE -
C      ADMIRALTY
C      COPPER
C      CU-10 NI
C      CU-30 NI
405 C      ALUMINUM
C      STEEL WELDED
C      STEEL SEAMLESS
C      WELDED SST
C
C      51-68  F10.0) CONL  R  THERMAL CONDUCTIVITY OF LINER MATER-
410 C      IAL (BTU/(HR SQFT DEG F/ FT) )
C.....
C.....
C  M1  1-28  (2A10,  FINTYP  R  TYPE OF FIN. MUST START IN COLUMN 1
415 C      XFINTY  R
C
C      MAY BE -
C      STRAIGHT FIN
C      SINGLE FOOT
C      DOUBLE FOOT
C      EMBEDDED
C      EXTRUDED
425 C      PLATE
C
C      21-38  A10,  FINMAT  R  FIN MATERIAL. MUST START IN COL. 21
430 C
C      MAY BE -
C      ALUMINUM
C      STEEL
C
C      31-48  F10.0) CONF  R  THERMAL CONDUCTIVITY OF FIN MATERIAL
435 C      (BTU/(HR SQFT DEG F/FT))
C.....
C.....
C  N1  1-18  (E10.0,  CFB  R  FIN BONDING COST ($/SQ FT)
440 C
C      11-28  E10.0,  COATC  R  FIN PROTECTIVE COATING COST ($/SQFT)

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C      21-35  E10.0,  ZINCC  R  ZINC COST FOR SPACERS ($/LB)
445  C
C      31-45  E10.0,  CASTC  R  FIXED CASTING COST FOR SPACERS
C      (3/SPACER)
C
C      41-55  E10.0)  EPREPC R  END PREPARATION COST ($/TUBE)
450  C
C      .....
C      .....
C
C      P1      1-25  (2A10,  HEDTYP, R  HEADER TYPE, MUST START IN COLUMN 1.
455  C      XHEDTY  R
C
C      MAY BE -
C      WELD REMOVABLE
C      WELD PLUG
C      FORM REMOVABLE
C      FORM PLUG
460  C
C
C      21-35  A10,      HEDMAT  R  HEADER MATERIAL, MUST START IN
C      COLUMN 21. MAY BE -
C      ALUMINUM
C      STEEL
C      GALVANIZED
465  C
C
C      31-45  E10.0)  TW      R  THICKNESS OF HEADER MATERIAL, INCHES
470  C
C      .....
C      .....
C
C      Q1      1-15  (E10.0,  CRJ  R  COST OF ROLLED JOINT, TUBE TO HEADER
475  C      (3/TUBE)
C
C      11-25  E10.0,  CWJ  R  COST OF WELDED JOINT, TUBE TO HEADER
C      (3/TUBE)
C
C      21-35  E10.0,  CHH  R  TUBE AND PLUG HOLE PREPARATION COST
480  C      (3/HOLE)
C
C      31-45  E10.0,  CN  R  NOZZEL AND ATTACHING COST ($/HOLE)
C
C      41-55  E10.0,  CWH  R  COST OF HEADER MACHINING AND WELDING
485  C      ($/FT)
C
C      51-65  E10.0,  CST  R  STRUCTURAL STEEL COST ($/LB)
C
C      61-75  E10.0)  CBJ  R  COST OF BOLTED HEADER JOINT ($/FT)
490  C
C      .....
C      .....
C
C      R1      1-15  (E10.0,  XNS  R  NUMBER OF CONDENSER SHELLS
495  C
C      11-25  E10.0,  VELN  R  NOMINAL DESIGN VELOCITY THRU CONDENSER
C      TUBES (FT/SEC)
C

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400      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.
405      C      41-50  E10.0,  FC      R  CLEANLINESS FACTOR (DF)
      C
      C      51-60  E10.0,  TTD      R  TERMINAL TEMPERATURE DIFFERENCE
      C      (DEGREES F)
410      C      61-80  2A10)  CONMAT, R  CONDENSER TUBING MATERIAL. MUST START IN
      C      CONMA2      R  COLUMN 61. MAY BE -
      C
      C      ADMISSALTY
      C      CU-15 NI
      C      304 S/S WELDED
415      C
      C.....
      C.....
420      C      S1      1-5      (15.      LFB      I  LFB AND LFE SPECIFY FIRST AND LAST
      C      5-10      15.      LFE      I  POSITION TO BE CONSIDERED IN THE
      C
      C      TABLE OF FANS. DEFAULT VALUES ARE
      C      LFB=1 AND LFE=153
425      C
      C      -----
      C      DIAMETER      IFAN      LFAN
      C      -----
      C      24.      1      27
430      C      26.      28      54
      C      28.      55      88
      C      30.      89      111
      C      40.      112      135
      C      50.      136      153
435      C
      C      11-15      15)      MXEXT      I  THE MAXIMUM ALLOWABLE NUMBER OF
      C
      C      CALLS TO SUBROUTINE XTEND FOR ANY
      C      ONE DESIGN TEMPERATURE.
440      C
      C      DEFAULT VALUE IS 10
      C
      C.....
      C.....
445      C      T1      1-15      A10      FFHX      R  CONTROL VARIABLE FOR SPECIFYING
      C
      C      METHOD TO USE IN COMPUTING FRICTION
      C      FACTOR. MUST START IN COLUMN 1.
      C      MAY BE -
450      C
      C      PFR
      C      FRICHO
455      C
      C.....
      C
      C      REAL NUB

```

```

      DIMENSION TOD(6),TGA(7)
      COMMON/DJR/DI,XDG,SF
      COMMON /INDIS/ DIST
460  COMMON /HEADEX/ CHH,CN,CHM,CW,CRJ,CWJ,CST,CMD,CSR,CSM,PITCHF,CPM,
      IPRESS,HEDMAT,HEDTYP,NPASS,WB
      COMMON /SURFFX/ DDL,GAGLIN,NTUB,TUBMAT,FINTYP,FINMAT,CFB,APLATE,
      SCOATC,FINCC,CASTC,SS,EPREPC,XTUBMA,XHEDTY,XFINTY
      COMMON/ELSW/ FXTLNG
465  COMMON /TINE/ XNS,ITD,TLA,XNTS,ARPS
      COMMON/TINE/CCM
      COMMON/TURE/KGA,FGA(7),LD,ESA(6),TID(7,6),FTF(7,4)
      COMMON/OHTC/FC,CU(6),VELN
      COMMON /SINK/ VAR(5),CPLN1,CPI1,CCOS1,W31,COSM1,EFF1,
470  S OIN1,CLAN1,REAI1,Z1,HFA2S,W41,U1,DEPW1,PPOW1,
      S FROW1,DEFC1,WIDT1,ELEN1,VAIR1,VWAT1,HI1,H01,T41,
      S REW1,NW1,NT1,NP1,ZPLNC2,ZSIZ12,ZSP92,SW41,SW31,
      S SPC1,PTOT1,PLNC31,AFR1,AAIR1,YFPMIN,SPCD1,SPS13,WT2MIN,
      S P22MIN,NW2MIN,TCOS1,DEPA1,DPWT1,DPAC1,CONBA1,XNTS1,VELJ1
475  S ,TLA1,UCON1,PMCS1,FMCS1,FBAC1,EFFC1,CHI,CA1,CS1
      S ,CLT1,CFC1,CPC1,FITC1,CSC1,CEPRE1,DEPIR1,AST1,OLOCS1
      S ,CAPOS1,XNFAN1,BLOAN1,CPLEN1,DPFEL1,WHL,MTTU1,AD11,ABL1
      S ,WTH1,WTR1,STRUC1,CFMPE1,HOPF1,TOTCF1,TP1,EFFIN1,ANTU1
480  S ,AIPEF1,WATFF1,XWOD1,TCTP1,FDCPF1,FMTRC1,ACTIP1,ADUTP1
      S ,ACTBF1,ADURP1,ACTVH1,ADJH1,ADUPP1,THPA1,TCTF1,AFCST1
      S ,CSR1,WATER1,WSTRC1,CFOJ1,HUBD1,TORLE1,NUMTO1,GTOWD1
      S ,ATUB1,CSTLV1,CSTHS1,CYLRN1,CFANE1
      COMMON /SCALER/HFAC1,ATUB,CPERA,SSCO,PLANC1,CASSS1,
485  S GATR,FAIR,HPAIR,HPWAT,PLANCT1
      COMMON /ENLOOP/ LFR,LFE
      COMMON /PLCOST/ WPL
      LOGICAL FXTLNG
      DIMENSION DESC(3)
      LOGICAL FIRST, FTEMP
490  COMMON
      S AFR,ALPHA
      S ,CAPF,CSSPKW,CONF,CONL,COSTL,CAPCHG,CONMAT,CONMA2,CAP
      S ,CRJ,CTUB,CDANG,CLUVR,CHALS,CVM
495  S ,DANGLE,DFIN,DEEPL,DESVEL
      S ,DEFF
      S ,FCR,FIRST,FXL,FCOS,FRHX,FTEMP
      S ,GSEFF
      S ,HXMP,HPCST
500  S ,ITMAX,ITMIN
      S ,JCON
      S ,KCON,KALEX
      S ,MXEXT
      S ,NTUCAL(2),NTA
      COMMON
505  S ,QOR
      S ,PSIZE,PER,PWCOS,PLANC,PEACT,POMDPL
      S ,POHBAF,POHFAN,POHLEC,POHCIR,POHCND,POHSTC,POHSCD
      S ,QREJ,QREDUCE
      S ,RBF,REDUCE,ROCF1,RFIX
510  S ,SIGMA,SAAF
      S ,TD,TPO(4),TEFF,TLIM,THFIN,TLPR,TFIX
      S ,TCD,TW
      S ,UCS,UWS

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515      S,VAS(5)
      S,WEV
      S,XDEPT,XW,XD
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W4, COSM, EFF,
      S QIN, CLAND, REAIR, Z,HFAC2, W4, U, DELPW, PPOW,
      S FPMW, DELEFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
520      S DEWAT, NW, NT, NP,PLANC2,PSI712, SPBP, SW4, SW3,
      S SPC,TOTAL,PLANC3,S4FRON, AAIR, YFP, SPCN,PSIZ13, WT2,
      S H2, NW2, TCOS, DELPA,DELPNT,DELPWC,CONBAS, XNTSX, VELOX
      S TLX, HCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
      S CLTC, CFC, CPOC, FITC, CSC,CEPSEP,DELPID, AST,OLOCST
525      S,CAPCST,XNFAN,RLOANG,CLEN,DPFEL,WHX,WTUR,ADIA,ABLV
      S, WTHR, WTRM,STRUC,CEPERF,PPERF,TOTCF,TPC,EFFIN,ANTU
      S, ATPE, WATFF, XNMOD, TOTPF, FDCPF, FMTRC, ACCTIP, ADJTP
      S, ACTBD, ADJBD, ACTVH, ADJVH, ADJPF, THPAIR, TOTF, AFCST
      S, CSPN, WATERW, WSTRCT, CFOUND, HJRDIA, TOWLEN, NUNTON, CTOWD
530      S,ATUR, CSTLVP, CSTHS, CYLRNG, CFANEL
      COMMON /VARVAR/ TPER(16), TA(16)
      COMMON /INLT/TIN(15),FTIN(15)
      COMMON /PH20/TH20(15),PROP(16,2)
      COMMON /CFHL/VELT(15),TELT(15),WBLT(15,2)
535      COMMON /FAV/ FANDAP(153,10),FANDAH(153,10),FMCPF,FRCPF,P2,R,S,
      SVELDEC,AFC,ELEV,EHR
      COMMON /PRESS/ IPRESS
      DATA BLANK/" "

540      C
      C SURFACE CONDENSER TUBE O.D. AND TUBE GAGE ARRAYS
      C
      DATA TGD/0.625,0.750,0.875,1.000,1.125,1.250/
      DATA TGA/12.,14.,16.,18.,20.,22.,24./

