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

Volume IV

January 1977

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

VOLUME IV

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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 G

AMMONIA VERSION OF THE BNW-I COMPUTER CODE

Figure G-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 G-1. Ammonia (NH_3) Circular Model Subroutine Linkages


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PROGRAM AMCIRC (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
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C
C      PROGRAM AMCIRC IS A PROGRAM WHICH DETERMINES THE OPTIMUM
C      DESIGN OF A DRY COOLED POWER PLANT WITH AMMONIA AS THE
5      C      INTERMEDIATE FLUID. THE OPTIMUM DESIGN IS DETERMINED BY
C      REPEATING THE DESIGN OF THE COOLING SYSTEM OVER A RANGE
C      OF DESIGN CONDITIONS IN ORDER TO FIND THE COOLING SYSTEM
C      WITH THE SMALLEST INCREMENTAL COST. THIS IS ACCOMPLISHED
C      BY VARYING FIVE PARAMETERS OF THE PLANT AND COOLING SYSTEM
10     C      OVER RANGES OF VALUES. THESE PARAMETERS ARE VARIED
C      SYSTEMATICALLY ACCORDING TO TECHNIQUES THAT PERFORM PATTERN
C      AND GRADIENT SEARCHES.
C      THE DRY COOLING SYSTEM OPTIMIZED BY PROGRAM AMCIRC IS
C      COMPOSED OF A CONDENSER/REBOILER (