545      C
      C EXTERNAL SURFACE AREA (53 FT) OF CONDENSER TUBE PER LINEAR
      C FOOT AS A FUNCTION OF TUBE O.D.
      C
      DATA TSA/0.1636,0.1763,0.2291,0.2618,0.2944,0.3271/

550      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/

555      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/0.407,0.459,0.495,0.527,0.555,0.559,0.581,
560      S 0.532,0.584,0.620,0.552,0.580,0.694,0.706,
      S 0.657,0.709,0.745,0.777,0.805,0.819,0.831,
      S 0.782,0.834,0.870,0.902,0.930,0.944,0.956,
      S 0.907,0.959,0.995,1.027,1.055,1.059,1.081,
      S 1.032,1.084,1.120,1.152,1.180,1.194,1.206/
565      DATA FTF/0.404,0.515,0.600,0.680,0.754,0.793,0.826,
      S 0.593,0.835,0.941,1.011,1.132,1.179,1.220,
      S 1.057,1.231,1.359,1.478,1.585,1.642,1.690,
      S 1.497,1.703,1.853,1.992,2.117,2.182,2.187,
      S 2.014,2.251,2.424,2.582,2.725,2.797,2.841,
570      S 2.607,2.877,3.071,3.249,3.409,3.490,3.560/

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C
C      CONDENSER INLET TEMPERATURE ARRAY INLET TEMPERATURE
C      CORRECTION FACTOR FOR OVERALL HEAT TRANSFER COEFFICIENT FOR
C      SURFACE CONDENSERS
675  DATA TFIN/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,
      $      1.000,1.023,1.042,1.050,1.074,1.083,1.100/

C
C      VELOCITY CONSTANT FOR OVERALL HEAT TRANSFER COEFFICIENT AS A
C      FUNCTION OF TUBE O.D.
680  DATA CU/267.,267.,263.,263.,259.,259./

C
C      WATER TEMPERATURE ARRAY AND WATER DENSITY AND VISCOSITY AS A
C      FUNCTION OF TEMPERATURE
695  DATA TH2O/32.,40.,50.,60.,70.,80.,90.,100.,110.,120.,130.,
      $      140.,150.,160.,170.,180./
      DATA WPROP/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,
      $      4.33,3.75,3.17,2.71,2.37,2.09,1.95,1.65,1.49,
      $      1.34,1.24,1.14,1.04,0.97,0.90,0.84/

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
699  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/0.05,0.035,0.050,0.110,0.150,0.220,0.280,0.360,0.450,0.540,
      $      0.643,0.752,0.873,1.002,1.146/
      DATA WELT/0.02,0.05,0.070,0.110,0.170,0.220,0.305,0.395,0.488,0.605,0.723,
      $      0.850,0.987,1.136,1.293,
      $      1.04,0.06,0.09,0.14,0.20,0.29,0.37,0.47,0.58,0.71,0.84,
      $      0.99,1.14,1.31,1.487/
      99 FORMAT('NO INPUT ERROR. THE SUM OF THE TPER(I) SHOULD BE 1.0000')
      6000 FORMAT('1H1//T05."RWX1 DRY COOLING TOWER COST MODEL" -- ",
      $      5H METAL FIN TUBE. CIRCULAR TOWER VERSION."
      $      5.733,0THIS RUN MADE ",A10,3X,A10)
      5001 FORMAT(A10)
      5001 FORMAT(T21,A10)
      5002 FORMAT(ME10.0)
      5002 FORMAT(/1X,8G15.8)
      5003 FORMAT(15F5.3)
      5003 FORMAT (/1X,8F8.1,8F8.4)
      5004 FORMAT(F10.0,4F15.3)
      5004 FORMAT(/1X,F10.2,4G15.8)
      5005 FORMAT(2A10,6F10.0)
      5005 FORMAT(/1X,2A10,1X,5G15.8)
      5006 FORMAT(3F10.0,2A10,F10.0)
      5006 FORMAT(/1X,3F10.5,1X,2A10,F10.5)
      5007 FORMAT(3A10,5F10.0)
      5007 FORMAT (/1X,2A10,1X,A10,5G15.8)
      5008 FORMAT(A15)
      5008 FORMAT(/1X,3I5)

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5009 FORMAT(6E10.0,2A10)
6009 FORMAT(/1X,6G15.9,5X,2A10)
430 5011 FORMAT(7E10.0,2F5.0)
6011 FORMAT(/1X,8G15.9,6I0.4)
7050 FORMAT(T5,"TSTAR",T21,"TEND",T35,"VAS(1)",T57,"VAS(3)"
      $ ,T56,"VAS(4)",T31,"VAS(5)",T95,"FTXL",T11,"DEEPL",T121,"DMMOPL")
7090 FORMAT( 4X,"TA(1)",3X"TA(2)",3X"TA(3)",3X"TA(4)",3X"TA(5)"
435 $ ,3X"TA(6)",3X"TA(7)",3X"TA(8)",1X"TPER(1)",1X"TPER(2)",1X"TPER(3)"
      $ ,1X"TPER(4)",1X"TPER(5)",1X"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
      $ 2)TPER(13)TPER(14)TPER(15)TPER(16))
440 7150 FORMAT(T5,"PSIZE",T23,"TEFF",T33,"CAPF",T54,"FCR",T69,"PER"
      $ ,T94,"CCM",T96,"ELEV",T108,"ROOFL")
7180 FORMAT(T5,"PCOS",T23,"PWCOS",T33,"PLANCH",T52,"COSTL",T67,"CSSPKW"
      $ ,T92,"CAPCHG",T97,"HPCST",T112,"CTUBB")
7185 FORMAT (T5,"POH4F",T20,"POH4FAN",T35,"POHLEC",T50,"POHCIR",
445 $ ,T65,"POHCND",T80,"POHSTC",T95,"POHSCN")
7210 FORMAT(T5,"RBP",T17,"TPO(1)",9X"TP0(2)",9X"TP0(3)",9X"TP0(4)")
7240 FORMAT(T5,"HEFFR",T20,"HDPRESS")
7270 FORMAT(T4,"VELREC",T20,"XDEPA",T35,"TLIM",T50,"TOWMIN",T65,"PFACT"
      $ ,T75,"TEIX",T90,"RFX",T105,"TOWMAX")
450 7280 FORMAT(5X,"GREFR")
7300 FORMAT(T5,"CPM",T20,"WEL",T35,"CLUVR",T50,"CHAILS",T65,"UCS",T80
      $ ,,"JNS",T95,"CVM",T110,"WFM")
7330 FORMAT(T5,"NTUCAL",T24,"HXNP",T44,"WB",T58,"VTUB",T75,"SS"
      $ )
455 7335 FORMAT(T5,"DESVEL",T21,"REDUCE",T35,"QREDUCE",T50,"DIST")
7360 FORMAT(5X,"XX",13X,"XD",13X,"XDS",12X,"SF",13X,"DFIN",11X,
      $ "THFI",10X,"DANGLE")
7390 FORMAT(5X"DDL",12X"DI",103X"GAGLIN",9X"TUBMA",13X"CONL")
7420 FORMAT(3X"HEINTYP",14X"HEINMAT",4X"CONF")
460 7450 FORMAT(5X"CFR",12X"COATC",10X"ZINCC",10X"CASTC",10X,"E2REPC")
7480 FORMAT(T4,"HEOTYP",T24,"HEOMAT",T35,"TX")
7510 FORMAT(5X,"CRU",12X,"CWJ",12X,"C4H",12X,"CN",12X,"CMW",12X,"CST",
      $ 12X,"FRU")
7540 FORMAT(5X"VNS",12X"VELN",11X"DDC",12X"GA",13X"FC",13X"TTD"
      $ ,15X"CONMAT")
465 7570 FORMAT(T4,"LFB",T11,"LFE",T15,"MXEXT")
7590 FORMAT(5X,"FFHX")
C
DO 18 I=1,5
470 18 VAR(I) = 0.0
      TCOS = 0.0
C
EXTNGE.FALSE.
EXTMP = .FALSE.
475 CALL DATE(DOY)
      CALL TIME(HEURE)
      WRITE(4,6000) DOY,HEURE
C
CAPDS A) - A2
480 30 READ(=,5001) DESC
      IF(EOF(5).NE.0.0) STOP "END METAL FIN CIRCULAR MODEL"
      DO 35 I=1,3
          IF(DESCR(I).NE.BLANK) GOTO 37
      35 CONTINUE

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685      GOTO 42
      37 WRITE(A,5001) DESCR
      GOTO 32
      40 CONTINUE
C
690      CARD B1
      READ(B,5011) TSTAR, TEND, VAS(1), VAS(3), VAS(4), VAS(5)
      $ .FIXL, DEEPL, POMDPL
      WRITE(A,5011) TSTAR, TEND, VAS(1), VAS(3), VAS(4), VAS(5)
      $ .FIXL, DEEPL, POMDPL
695      WRITE(A,7060)
C
      CARD C1
      READ(A,5003) (TA(I),I=1,8) , (TPER(I),I=1,8)
      WRITE(A,6003) (TA(I),I=1,8) , (TPER(I),I=1,8)
700      WRITE(A,7090)
C
      CARD C2
      READ(A,5003) (TA(I),I=9,16) , (TPER(I),I=9,16)
      WRITE(A,6003) (TA(I),I=9,16) , (TPER(I),I=9,16)
705      WRITE(A,7120)
C
      CARD D1
      READ(A,5002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
      WRITE(A,6002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
710      WRITE(A,7150)
C
      CARD E1
      READ(A,5002) ECOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
      $ .CTUR
      WRITE(A,6002) ECOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
      $ .CTUR
715      WRITE(A,7190)
C
      CARD E2
      READ(A,5002) POHRAF, POHFAN, POHLEC, POHCIR, POHOND, POHSTC
      $ .POHSCL
      WRITE(A,6002) POHRAF, POHFAN, POHLEC, POHCIR, POHOND, POHSTC
      $ .POHSCL
720      WRITE(A,7195)
C
      CARD F1
      READ(A,5004) RBP, (TPO(I),I=1,4)
      WRITE(A,6004) RBP, (TPO(I),I=1,4)
      WRITE(A,7210)
725      C
      CARD G1
      READ(A,5002) EFPF, DPRESS
      WRITE(A,6002) EFPF, DPRESS
      DPRESS = DPRESS + 1.E-30
      IPRESS = DPRESS
730      WRITE(A,7240)
C
      CARD H1
      READ(A,5002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX, RFIX
      $ .TOWMAX
735      WRITE(A,6002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX, RFIX
740

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```

      $      ,TOWMAX
      ITMIN = TOWMIN + 1.E-30
      IF (ITMIN.LT. 1) ITMIN = 1
745      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) FXTMP = .TRUE.
750      WRITE(4,7270)

C
CARD H2
      READ(5,5002) GREFF
      WRITE(4,6002) GREFF
755      WRITE(4,7280)

C
CARD I1
      READ(5,5002) CPM, WPL, CLUVR, CHAILS, UCS, JWS, CVM, WCV
      WRITE(4,6002) CPM, WPL, CLUVR, CHAILS, UCS, JWS, CVM, WCV
760      WRITE(4,7300)

C
CARD J1
      READ(5,5005) NTUCAL, HXNP, W3, NTUB, SS
      WRITE(4,6005) NTUCAL, HXNP, W3, NTUB, SS
765      WRITE(4,7330)

C
CARD J2
      READ(5,5002) DESVEL, REDUCE, GREDOCE, DIST
      WRITE(4,6002) DESVEL, REDUCE, GREDOCE, DIST
770      WRITE(4,7335)

C
CARD K1
      READ(5,5002) XW, XD, XDG, SF, OFIN, THFIN, DANGLE
      WRITE(4,6002) XW, XD, XDG, SF, OFIN, THFIN, DANGLE
775      WRITE(4,7350)
      CONVERT DEGREES TO RADIAN
      DANGLE = DANGLE * 3.14159 / 180.
      CDANG = COS (DANGLE)

C
780      CARD L1
      READ(5,5006) ODL, DI, GAGLIN, TUBMAT, XTUBMA, CONL
      WRITE(4,6006) ODL, DI, GAGLIN, TUBMAT, XTUBMA, CONL
      WRITE(4,7390)

C
785      CARD M1
      READ(5,5007) FINTYP, XFINTY, FINMAT, CONF
      WRITE(4,6007) FINTYP, XFINTY, FINMAT, CONF
      WRITE(4,7420)

C
790      CARD N1
      READ(5,5002) CFB, COATC, ZINCC, CASTC, EPREPC
      WRITE(4,6002) CFB, COATC, ZINCC, CASTC, EPREPC
      WRITE(4,7450)

C
795      CARD P1
      READ(5,5007) HEDTYP, XHEDTY, HEDMAT, TW
      WRITE(4,6007) HEDTYP, XHEDTY, HEDMAT, TW
      WRITE(4,7480)

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C
800 CARD 01
      READ(5,5002) CRJ, CWJ, CHH, CV, CMW, CST, CSU
      WRITE(6,6002) CRJ, CWJ, CHH, CV, CMW, CST, CSU
      WRITE(6,7510)

C
805 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
810 CARD S1
      READ(5,5008) LFB, LFE, MXEXT
      WRITE(6,6008) LFB, LFE, MXEXT
      WRITE(6,7570)
      IF (LFE .LT. LFB) STOP "LFB EXCEEDS LFE ON INPUT CARD"
      IF (MXEXT .LT. 1) MXEXT = 10

C
C
CARD T1
820      READ(5,5005) FFHX
      WRITE(6,6005) FFHX
      WRITE(6,7580)
      IF (FFHX .NE. "PER" .AND. FFHX .NE. "ERICHO")
        * STOP "**** UNRECOGNIZED FFHX ON CARD Tj"
      EHP = 3414.43 / TEFF
      IF (FIX(0.9T.0.0) FXTLNG=.TRUE.
825      DO 45 J=1,16
      IF (TPER(J).LT.1.E-20) GOTO 46
      NTA=J
45 CONTINUE
830 46 CONTINUE
      SUPER=0.0
      DO 20 I=1,16
      SUPER=MPER + TPER(I)
      IF (ABS(SUPER-1.0).LT.1.E-10) GOTO 22
835      WRITE(6,89)
      STOP
      22 CONTINUE

C
C
840 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
845 99 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE OD"

C
1011 DO 98 J= 1,7
      KGA = J
      IF (ABS(GA-TGA(KGA)).LT. .001) GOTO 100
850 98 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE GAGE"

C
100 CONTINUE
855 C

```


SUPROUTINE SETUP

74/74 OPT=1

FTN 4.2+74351

12/21/78

C CALLI C0STEX TO EVALUATE ODR

C

CALLI C0STEX (DUMX1)

C

. A60

RETURN

END

SUBROUTINE SHOT(L)

C
C
C
C

THIS ROUTINE ESTABLISHES A STARTING PLACE FOR THE MINIMIZING PROCEDURE BY SAMPLING POINTS AROUND THE STARTING VALUES PROVIDED.

5

LOGICAL EXTNG
 DIMENSION T(3),CWAR(4),RANG(3),AFRO(3),WLRA(4),VAM(5)
 LOGICAL FIRST, EXTEMP
 COMMON

10

\$ AFTR, ALPHA
 \$ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAF
 \$ CRJ, CTURB, CDANG, CLUVR, CHAITS, CVM
 \$ DANGIE, DFIN, DEEPL, DESVEL
 \$ EFFF

15

\$ FOR, FIRST, FIXL, FCOS, FFHX, EXTEMP
 \$ GREFE
 \$ HXND, HPCST
 \$ ITMAX, ITMIN
 \$ JCONC

20

\$ KCONV, KALEXT
 \$ MXEXT
 \$ NTUCAL(2), NTA
 COMMON

25

\$ ODR
 \$ PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
 \$ POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
 \$ PREU, REDUCE
 \$ REP, REDUCE, ROOFL, RFIX

30

\$ SIGMA, SAAF
 \$ TD, TPO(4), TEF, TLIM, TFIN, TLPA, TFIX
 \$ TCD, TW
 \$ UCS, UWS
 \$ VAS(5)

35

\$ WFM
 \$ XREP, XW, XD
 COMMON /ELSW/ EXTNG
 COMMON /LACALL/ SRN
 COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,

40

\$ QIN, CLAND, REAR, Z1, HFA2S, W4, U, DELPW, PPOW,
 \$ FPOW, DEFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
 \$ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
 \$ SPC, PTOTL, PLANC3, SAFRON, AAIR, YFP, SPC, PSIZ13, WT2,
 \$ RQ2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX

45

\$ TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
 \$ CLTC, CFC, CPCC, FITC, CSC, CEPREP, DELPID, AST, OLOCST
 \$ CAPST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTUB, ADIA, ABLV
 \$ WTHAR, WTRM, STRUCC, CPERF, HPERF, TOTCF, TPC, EFFIN, ANTU
 \$ AIRF, WATER, XNMO, TCTP, FDCP, FMTRC, ACCTIP, ADUTP
 \$ ACTARD, ADURPD, ACTVH, ADUVH, ADJPP, THPAIR, TCTF, AFCST
 \$ CSRA, WATERW, WSTPT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD

50

\$ ATUBC, CSTLVR, CSTHS, CYLRNG, CFAVEL
 COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
 \$ QIN1, CLAN1, REA1, Z1, HFA2S, W41, U1, DEPW1, PPOW1,
 \$ FPO1, DEFC1, WIDT1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,
 \$ REW1, NW1, NT1, NP1, PLNC2, ZSIZ12, ZSPBP, SW41, SW31,
 \$ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
 \$ RQ2MIN, NW2MIN, TCOS1, DELPA1, DELPWT1, DELPWC1, CONBAS1, XNTS1, VELO1

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      S. TLF1, UCON1, PMOS1, FMCS1, FRAC1, EFFC1, CH7, CA1, CS1
      S. CLT1, CFC1, CPOC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLOC1
60  S. CAPCS1, XNFAV1, BLDAV1, CPLEN1, DPEL1, WH1, WTTU1, ADI1, ABL1
      S. WTH1, WTR1, STRUC1, CFMP1, HPP1, TOTCF1, TP1, EFFIN1, ANTU1
      S. AIRF1, WATF1, XNMOD1, TOTF1, FOCF1, FMTRC1, ACTTP1, ADJTP1
      S. ACTR1, ADJRP1, ACTVH1, ADJWH1, ADJPP1, TPA1, TCF1, AFCS1
      S. CSR1, WATER1, WSTRC1, CFOU1, HJBD1, TOWLE1, NUMT1, CTOWD1
65  S. ATURC1, CSTLV1, CSTHS1, CYLRN1, CFANE1
      COMMON /SCALER/ HPPAC1, ATUB, CPRA, SSCD, PLANC1, CASSS1,
      S. GAIR, FAIR, HPAIR, HPWAT, PLANC1
      COMMON /TINE/ XNS, TTD, TLA, XNTS, ARPS
9500 FORMAT('0IN SHOT AT CHECKPOINT A. VAR(4)=",IPE12.4,6X,"VAM(4)=",
      S.12.4,6X,"DAFRO=",E12.4)
70 9501 FORMAT('0IN SHOT AT CHECKPOINT B. I=",I1,6X,"DAFRO=",IPE12.4,6X,
      S. "VAR(4)=",E12.4,6X,"AFRO(I)=",E12.4)
9502 FORMAT('0IN SHOT AT CHECKPOINT C. I=",I1,6X,"VAR(4)=",IPE12.4,
      S. 6X,"FAF=",E12.4)
75 9503 FORMAT('0IN SHOT AFRO WILL BE BAD BECAUSE VAS(4)=",IPE12.4)
      IF (EXTMP) CALL ROOT (TFIX, RFIX, TTD, TD, CWARL)
      IDB=0
      IF (LEQ.2) GO TO 31
      DO 1 I=1,5
80 1 VAM(I)=0.0
      TCS1=0.
      TCS2=0.
      DO 20 I=1,3
      T(I)=VAS(1)+(I-2)*5.
85 IF (EXTMP) T(I) = TFIX
      IF (T(I) .GT. 190.) T(I) = 190.
20 IF (T(I) .LE. 0.0) T(I) = 10.0
      DO 21 I=1,4
      CWAR(I)=VAS(3)+(I-2)*2.
90 21 IF (CWAR(I) .LE. 0.) CWAR(I) = .5
      IF (.NOT. EXTMP) GOTO 24
      CWAR(1) = CWARL * .9
      CWAR(2) = CWARL * .8
      CWAR(3) = CWARL * .7
95 CWAR(4) = CWARL * .5
24 CONTINUE
      DO 22 I=1,4
      WLR(I)=VAS(5)+(I-2)*10.
700 22 IF (CWAR(I) .LE. 0.) WLR(I) = 5.
      AFRO(1)=VAS(4)/2.
      AFRO(2)=VAS(4)
      AFRO(3)=VAS(4)*2.
      DT1=1.
      OCWAR=1.
705 DAFRO=1.
      DWLRA=1.
      LC=4
      LW=4
      GO TO 31
710 31 DT1=VAS(1)-VAM(1)
      OCWAR=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

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115      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(EXT=VP) T(I) = TFIX
120      32 CONTINUE
      GO TO 35
      33 DO 34 I=1,3
      T(I)=V.R(1)+(I-2)*2.
      IF(EXT=MP) T(I) = TFIX
125      34 IF(T(I).GE.170.) T(I)=170.
      35 IF(DCWAP.EQ.0.0..OR.DCWAP.EQ.VAR(3)) GO TO 37
      DO 36 I=1,4
      CWAP(I)=VAR(3) - (I-1)*DCWAP/3.
      IF(CWAP(I).LE.0.0) CWAP(I)=0.25
130      36 CONTINUE
      GO TO 39
      37 DO 38 I=1,3
      CWAP(I)=VAR(3) + (I-2)
      IF(CWAP(I).LE.0.0) CWAP(I)=0.25
135      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.
140      C
      IF(IDB.EQ.0) GOTO 43
      DO 404 I=1,3
      IF(AFRO(I).LE.0.0) WRITE(6,9501) I,DAFRO,VAR(4),AFRO(I)
      4040 CONTINUE
      GO TO 43
145      41 FAF=.5F5
      TC=ABS(FAF-VAR(4))
      IF(TC.GT.1.E+4) FAF=FAF*0.9
      DO 42 I=1,3
150      AFRO(I)=VAR(4)+(I-2)*FAF
      IF(AFRO(I).LE.0.0) AFRO(I)=1000. * I
      42 CONTINUE
      C
      IF(IDB.EQ.0) GOTO 43
      DO 404 I=1,3
      IF(AFRO(I).LE.0.0) WRITE(6,9502) I,VAR(4),FAF
      4042 CONTINUE
155      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 41
      45 DO 46 I=1,3
      46 WLRA(I)=VAR(5)+(I-2)*5.
      LW=3
160      45 DO 45 I=1,3
      DO 45 I=1,LC
      IF(CWAP(IC).EQ.0.0) WRITE(6,9504) IC
      9504 FOR 'AT MOIN SHOT, DIVISION BY ZERO. CWAP("I2")=0.0"
      RANGL = (T(IT)-T(TD-TD))*(1.-EXP(-CWAP(IC)))/CWAP(IC)
165      2 RANG(1)=.9*RANGL
      RANG(2)=.7*RANGL
170

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RANG(3)=.5*PANGL
IF(EXT=MP) RANG(1) = RFIX
IF(EXT=MP) RANG(2) = RFIX
175 IF(EXT=MP) RANG(3) = RFIX
DO 15 IR=1,3
DO 15 IA=1,3
DO 15 IW=1,LW
KCALC=1
180 IF(IR.GT.1.OR.IC.GT.1) KCALC=2
IF(IA.GT.1) KCALC=4
IF(IW.GT.1) KCALC=5
SRN="/=HOT-1/ "
CALL CALC(T(IT),RANG(IR),CWAR(IC),AFRO(IA),WLRA(IW),KCALC)
185 IF(KCO=V.EC.1) GO TO 15
C IF(DELTA.LT.XDEPA) GO TO 16
IF(DELTA.LE.XDEPA) GO TO 16
IF(TCOS1.EQ.0.) GO TO 14
C IF(TCOS.GT.TCOS1) GO TO 16
190 IF(TCOS.GE.TCOS1) GO TO 16
IF(TCOS2.EQ.0.) GO TO 14
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)
200 VAR(2)=RANG(IR)
VAR(3)=CWAR(IC)
VAR(4)=AFRO(IA)
VAR(5)=WLRA(IW)
CAF=AFCO(1)*.1
GO TO 15
205 16 IF(LV.EC.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
210 17 TCOS2=TCOS
VAM(1)=T(IT)
VAM(3)=CWAR(IC)
VAM(4)=AFRO(IA)
VAM(5)=WLRA(IW)
15 CONTINUE
215 IF(IDR.EQ.0) RETURN
WRITE(7,553)TCOS1,VAR(1),VAR(2),VAR(3),VAR(4),VAR(5)
553 FORMAT(" TCOS1="E12.5," T11="E4.0," RANG1="F7.4," CWAR1="F7.3,
1" AFRO1="E10.3," WLRA1="F4.0)
RETURN
220 END

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SUBROUTINE SPDES(TD,TS,TR,TTD,XNS,CHLD,VELD,RHO,ARPS,TLW,XNTS,HOLD
15)

5 SUBROUTINE SPDES DESIGNS A SINGLE PRESSURE SURFACE CONDENSER
IN ACCORDANCE WITH HEAT EXCHANGE INSTITUTE (HEI) STANDARDS
FOR SURFACE CONDENSERS FOR GIVEN DESIGN VALUES OF TURBINE
EXHAUST STEAM SATURATION TEMPERATURE, CIRCULATING WATER
10 TEMPERATURE RISE IN THE CONDENSER, CONDENSER TERMINAL
TEMPERATURE DIFFERENCE, CLEANLINESS FACTOR, TUBE SIZE AND
NOMINAL VELOCITY THROUGH THE TUBES, AND FOR A GIVEN TUBE
MATERIAL

15 DEFINITION OF VARIABLES

ARPS - AREA PER CONDENSER SHELL (SQ FT)
AOT - TOTAL AREA OF CONDENSER SHELLS (SQ FT)
CHLD - HEAT TRANSFERED IN THE CONDENSER (BTU/HR)
20 CH - ARRAY OF VELOCITY CONSTANTS FOR THE OVERALL HEAT
TRANSFER COEFFICIENT AS A FUNCTION OF THE TUBE
OUTSIDE DIAMETER (DIMENSIONLESS)
DELPWC - PRESSURE DROP OF THE WATER THROUGH THE CONDENSER
(LBF/SQ FT)
25 EFFC - EFFECTIVENESS OF THE CONDENSER (DIMENSIONLESS)
ESA - ARRAY OF EXTERNAL SURFACE AREA OF CONDENSER TUBE
PER LINEAR FOOT AS A FUNCTION OF TUBE OUTSIDE
DIAMETER (SQ FT/FT)
30 FO - FOULING FACTOR FOR THE OVERALL HEAT TRANSFER
COEFFICIENT (DIMENSIONLESS)
FSA - ARRAY OF TUBE WALL GAGE CORRECTION FACTORS FOR THE
OVERALL HEAT TRANSFER COEFFICIENT FOR ADMIRALTY
METAL, ARSENICAL COPPER OR ALUMINUM TUBES FOR
SURFACE CONDENSERS (DIMENSIONLESS)
35 FAL - LENGTH OF FLOW PATH PER SHELL (FT)
FTF - ARRAY OF GPM PER FPS VELOCITY THRU TUBES AS A
FUNCTION OF TUBE GAGE AND TUBE OUTSIDE DIAMETER
(GPM/FT/SEC)
FTI - INLET TEMPERATURE CORRECTION FACTOR FOR THE
OVERALL HEAT TRANSFER COEFFICIENT (DIMENSIONLESS)
40 FTIN - ARRAY OF INLET TEMPERATURE CORRECTION FACTORS AS
A FUNCTION OF INLET TEMPERATURES (DIMENSIONLESS)
GPM - VOLUMETRIC FLOW RATE THROUGH THE CONDENSER
GPM - VOLUMETRIC FLOW RATE OF WATER THROUGH THE CONDENSER
(GALLONS/MINUTE)
45 GMS - VOLUMETRIC FLOW RATE OF WATER THROUGH EACH SHELL
OF THE CONDENSER (GALLONS/MINUTE)
HLOS - HEAD LOSS OF THE WATER THROUGH THE CONDENSER (FT)
HOLS - HEAD LOSS OF THE WATER THROUGH THE TUBES OF THE
CONDENSER (FT/100 FT)
50 PEOP - ARRAY OF THE WATER PROPERTIES DENSITY AND VISCOSITY
AS A FUNCTION OF TEMPERATURE (LBM/CU FT LBM/FT HR)
RHO - DENSITY OF THE WATER (LBM/CU FT)
TAVT - AVERAGE TEMPERATURE OF THE WATER GOING THROUGH THE
CONDENSER (DEG F)
55 TLM - LOG MEAN TEMPERATURE DIFFERENCE OF THE CONDENSER
(DEG F)
TE - EXIT TEMPERATURE OF THE WATER LEAVING THE CONDENSER

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C      (DEG F)
60  C      TFIOS - 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      TH20 - ARRAY OF WATER TEMPERATURES (DEG F)
C      TI - INLET TEMPERATURE OF THE WATER ENTERING THE
75  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 CONJUNCTION WITH
C      THE INLET TEMPERATURE CORRECTION FACTOR (DEG F)
70  C      TLA - INTEGER VALUE OF FLOW PATH LENGTH PER SHELL (FT)
C      TO - TEMPERATURE RANGE OF THE WATER FLOWING THROUGH THE
C      CONDENSER (DEG F)
C      TS - TURBINE EXHAUST STEAM SATURATION TEMPERATURE
C      (DEG F)
75  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
80  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)
85  C      VFLT - 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      WFIOS - ARRAY OF HEAD LOSS IN THE WATER BOXES OF THE
90  C      CONDENSER AS A FUNCTION OF THE VELOCITY OF THE
C      WATER IN THE CONDENSER TUBES (FT)
C      WFLT - 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)
95  C      XNTS - NUMBER OF TUBES PER CONDENSER SHELL (DIMENSIONLESS)

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COMMON /RPT2/ DMM4 ,TI ,TE ,TOLM ,XNP
* ,VELD ,DELPH7 ,ARPS7 ,TLA7 ,XNTS7 ,XNS7 ,TS7
COMMON /TUBE/ KGA ,FBA(7) ,LO ,ESA(5) ,TID(7,5) ,FTF(7,6)
COMMON /OHTC/ FC ,CU(5) ,VELN
COMMON /INLT/ TIN(15) ,FTIN(15)
COMMON /R20/ TH20(15) ,PROP(15,2)
COMMON /STEM/ TSTM(51) ,PSTM(51)
COMMON /CFHL/ VELT(15) ,TELT(15) ,WBLT(15,2)
100  COMMON /SUPPLY/ VAL(5) ,CPLN ,CPIP ,CCOS ,W3 ,COSM ,EFF ,
* RYN ,CLAND ,REAIR ,ZTRFAC2 ,W4 ,U ,DELPW ,PPOW ,
* FPAW ,DELFC ,WIDTH ,ELENG ,VAIR ,VWAT ,HT ,HO ,T4 ,
* RENAT ,NW ,NT ,NP ,PLANC2 ,PSIZ12 ,SP35 ,SW4 ,SW3 ,
* SPC ,PTOTAL ,PLANC3 ,SAFRON ,AAIR ,YFP ,SPC3 ,PSIZ13 ,WT2 ,
105  * SP2 ,NWP ,TCOS ,DELP4 ,DELPAT ,DELPWC ,CONBAS ,XNTSX ,VELOX
* ,TLAX ,UCON ,PMOST ,FMOST ,FBACC ,EFFC ,CH ,CA ,CS
* ,CLIC ,CFC ,CPC ,FITC ,CSC ,CEPREP ,DELP15 ,AST ,OLDOST
* ,CAPOST ,XNFAN ,OLDANG ,CLEN ,DPFEL ,WHX ,ATTUB ,ADIA ,ABLN
* ,WTHAR ,WTFRM ,STRUCC ,CFPERF ,HPPERF ,TOTCF ,TPC ,EFFIN ,ANTU

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115      S, ATRFF, WATERF, XNMOD, TCTPF, FDCPF, FMTRC, ACCITP, ADJTP
      S, ACTBOD, ADJBDP, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
      S, CSRH, WATERV, WSTRT, CFOJND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S, ATUBC, CSTLVP, CSTHS, CYLRNG, CFANEL

120      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
125      C
      901 FORMAT(" NON INTEGER TLA* VALUE=",1PE13.6)
      110  TE=TS-ITD
      TI=TE-TR
      TAVT=(TI+TE)/2.
130      RHO=TLU(TAVT,TH20,PROP,16)
      GPMCHLD/(8.021-RHO*TR)
      C      WRITE(6,901) RHO,GPM
      GPMSE=GPM/XNS
135      TOLM=TR/ALOG((TR+TID)/TID)
      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-
140      C      SEQUENT CALCULATION OF SURFACE AREA FOR GIVEN DESIGN
      C      CONDITIONS
      C
      VELO=VELN
      ISA=1

145      C
      C      DETERMINE OVERALL HEAT TRANSFER COEFFICIENT AND SURFACE AREA
      C      PER SHELL
      C
150      104  UCON=CU(LO)*SQRT(VELO)*FTI*FGA(KGA)*FC
      DMMH=UCON
      ARPS=(CHLD/XNS)/(UCON*TOLM)
      NAMELIST/DBGPO/
      S      ARPS,VELO,GPM,XNP,VEL,TLA,XNS,CHLD,UCON,TOLM,ISA
155      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
160      C
      IF(TS.-1)100,100,101
170      100  FPL=ARPS*VELO*FTF(KGA,LO)/(GPM*ESA(LO))
      IF(FPL,LT,1.E-20) WRITE(6,DBGPO)
      IF(FPL,LT,1.E-20) STOP"IN SPDES2"
165      XNP=1.
      IF(FPL,GT,50.) XNP=2.
      TLA=INT(FPL/XNP)
      IF(TLA,LT,1.0) TLA=FPL/XNP
      IF(TLA,LT,1.0) WRITE(6,901) TLA
170      IF(TLA,LT,1.0) GOTO 103
      C

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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
175 C      SURFACE AREA USING CALCULATED VALUE OF VELOCITY
C
101  VEL=GAMS-ESA(LD)+TLA*XNP/(ARPS*FTF(KGA,LD))
      IF(VEL.LT.1.E-20) WRITE(6,DBGPO)
      IF(VEL.LT.1.E-20) STOP "IN SPDES3"
180 C
      IF((ABS(VEL-VELD)/VELD)-0.002)103,103,102
102  ISA=2
      VELD=VEL
      GO TO 104
185 C
C      DETERMINE NUMBER OF TUBES OF GIVEN SIZE PER SHELL AND TOTAL
C      CONDENSER HEAT TRANSFER SURFACE AREA
C
103  XNTS=INT(GPMS/(VELD*FTF(KGA,LD))+0.5)*XNP
190  XNTSX=XNTS * XNS
      AST=ARPS*XNS
C
C      DETERMINE HEAD LOSS THRU THE CONDENSER, INCLUDING TUBE-END
C      AND WATERBOX LOSSES
195 C
      VIS=TLU(TAVT,TH20,PROP(1,2),15)
      CALL HYDLOS(TID(KGA,LD),VELD,VIS,RHO,1,HOLS)
      TELOS=TLU(VELD,VELT,TELT,15)*XNP
      INP=XNP
200  WBLOS = TLU(VELD,VELT,WBLT(1,INP),15)
      HOLOS=TLA*XNP/100.*HOLS+TELOS+WBLOS
      DELPWC=HOLOS * RHO
C
C      STORAGE OF VARIABLES
205 C
      TLA7=TLA
      VELDX=VELD
      EFFC=TD/(TR+TID)
      VELD7=VELD
210  DELPWT=DELPWC
      ARPS7=ARPS
      TLA7=TLA
      XNTS7=XNTS
      XNST=XNS
215  TST=TS
      RETURN
      END

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SUBROUTINE SSSCALE

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C
C      SUBROUTINE SSSCALE SCALES THE STEAM SUPPLY SYSTEM UP TO
C      OBTAIN THE SPECIFIED POWER OUTPUT OF THE PLANT (PSIZE) AT THE
5      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
10
C      C$SSS1 - INCREMENTAL COST OF STEAM SUPPLY FOR MAKE UP OF
C      POWER OUTPUT DUE TO INCREASED HEAT RATE AT RATED
C      BACK PRESSURE ($)
C      C$SPKW - COST OF STEAM SUPPLY SYSTEM PER KILOWATT ($/KW)
15      HRFAC1 - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
C      PRESSURE (DIMENSIONLESS)
C      PLANC - COST OF POWER PLANT PER KILOWATT ($/KW)
C      P$IZE - PLANT SIZE (MW)
C      RBP - STEAM TURBINE RATED BACK PRESSURE (IN HGA)
20      SACC - INCREMENTAL PLANT COST DUE TO INCREASED HEAT RATE
C      AT RATED BACK PRESSURE OF STEAM TURBINE ($)
C      TDO - COEFFICIENTS OF THIRD ORDER HEAT RATE CURVE FIT
C      FOR STEAM TURBINE (DIMENSIONLESS)
C
25      LOGICAL FIRST, FEXTMP
C      COMMON
C      $ AETR, ALPHA
C      $ ,CAPF, C$SPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP
30      $ ,CRJ, CTURR, CDANG, CLUVR, CHA1LS, CVM
C      $ ,DANGLE, DFIN, DEEPL, DESVEL
C      $ ,EETR
C      $ ,FCR, FIRST, FIXL, FCOS, FPHX, FEXTMP
C      $ ,GREFP
35      $ ,HXWR, HRCST
C      $ ,ITMAX, ITVIN
C      $ ,JCONC
C      $ ,KCONV, KALEXT
C      $ ,MXEXT
C      $ ,NTJCAL(2), NTA
40      C      COMMON
C      $ QOR
C      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
C      $ ,POHAP, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
45      $ ,QREJ, QREDUCE
C      $ ,RAP, REDUCE, ROOPL, RFIX
C      $ ,SIGMA, SAAF
C      $ ,TD, TDO(4), TEFF, TLIM, THEIN, ILRA, TFIX
C      $ ,TCD, TX
C      $ ,UCS, UWS
50      $ ,VAS(5)
C      $ ,WCV
C      $ ,XDEP, XW, XD
C      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W1, COSM, EFF,
65      $ GEN, CLAND, REAR, Z-HRFAC2, W4, U, DELPW, POW,
C      $ FLOW, DELFO, WIDTH, ELENG, VAIR, VMAI, HT, HO, T4,
C      $ REWAT, NW, NT, VP, PLANC2, PSIZ12, SPBP, SW4, SW3,
C      $ STC, PTOTAL, PLANC3, SAFPON, AAIR, YFP, SPCN, PSIZ13, WT2,

```

```

60      B22, NWD, TCOS, DELPA,DELPWT,DELPWC,CONBAC, XNTSX, VELOX
      $ , TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
      $ , CLTC, CFC, CPCC, FITCO, CSC,CEPRE,DEPIG, AST,OLOCST
      $ ,CAPOST,XNFAN,BLOAVG,CLEN,DPFEL,WHX,WTUB,ADIA,ABLV
      $ ,WTHD,WTRM,STRUC,CPREF,HPREF,TOTCF,TPC,EFFIN,ANTU
      $ ,AIRF,WATF,XNMO,TOTPF,FOCPF,FMTRC,ACCTP,ADJTP
      $ ,ACTRD,ADURD,ACTVH,ADJVH,ADJPF,THPAI,TCTF,AFCST
      $ ,CSR,WATER,WSTPC,CFOUND,HUBDIA,TOWLEN,NUMTOW,CTOWD
      $ ,ATUB,CSTLVR,CSTHS,CYLRNG,CFANEL
      COMMON /SINK/ VAR(5), CPLN1,CP1P1,CCOS1,W3T,COSM1,EFF1,
      $ ,D1M1,CLAN1,REAI1,Z1,HFA2S,W41,UI,DEPW1,PSOW1,
      $ ,FPOW1,DEFC1,WIDT1,ELEN1,VAIR1,VWAT1,HIT,H01,T41,
      $ ,REWA1,NW1,NT1,NP1,ZPLNC2,ZSIZ12,ZSP3D,SW41,SW31,
      $ ,SPC1,PTOT1,PLNC1,AFRO1,AAIR1,YPMIN,SPC1,SPS13,WT2MIN,
      $ ,B2PMIN,W2MIN,TCOS1,DEPA1,DPWT1,DPWC1,CONBAC,XNTS1,VELO1
      $ ,TLAX,UCON1,PMOS1,FMOS1,FBAC1,EFFC1,CH1,CA1,CS1
      $ ,CLTC1,CFC1,CPCC1,FITCO1,CSC1,CEPRE1,DEPIG1,AST1,OLOCST1
      $ ,CAPOST,XNFAN1,BLOAV1,CLEN1,DPFEL1,WH1,WTU1,AD11,AB11
      $ ,WTH1,WTR1,STRUC1,CPREF1,HPREF1,TOTCF1,TP1,EFFIN1,ANTU1
      $ ,AIRF1,WATF1,XNMO1,TOTPF1,FOCPF1,FMTRC1,ACTTP1,ADJTP1
      $ ,ACTRD1,ADURD1,ACTVH1,ADJVH1,ADJPF1,THPAI1,TCTF1,AFCST1
      $ ,CSR1,WATER1,WSTPC1,CFOUND1,HUBD1,TOWLE1,NUMTOW1,CTOWD1
      $ ,ATUB1,CSTLVR1,CSTHS1,CYLRN1,CFANEL1
      COMMON /SCALER/HRFAC1,ATUB,CPERA,SSCD,PLANC1,CASSS1,
      $ ,CAIR,FAIR,HPAIR,HPWAT,PLANCT1

```

```

95      EQUATION FOR HEAT RATE FACTOR AS A FUNCTION OF TURBINE
      BACK PRESSURE

      HRF(P)=TPO(1) + TPO(2)*P + TPO(3)*P**2 + TPO(4)*P**3

      HEAT RATE FACTOR AT RATED BACK PRESSURE:

      HRFAC1=HRF(RBP)

      INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
      FACTOR AT RATED BACK PRESSURE ($)

      DTURBC = CTURB * PSIZE * 1000.
      CASSS1 = CSSPKW * (HRFAC1 - 1.) * PSIZE * 1000.
      SSSPC = PLANC * PSIZE * 1000. + CASSS1

100      PLANT COST TAKING INTO ACCOUNT INCREASED STEAM SUPPLY
      COST ($/MW)

      PLANCT1 = SSSPC + DTURBC
      PLANC1 = PLANCT1 / (PSIZE * 1000.)

105      INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
      OF TURBINE ($)

      SSPLC = SSSPC / (PSIZE * 1000.)
      SSCD = (SSPLC - PLANC) * PSIZE * 1000.
      TOD = DTURBC

      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(5038)
COMMON /RPRT2/ R2(12)
COMMON /RPRT3/ R3(4)
COMMON /KPRT1/ SPRT1(5038)
10 COMMON /KPRT2/ SPRT2(12)
COMMON /KPRT3/ SPRT3(4)
COMMON /SINK/ VSTO(121)
COMMON /SUPPLY/ VIN(121)
LOGICAL FIRST, EXTEMP
15 COMMON
$ .AFTR, ALPHA
$ .CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHS, CONMAT, CONMA2, CAP
$ .CRU, CTURB, COANG, CLUVR, CHALS, CVM
20 $ .DANGIE, OFIN, DEEPL, DESVEL
$ .EFPF
$ .FCR, FIRST, FIXL, FCOS, FFHX, EXTEMP
$ .GREFP
$ .HXNP, HPCST
$ .ITMAX, ITMIN
25 $ .JCONS
$ .KCON, KALEXT
$ .MXEX
$ .NEICAL(2), NTA
COMMON
30 $ .ORD
$ .PSIZE, PER, PWCOS, PLANC, PFACT, POMORL
$ .POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
$ .PREU, PREUCE
$ .RAB, REDUCE, RODEL, RFIX
35 $ .SIGM, SAAF
$ .TD, TPO(4), TEFF, TLIM, THFN, TLPA, TFIX
$ .TOD, TW
$ .UCS, UWS
$ .VAS(7)
40 $ .WFM
$ .XDEP, XW, XD
DO 1 I=1,121
VSTO(I)=VIN(I)
1 CONTINUE
DO 2 I=1,5038
45 SPRT1(I)=R1(I)
2 CONTINUE
DO 3 I=1,12
SPRT2(I)=R2(I)
50 3 CONTINUE
DO 4 I=1,4
SPRT3(I)=R3(I)
4 CONTINUE
JCONS=F
55 RETURN
END

```

```

SUBROUTINE SUMCOS(FOR,PSIZE,CAPF,CCOS1,CPIP1,CONB1,ATUBC,CLEN,
&FACC,FMCST,STRUC,CFOUND,CAPCST,SPCD1,SSCD,HRFAC1,HRFAC2,YFP,
&PLANC,CLAN1,CLSUM,FCSUM,COSM1,CSTLV1,CSTHS1,CFANEL,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"/

```

```

&,T15,43(" "),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,"PIENUM",T23,F13.0

```

```

R,T75,"PIENUM",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 T48,12("=")/)
60 6160 FORMAT(
      L T2,"TOTAL CAPITAL COST",T46,"5",T48,F13.0
      P,T62,"TOTAL CAPITAL COST",T119,G12.6/)
6170 FORMAT(
      R T69,"ENERGY PENALTY",T119,G12.6/)
65 6180 FORMAT(
      R T69,"ADDITIONAL BASE PLANT FUEL",T119,G12.6/)
6190 FORMAT(
      R T69,"OPERATION AND MAINTENANCE",T119,G12.6/)
70 6200 FORMAT(
      R,T72,"TOTAL",T119,G12.6)
      YFPP1 = YFP + 1.
      FACTOR2 = FCR/(PSIZE*CAPE*8760)
      WRITE(4,6001)
      WRITE(4,6010) (CCOS1,CPIP1+CONBA1),((CCOS1+CPIP1+CONBA1)*FACTOR)
75 WRITE(4,6020) CCOS1,CCOS1*FACTOR
      WRITE(4,6030) ATURC,ATURC*FACTOR
      WRITE(4,6040) CPLEN,CPLEN*FACTOR
      WRITE(4,6042) CSTLV1,CSTLV1*FACTOR
      WRITE(4,6044) CSTHS1,CSTHS1*FACTOR
80 WRITE(4,6050) (FRACC + FMCST + CYLRN1 + CFANE1)
      * (FRACC + FMCST + CYLRN1 + CFANE1) * FACTOR
      WRITE(4,6060) STRUCC,STRUCC*FACTOR
      WRITE(4,6070) CFUND,CFUND*FACTOR
      WRITE(4,6080) CPIP1,CPIP1*FACTOR
85 WRITE(4,6090) CONBA1,CONBA1*FACTOR
      WRITE(4,6100) CAPCST,CAPCST*FACTOR
      WRITE(4,6110) SPCD1,SPCD1*FACTOR
      WRITE(4,6120) SSCD*HRFAC2/HRFAC1*YFPP1,SSCD*HRFAC2/HRFAC1*YFPP1*
      *FACTOR
90 WRITE(4,6130) PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10**3 * PSIZE,
      * PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10**3 * PSIZE * FACTOR
      WRITE(4,6140) CLAN1
      WRITE(4,6150)
95 WRITE(4,6160) CLAN1+SPCD1+CAPCST+CCOS1+CPIP1+CONBA1
      *,(CLAN1+SPCD1+CAPCST+CCOS1+CPIP1+CONBA1)*FACTOR
      WRITE(4,6170) CLSUM
      WRITE(4,6180) FCSUM
      WRITE(4,6190) COSM1
100 TOTAL = (CLAN1 + SPCD1 + CAPCST + CCOS1 + CPIP1 + CONBA1) *
      * FACTOR + CLSUM + FCSUM + COSM1
      WRITE(4,6200) TOTAL
      END

```

```

SUBROUTINE STRUCT(DTOW, WHX, WATERW, ROOFL, CSTRUC, CFND, WSTRC,
                  ITOWN, ELENG, POHSTC)
  SUBROUTINE STRUCTURES DETERMINES THE COST OF THE STRUCTURES
  AND THE FOUNDATION FOR THE CIRCULAR TOWERS. THE STRUCTURE
  COST IS BASED ON THE HEIGHT AND DIAMETER OF EACH TOWER AND
  THE DESIGN ROOF LOAD. THE FOUNDATION COST IS BASED ON THE
  TOTAL WEIGHT OF THE HEAT EXCHANGERS AND THE SURFACE AREA
  COVERED BY THE TOWERS.

  DEFINITION OF VARIABLES

  CFND - COST OF FOUNDATION ($)
  CSTRUC - COST OF STRUCTURES ($)
  DTOW - TOWER DIAMETER (FT)
  ITOWN - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
  POHSTC - DIRECT AND INDIRECT CONSTRUCTION COSTS FOR THE
          STRUCTURES (DECIMAL PERCENT)
  ROOFL - DESIGN ROOF LOAD (LBF/SQ FT)
  WATERW - WEIGHT OF THE WATER IN THE HEAT EXCHANGER (LBF)
  WHX - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
  WSTRC - CIRCULAR TOWERS STRUCTURAL WEIGHT (LBF)

  DATA PI /3.14156265/

  STRUCTURAL COSTS

  CSTRUC = ELENG * .2458 * PI/4 * DTOW**2 * ITOWN +
  $ (.00605 * ROOFL + .726)

  FOUNDATION COSTS

  CFND = .019 * (WHX + WATERW) + .82 * PI/4 * DTOW**2 * ITOWN

  STRUCTURAL WEIGHT OF COOLING TOWERS BASED ON 50.63/LB

  WSTRC = CSTRUC / .63

  STRUCTURAL COST TAKING INTO ACCOUNT DIRECT AND INDIRECT
  CONSTRUCTION COSTS.

  CSTRUC = CSTRUC * POHSTC
  RETURN
  END

```

SUBROUTINE SURCON (ISUR, KGA, LD, TLA, XNYS, ARPS, XNS, CONCS
 ,CONMAT, PCHOND)

```

C
C
5  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, 1975 TO CURRENT PRICES
C
10 C
C      DEFINITION OF VARIABLES
C
C      APCF - ACCESSORY COST CORRECTION FACTOR FOR THE CONDENSER
C      ADDER - INCREASES COST OF TUBING MATERIAL
C      ARPS - AREA PER SHELL OF THE CONDENSER (SQ FT)
15 C      AUXCST - AUXILIARY COST ($)
C      CFAC - LENGTH CORRECTION FACTOR (DIMENSIONLESS)
C      CONCS - CONDENSER COST ($)
C      CONMAT - VARIABLE FOR CONDENSER MATERIAL (DIMENSIONLESS)
C      DQCT - QUANTITY DISCOUNT FOR TUBES (DIMENSIONLESS)
20 C      ERTOST - ERECTION COST ($/SQ FT)
C      F - TUBING LENGTH PENALTY (DIMENSIONLESS)
C      FETOST - FIELD ERECTION COST ($/SQ FT)
C      FFD - TUBE SIZE FACTOR (DIMENSIONLESS)
C      PCHOND - INDIRECT COST FACTOR FOR THE TUBE, SHELL, AND
25 C      FIELD ERECTION COSTS (DIMENSIONLESS)
C      SHLCST - SHELL COST FOR THE CONDENSER ($)
C      TOSTIP - TOTAL COST OF TUBING MATERIAL ($/FT)
C      WT - WEIGHT OF TOTAL AMOUNT OF TUBES IN THE CONDENSER
30 C      (LBS)
C      XNS - NUMBER OF SHELLS IN THE CONDENSER (DIMENSIONLESS)
C      XNYS - NUMBER OF TUBES PER SHELL (DIMENSIONLESS)
C
C      DEFINITION OF ARRAYS.
C
35 C      TUBMA - TUBE MATERIAL NAMES)
C      CL - TUBE FIXED COSTS ($)
C      CLM - TUBE MATERIAL COSTS ($/LBM)
C      GGLI - DENSITY OF TUBE MATERIALS (LB/MCU IN)
40 C      GGLI - TUBE GAGE (DIMENSIONLESS)
C      THKLIN - THICKNESS OF TUBE (IN)
C      ONLINE - COMMON DIAMETERS OF TUBES (IN)
C
C      LOGICAL FIRST
C      DIMENSION SCC1(4), SCC2(6)
45 C      DIMENSION TUBMA(10), CL(10), CLM(10), PDEL(10), GGLI(7),
C      * THKLIN(7), ONLINE(6), FF(10,7)
C      COMMON /RPP13/ TUBCST,SHLCST,FETOST,CONBA7
C
C      TUBING MATERIALS, COSTS, AND DENSITY
50 C
C      DATA CL / 0.00, 0.00, 0.00, 0.08, 0.04, 0.38, 0.12, 0.20, 0.15,
C      * 0.10 /
C      DATA CLM / 1.30, 1.52, 1.83, 1.40, 1.36, 0.44, 0.32, 1.63, 7.50,
C      * 7.00 /
55 C      DATA PDEL / 0.308, 0.323, 0.323, 0.0975, 0.0975, 0.284, 0.284, .290
C      * 0.163, 0.163 /
C      DATA TUBMA / "ADIRALTY ", "CU-10 NI ", "CU-30 NI ",

```



```

*          "6061-T5 AL", "3003-H14 AL", "STEEL SEAM",
*          "STEEL WELD", "304 S/S WE", "TITANIUM 1",
*          "TITANIUM 2" /
60      C
      C          STANDARD TUBE DIAMETERS, GAGE, AND THICKNESSES
      C
      DATA ONLINE / 0.625, 0.750, 0.875, 1.000, 1.125, 1.250 /
85      DATA GAGLI / 12., 14., 16., 18., 20., 22., 24. /
      DATA THKLIN / .109, .083, .063, .049, .035, .028, .021 /

      C
      C          TUBING LENGTH PENALTIES
      C
70      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, 0.07, 0.00, 0.00, 0.07, 0.08, 0.09 /

      C
85      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
80      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
85      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 /

90      C          CONSTANTS FOR COST EQUATION FOR BASIC CONDENSER SHELL AS A
      C          FUNCTION OF TUBE O.D. (UPDATED FEBRUARY, 1976)
      C
      DATA SOC1 / 0.00000, 7.69583, 9.805882, 10.33636, 12.954545,
      C          15.22326 /
95      DATA SOC2 / 0.0000, 0.7125, 0.0, 102154.71, 102181.92, 103272.73,
      C          102237.21 /

      C
      C          COST OF FIELD ERECTION AND TUBING PER SQUARE FOOT OF
      C          SURFACE AREA IS BASED UPON INFORMATION SUPPLIED BY
100      C          WESTINGHOUSE COMPANY AND AVERAGE WAGE LABOR RATES OBTAINED
      C          FROM JUNE 1975 CONSTRUCTION REVIEW

      DATA ENTOST / 2.50 /

105      DATA FIRST/.TRUE./

      C
      C          DEFINING THE CASE UNDER CONSIDERATION
      C
110      IF(.NOT.FIRST) GOTO 55
      LFLAG=0
      DO 10 I = 1, 10
      ITURMA = 1
      IF(CONCAT.EQ.TURMA(I)) GO TO 55
10      CONTINUE

```

```

715      WRITE(2,11)
          LFLAG=1
          11 FORMAT(5X,"NO MATCH FOR CONDENSER TUBE MATERIAL")
          IF(LFL/G.NE.0) STOP
720      55 CONTINUE
          FIRST = .FALSE.

C
C
C          DETERMINE TOTAL LENGTH OF TUBING REQUIRED AND CORRESPONDING
C          QUANTITY DISCOUNT
725      C
          TOTLT=TLA*XNTS*XNG
C
          IF(TOTLT-50000.)102,101,101
730      101 DSCT=A.04
          GO TO 103
          102 IF(TOTLT-30000.)105,104,104
735      104 DSCT=B.02
          GO TO 103
          105 DSCT=A.
740      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
745      C
          109 WT = 10. * 3.14159 * ROEL(ITUBMA) * (COLINE(10)-TRKLIN(KGA))
          * THKLIN(KGA)
          TCSTPF = CLW(ITUBMA)*WT + CL(ITUBMA)
          TCSTPF = TCSTPF*F + ADDER
750      C
          C          TUBE COST ARE F.O.B. COSTS. 1.11 ACCOUNTS FOR PURCHASING
          C          AND SHIPPING
          C
          TUBCST = TOTLT * TCSTPF * (1.11-DSCT)
755      TUBCST = TUBCST * POHCNO

C
C          DETERMINE SHELL COST INCLUDING LENGTH, MULTIPRESSURE, AND
C          ACCESSORY COST CORRECTIONS, AS APPROPRIATE
760      C
          CFAC = 0.016*TLA + 0.53
          GO TO(100,111,112,113),ISUR
          111 CFAC=CFAC+0.03
          GO TO 100
          112 CFAC=CFAC+0.16
          GO TO 100
765      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
          ACCF = (0.116*ALOG(XNTS) - 0.485)*FOD
770

```

```

      IF (TU=MA .EQ. 2) ACCF = (0.239*ALOG(XNTS) - 1.414)*FOD
C
C      THE CONDENSER SHELL COSTS WERE OBTAINED FROM WESTINGHOUSE'S
775 C      1973 PRICE LISTING 1312
C
      AUXCST = 0.45*ARPS*XNS
      BSHCST = (SCC1(LD)*XNTS + SCC2(LD))
80 C      SHLCST = BSHCST*(CFAC+ACCF)*XNS + AUXCST
      SHLCST = SHLCST + POHCND
C
C      DETERMINE COST OF FIELD ERECTION AND TUBING
C
85 C      FETCST = ERTCST*ARPS*XNS
      FETCST = FETCST + POHCND
C
C      DETERMINE TOTAL COST OF CONDENSER
C
90 C      CONCST = TURCST + SHLCST + FETCST
      CONBAT = 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      NT      - NUMBER OF DATA POINTS
      C      TLA      - DEPENDENT VARIABLE
      C      X        - INDEPENDENT VARIABLE
      C      XT       - INDEPENDENT VARIABLE ARRAY
      C      YT       - DEPENDENT VARIABLE ARRAY

```

```

      C
      C      DIMENSION XT(NT),YT(NT)

```

```

      C
      C      DETERMINE IF INDEPENDENT VARIABLE IS WITHIN RANGE OF
      C      TABULATED DATA

```

```

      C
      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
      C      100 IF(XT(1)-XT(2))102,102,103

```

```

      C
      C      DETERMINE POSITION OF INDEPENDENT VARIABLE IN ASCENDING
      C      ARRAY

```

```

      C
      C      102 DO 99 I=1,NT
      C      IF(X-XT(I))105,104,99
      C      99 CONTINUE

```

```

      C
      C      DETERMINE POSITION OF INDEPENDENT VARIABLE IN DESCENDING
      C      ARRAY

```

```

      C
      C      103 DO 98 I=1,NT
      C      IF(X-XT(I))98,104,105
      C      98 CONTINUE

```

```

      C
      C      IF INDEPENDENT VARIABLE IS EQUAL TO TABULATED VALUE, SET
      C      FUNCTION EQUAL TO CORRESPONDING VALUE OF DEPENDENT VARIABLE

```

```

      C
      C      104 TLU=YT(I)

```

```

      C
      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
      C      105 IF(I=2)106,106,107
      C      106 I=I+1
      C      GO TO 108
      C      107 IF(I=NT)108,109,109
      C      109 I=I-1

```

```

      C
      C      DETERMINE FUNCTION VALUE USING FOUR-POINT LAGRANGIAN

```

```

C      INTERPOLATION
C
60      108 X1=XT(I-2)
          X2=XT(I-1)
          X3=XT(I)
          X4=XT(I+1)
C
65      TLJ=(Y-X2)*(X-X3)*(X-X4)/((X1-X2)*(X1-X3)*(X1-X4))*YT(I-2)
          $ +(Y-X1)*(X-X3)*(X-X4)/((X2-X1)*(X2-X3)*(X2-X4))*YT(I-1)
          $ +(Y-X1)*(X-X2)*(X-X4)/((X3-X1)*(X3-X2)*(X3-X4))*YT(I)
          $ +(Y-X1)*(X-X2)*(X-X3)/((X4-X1)*(X4-X2)*(X4-X3))*YT(I+1)
C
70      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,3H X =,F15.5,5X,7HXT(1) =,F15.5,5X,7HYT(1) =,F15.5)
75      C
          STOP
          END

```

SUBROUTINE VARIT(TA, TPER, PCST, KALL, CLSUM, FCSUM)

C
 C
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 5 C
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 10 C
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 15 C
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 45 C
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 50 C
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 55 C
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 C

SUBROUTINE VARIT CALCULATES THE PERFORMANCE OF THE POWER
 PLANT AND DRY COOLING TOWER UNDER THE ASSUMPTION THAT THE
 AIR SIDE HEAT TRANSFER COEFFICIENTS AND AIR VELOCITY
 THROUGH THE HEAT EXCHANGER TUBES ARE UNCHANGED. THIS IS
 DONE FOR THE CASE HAVING THE MINIMUM INCREMENTAL COST.

DEFINITION OF VARIABLES

CAPCHG - GAS TURBINE CAPITAL COST (\$/MW)
 CPOST - COST OF GAS TURBINE (\$)
 CAPF - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER
 (PERCENT)
 CCOOL - COST OF THE DRY COOLING TOWERS (\$)
 CLAND - COST OF LAND TAKEN UP BY THE DRY COOLING TOWERS (\$)
 CONRAD - COST OF SURFACE CONDENSER (\$)
 CDSM - COST OF MAINTAINING THE DRY COOLING TOWER (\$)
 CPIP - COST OF PIPING AND PUMPING SYSTEMS (\$)
 20 COTOL - COST OF MAKE-UP POWER BY GAS TURBINES AT EACH
 AMBIENT AIR TEMPERATURE (MILLS/KW-HR)
 DFLEO - INCREMENTAL FUEL COST FOR STEAM SUPPLY SYSTEM
 (MILLS/KW-HR)
 EFF1 - HEAT EXCHANGER EFFECTIVENESS OF DRY COOLING
 25 TOWERS (DIMENSIONLESS)
 EFFO1 - CONDENSER EFFECTIVENESS
 FACS - FUEL COST FOR THE STEAM SUPPLY SYSTEM (MILLS/BTU)
 FCR - FIXED CHARGE RATE ON CAPITAL PER YEAR (PERCENT)
 FROW1 - POWER REQUIREMENTS OF FAN SYSTEM (KW)
 30 HRFAC1 - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
 PRESSURE (DIMENSIONLESS)
 HRFAC2S - HEAT RATE FACTOR OF STEAM TURBINE AT DESIGN
 CONDITIONS OF POWER PLANT (DIMENSIONLESS)
 HRFAC4 - HEAT RATE FACTOR OF STEAM TURBINE AT A PARTICULAR
 35 AMBIENT AIR TEMPERATURE (DIMENSIONLESS)
 P - BACK PRESSURE OF STEAM TURBINE (IN. HG.)
 TACS - INCREMENTAL POWER PRODUCTION COST OF THE DRY
 COOLED POWER PLANT FOR A PARTICULAR AMBIENT AIR
 40 TEMPERATURE (MILLS/KW-HR)
 POUT - POWER OUTPUT OF PLANT AT A PARTICULAR AMBIENT AIR
 TEMPERATURE (MW)
 PROW1 - POWER REQUIREMENTS OF THE PIPING SYSTEM (KW)
 45 S613 - POWER OUTPUT OF STEAM TURBINE AT RATED BACK
 PRESSURE TO PRODUCE REQUIRED OUTPUT OF PLANT
 OF PLANT AT DESIGN CONDITIONS (MW)
 PTOTAL - POWER OUTPUT OF PLANT AT SPECIFIED AMBIENT AIR
 TEMPERATURE (MW)
 P-COS - COST OF FUEL FOR GAS TURBINE (MILLS/KW-HR)
 50 QIN1 - THERMAL ENERGY OUTPUT OF STEAM SUPPLY SYSTEM AT
 RATED BACK PRESSURE OF TURBINE (BTU/HR)
 QREJ - HEAT REJECTED AT A SPECIFIED AMBIENT AIR TEMPERA-
 TURE (BTU/HR)
 RANGE - TEMPERATURE RANGE OF WATER PASSING THROUGH THE
 HEAT EXCHANGER (DEG F)
 55 SPEC1 - INCREMENTAL COST OF PLANT DUE TO SCALE-UP OF STEAM
 SUPPLY SYSTEM AND THE SCALE UP OF THE PLANT TO
 TAKE INTO ACCOUNT FOR FAN AND PUMP POWER

```

      C      REQUIREMENTS (3)
      C      TA      - AMBIENT AIR TEMPERATURE (DEG F)
60      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
65      C      PLANT DESIGN CONDITIONS (DIMENSIONLESS)
      C      TEFF4   - THERMAL EFFICIENCY OF STEAM TURBINE ASSOCIATED
      C      WITH A PARTICULAR AMBIENT AIR TEMPERATURE
      C      (DIMENSIONLESS)
      C      TPER    - PERCENT OF TIME AN AMBIENT TEMPERATURE OCCURS
70      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
75      C      TTD     - TERMINAL TEMPERATURE DIFFERENCE OF SURFACE CONDENS-
      C      ER AT DESIGN CONDITIONS (DEG F)
      C      TE      - EXIT TEMPERATURE OF STEAM TURBINE (DEG F)
      C      VOST    - TOTAL INCREMENTAL COST OF DRY COOLING (MILLS/KW-HR)
      C      WS      - MASS FLOW RATE OF WATER THROUGH THE HEAT EXCHANGER
80      C      (LBM/HR)
      C      POST    - 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)
85      C
      LOGICAL FIRST, FXTMP
      COMMON
      $ ASTR, ALPHA
      $ CAPF, C5SPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
90      $ CRU, CTUR3, CDANG, CLUVR, CHAIB, CVM
      $ DANGLE, OFIN, DEEPL, DESVEL
      $ EFPF
      $ FOR, FIRST, FIXL, FCO3, FPHX, FXTMP
      $ GTEFF
95      $ HXNP, HPOST
      $ ITMAX, ITMIN
      $ JCONR
      $ KCONV, KALEXT
      $ MXEXT
100      $ NTICL(2), NTA
      COMMON
      $ ORR
      $ PSIZE, PER, PWOS, PLANC, PFACT, POMDPL
      $ POHBF, POHFAN, POHLEC, POHCIR, POHCND, PO4STC, POHSC
105      $ OREU, OREDUCE
      $ PRP, REDUCE, ROOFL, RFIX
      $ SIGMA, SAAF
      $ TD, TPO(4), TEFF, TLIM, THFIV, TLPRA, TFIX
      $ TCD, TW
110      $ UCS, UWS
      $ VAS(4)
      $ W=V
      $ XDEPA, XW, XD
      COMMON /SCALER/HRFAC1, ATUB, CPRA, SSCD, PLANC1, CASSS1,

```

```

115      $ GAIR, FAIR, HPAIR, HPWAT, PLANCT1
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      $ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
      $ PPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
120      $ REWAT, NM, NT, NP, PLANC2, PSIZ12, SP85, SW4, SW3,
      $ SPC, PTOT1, PLANC3, SAFRON, AAIR, YFP, SPC5, PSIZ13, WT2,
      $ RPP, NWD, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX
      $ , TLAX, UCON, PMOST, FMOST, FHACC, EFFC, CH, CA, CS
      $ , CLIC, CFC, CPOC, FITC, CSC, CEPRE, DELPI, AST, OLDOST
      $ , CAPST, XNFAN, BLDANG, CPLEN, DPFE1, WHX, WTTUR, ADIA, ABLN
125      $ , WTHR, WTERF, STRUC, CPERF, HPERF, TOTCF, TP, EFFIN, ANTU
      $ , AIRFF, WATER, XMOD, TCIPF, FOCPE, FMTRC, ACCITP, ADJTP
      $ , ACTBD, ADJBD, ACTVH, ADJVH, ADJPP, THPAIR, TCTF, AFCST
      $ , CSRI, WATER, WSTRCT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      $ , ATURC, CSTLV, CSTHS, CYLRNG, CFANEL
130      COMMON /STNK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
      $ QIN1, CLAN1, REA11, Z1, HRFAC2S, W41, U1, DEPW1, PPOW1,
      $ FROM1, DEFC1, WIDT1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,
      $ REW1, NM1, NT1, NP1, ZPLNC2, ZSIZ12, ZSP85, SW41, SW31,
      $ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
135      $ RPPMIN, W2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
      $ , TL1, UCON1, PMOS1, FMOS1, FBAC1, EFFC1, CH1, CA1, CS1
      $ , CLIC1, CFC1, CPOC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLDOS1
      $ , CAPST1, XNFAN1, BLDANG1, CPLEN1, DPFE1, WH1, WTTU1, ADI1, ABL1
      $ , WTH1, WTER1, STRUC1, CPERF1, HPERF1, TOTCF1, TP1, EFFIN1, ANTU1
140      $ , AIRFF1, WATER1, XMOD1, TCIPF1, FOCPE1, FMTRC1, ACCITP1, ADJTP1
      $ , ACTBD1, ADJBD1, ACTV1, ADJV1, ADJPP1, THPAI1, TCTF1, AFCST1
      $ , CSRI, WATER1, WSTRCT1, CFOUND1, HUBDI1, TOWLE1, NUMTO1, CTOWD1
      $ , ATURC1, CSTLV1, CSTHS1, CYLRN1, CFANEL
      COMMON /TINE/ XNS, TTD, TLA, XNTS, ARPS

145      C
      C      THERMAL EFFICIENCY OF TURBINE AT THE DESIGN POINT OF THE
      C      PLANT
      C
      TEFF3=TEFF/HRFA2S

150      C
      C      THERMAL EFFICIENCY OF TURBINE AT THE RATED BACK PRESSURE
      C
      TEFF1=TEFF/HRFAC1

155      C
      C      HEAT SUPPLIED BY THE STEAM SUPPLY SYSTEM
      C
      QIN1=3413*E*3.6 SPS13/TEFF1
      T1=140.

160      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

165      C
      C      ITERATIVE LOOP FOR CALCULATING THE EXIT TEMPERATURE OF THE
      C      STEAM TURBINE AS A FUNCTION OF THE AMBIENT AIR TEMPERATURE.
      C
      C
170      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
775  RANGE=QREJ/(WB1*(1.+YFPMIN))
C
C      TERMINAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND THE
C      STEAM OF THE SURFACE CONDENSER
C      TTDP= RANGE/EFFC1- RANGE
C
C      EXIT TEMPERATURE OF THE STEAM TURBINE ON PREVIOUS ESTIMATE
780  IF (VAR(3).GT.1.) GO TO 2
C      T11 = RANGE/EFF1 + TA + TTDP
C      GO TO 1
785  2 T11 = RANGE*VAR(3)/EFF1 + TA + TTDP
C
C      CONVERGENCE CRITERION FOR EXIT TEMPERATURE OF TURBINE
C      3 IF (.NOT. EXTEND .AND. (T11-T1)**2 .LT. .001) GOTO 4
C      CVT = ABS( (T11-T1) / T11)
C      IF (EXTEND .AND. CVT .LT. 0.0001) GOTO 4
790  T1=T11
C      GO TO 1
C
C      TOTAL POWER OUTPUT OF TURBINE AT THE PARTICULAR AMBIENT
C      AIR TEMPERATURE
795  4 PTOTAL = QIN1*TEFF4/3413.E+3
C
C      POWER OUTPUT FROM PLANT AT THE PARTICULAR AMBIENT AIR
C      TEMPERATURE
800  PGEN=PTOTAL-PPW1/1000. - FPW1/1000.
C      TEFFD=TEFF4
C      IF (PGEN.LE.PSIZE) GOTO 5
C
C      COST OF FUEL FOR GAS TURBINE MAKE UP POWER
805  CSTOL=(PSIZE-PGEN)/PSIZE*PWCOS
C      TEFFD=TEFF3
C      GO TO 1
810  5 CSTOL=0
C
C      INCREMENTAL COST OF FUEL FOR STEAM SUPPLY SYSTEM DUE TO STEAM
C      TURBINE OPERATING AT OFF DESIGN CONDITIONS
C
815  6 DELFC=PCOS*3413.E+3*((1.+YFPMIN)/TEFFD-1./TEFF)
C
C      CAPITAL COST OF GAS TURBINE FOR MAKE UP POWER
C
C
820  IF (KAIL.NE.1) GO TO 10
C      CAPCST=0.0
C      IF (PSIZE.LE.PGEN) GO TO 10
C      CAPCST=CAPCHG*(PSIZE-PGEN)
825  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)

```

```

235      C      TCOS = (CCOS1+SPCD1+CLAN1+CPIP1+CONBA1+CAPCST)*FCR/(PSIZE*CAPF*
      $ 8750.) + COSM1+DELFC+CSTCL
      POST=TPER+TCOS
      CLSUM = CLSUM + CSTCL * TPER
      FCSUM = FCSUM + DELFC * TPER
235      935 FORMAT(T2,F6.1, T10,F6.1, T13,F6.2, T25,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, T100,F7.3, T115,G11.5)
239      239 FORMAT(T2,"TAI,TAO,TWI,TWO,T11,RANGE,TTD",7G15.6)
240      300 CONTINUE

245      C      TEMPERATURES OF FLUIDS ENTERING AND EXITING THE HEAT
      C      EXCHANGER
      C
      C      TEMPERATURE OF AIR ENTERING THE HEAT EXCHANGER
245      TAI = TA
      C
      C      TEMPERATURE OF AIR EXITING THE HEAT EXCHANGER
      C      TAO = TAI + VAR(3) * RANGE
250      C      TEMPERATURE OF WATER EXITING THE HEAT EXCHANGER
      C      TWO = T11 - RANGE - TTD
      C
      C      TEMPERATURE OF WATER ENTERING THE HEAT EXCHANGER
255      TWI = RANGE * TWO
      C
      C      THE LOG MEAN TEMPERATURE DIFFERENCE OF THE FLUIDS IN THE
      C      HEAT EXCHANGER
      C
      C      HXLMTD = 1.E+30
260      TESTR = (TWI-TAO) / (TWO-TAI)
      IF (TESTR .GT. 0.9) GOTO 920
      WRITE(4,239) TAI,TAO,TWI,TWO,T11,RANGE,TTD
      GOTO 930
265      920 IF (TESTR .EQ. 1.0) HXLMTD = TWI-TAO
      IF (TESTR .NE. 1.0) HXLMTD =
      * ((TWI-TAO) - (TWO-TAI)) / A.LOG((TWI-TAO) / (TWO-TAI))
270      830 CONTINUE
      C
      C      INITIAL TEMPERATURE DIFFERENCE BETWEEN THE WATER AND AIR IN
      C      THE HEAT EXCHANGER
      C      HXIID = TWI - TAI
      C
      C      PRINTOUT OF HEAT EXCHANGER PERFORMANCE PARAMETERS
275      WRITE(4,235) TA
      $,T1
      $,P
      $,HREFAC
      $,RANGE
      $,TTD
280      $,HXLMTD
      $,HXIID
      $,PCEN
      $,DELFC
      $,CSTCL
285      $,TCOS

```

SUBROUTINE VARIT 74/74 OPT=1

FTN 4.2+74351

12/21/76

S,TPER = 100.
S,POST
RETURN
END

SUBROUTINE XTEND(L)

C
C
C

THIS ROUTINE CHECKS EXTREME VALUES AT MINIMAL COST POINT.

```

5      DIMENSION TTRY(2),RTRY(2),CTRY(2),ATRY(2),WTRY(2)
      COMMON /SINK/ VAR(5), CPLV1, CPIP1, CCOS1, W31, COSM1, EFF1,
      $ CIL1, CLAN1, REA11, Z1,HRFA2S, W41, U1, DEPW1, PPOW1,
      $ PPOW1, DEFC1, WIDT1, ELN1, VAIR1, VWAT1, HI1, HO1, T41,
      $ REWAT1, NW1, NT1, NP1,ZPLNC2,ZSIZ12, ZSPBP, SW41, SW31,
15     $ SPC1, PTOT1,PLNCB1, AFRO1, AAIR1,YEPMIN, SPCOT, SPS13,WT2MIN,
      $ RPTMIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBAS, XNTS1, VELD1
      $ , TL1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CA1, CS1
      $ , CLTC1, CFC1, CPCC1,FITC1, CSC1,CEPRE1,DEPIPT, AST1,OLDOS1
      $,CAPCS1,XNEAN1,BLDANI,CPLEN1,DPFEL1, WH1, WTTU1, ADI1, ABL1
15     $, WTHA1, WTER1,STRUCL,CFPERF1,HPERF1,TOTCF1, TPT,EFFIN1, ANTU1
      $, AIRFE1, WATER1, XNMOD1, TOTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
      $, ACTRD1, ADURD1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1
      $, CSRP, WATER1, WSTRC1, CFOUND1, HUBD1, TOWLE1, NUMTOL, CTOWD1
      $,ATURC1, CSTLV1, CSTHS1, CYLRN1, CFANEL
20     COMMON /SUPPLY/ VAL(5), CPLV, CPIP, CCOS, W3, COSM, EFF,
      $ CIL, CLAN, REAIR, Z,HRFAC2, W4, U, DELPW, PPOW,
      $ PPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
      $ DEWAT, NW, NT, NP,PLANC2,PSIZ12, SPBP, SW4, SW3,
      $ SSC,PTOTAL,PLANC3,SAFRON, AAIR, YEP, SPCB,PSIZ13, WT2,
25     $ B2, NW2, TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELDX
      $ , TLX, UCON, PMCS1, FMCS1, FBACC, EFFC, CH, CA, CS
      $ , CLTC, CFC, CPCC, FITC, CSC,CEPRE,DELPIT, AST,OLDOST
      $,CAPCS1,XNEAN,BLDANG, CPLEN,DPFEL, WHX, WTTUB, ADIA, ABLN
      $, WTHAP, WTERM,STRUCC,CFPERF,HPERF, TOTCF, TPT, EFFIN, ANTU
30     $, AIRFE, WATER, XNMOD, TOTPF, FDCPF, FMTRC, ACTTP, ADJTP
      $, ACTRD, ADURD, ACTVH, ADJVH, ADJPP, THPA1, TCTF, AFCST
      $, CSRP, WATERM, WSTRCT, CFOUND, HUBDIA, TOWLEN, NUMTON, CTOWD
      $,ATURC, CSTLVR, CSTHS, CYLRNG, CFANEL
      LOGICAL FIRST, EXTEND
35     COMMON
      $ APT, ALPHA
      $ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAP
      $ ,CBJ, CTURB, CDANG, CLUVR, CHA1S, CVM
      $ ,DANGIE, DFIN, DEEPL, DESVEL
40     $ ,EFFP
      $ ,FCR, FIRST, FIXL, FCO5, FFHX, EXTEND
      $ ,GREFP
      $ ,HXNP, HPCST
      $ ,ITMA, ITMIN
45     $ ,KCON,
      $ ,KCON, KALEXT
      $ ,MXEXT
      $ ,NTJCL(2), NTA
      COMMON
50     $ DDR
      $ ,PSIZE, PER, PMCOS, PLANC, PFACT, POMDPL
      $ ,POHAF, POHAF, POHLEC, POHCIR, POHCND, POHSTC, POMHCL
      $ ,PREU, PREUCE
      $ ,REP, REDUCE, ROOFL, REIX
55     $ ,SIGMA, SAAF
      $ ,TD, TPD(4), TEPF, TLIV, THEIN, TLPRA, TPIX
      $ ,TCD, T4

```

```

      $ .UCS, .UWS
      $ .VAS(5)
60      $ .WFSV
      $ .XDEPA, .XW, .XD
      COMMON /LACALL/ SRN
      COMMON /TINE/ XNS,TTD,TLA,XNTS,4RPS
      TTRY(1)=VAR(1)+20.
65      IF (TTRY(1).LE.0.0) TTRY(1)=10.
      TTRY(2)=VAR(1)+20.
      IF (TTRY(2).GE.170.) TTRY(2)=170.
      IF (EXT=MP) TTRY(1) = TFIX
      IF (EXT=MP) TTRY(2) = TFIX
70      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.
75      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)
80      RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
      IF (EXT=MP) RTRY(1) = RFIX
      IF (EXT=MP) RTRY(2) = RFIX
      SRN="//XTEND=1/"
      DO 3 IR=1,2
85      CALL CALC(TTRY(IR),RTRY(IR),VAR(3),VAR(4),VAR(5),1)
      IF (KCONV.EQ.1) GO TO 3
      C
      IF (DELEA.LT.XDEPA) GO TO 3
      IF (DELEA.LE.XDEPA) GO TO 3
      IF (TCOS.GT..99*TCOS1) GO TO 3
90      TCOS1=TCOS
      VAS(1)=TTRY(1)
      VAS(3)=VAR(3)
      VAS(4)=VAR(4)
      VAS(5)=VAR(5)
95      L=1
      3 CONTINUE
      DO 10 I=1,2
      RANGL=(VAR(1)-TTD-TD)*(1.-EXP(-CTRY(I)))/CTRY(I)
100      RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
      IF (EXT=MP) RTRY(1) = RFIX
      IF (EXT=MP) RTRY(2) = RFIX
      SRN="//XTEND=3/"
      DO 10 IR=1,2
105      CALL CALC(VAR(1),RTRY(IR),CTRY(IR),VAR(4),VAR(5),I)
      IF (KCONV.EQ.1) GO TO 10
      C
      IF (DELEA.LT.XDEPA) GO TO 10
      IF (DELEA.LE.XDEPA) GO TO 10
      IF (TCOS.GT..99*TCOS1) GO TO 10
110      TCOS1=TCOS
      VAS(1)=VAR(1)
      VAS(3)=CTRY(I)
      VAS(4)=VAR(4)
      VAS(5)=VAR(5)

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115      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
120      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
125      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
135      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)
140      VAS(4)=VAR(4)
      VAS(5)=WTRY(I)
      L=1
12      CONTINUE
      IF(L.EQ.1) WRITE(6,13)
145      13 FORMAT(" XTEND CALLED, AND CHANGE MADE")
      IF (L.EQ. 1) KALEXT = KALEXT + 1
      IF (KALEXT .GT. MXEXT) STOP "CALLS TO S.P. XTEND EXCEED MXEXT"
      RETURN
      END

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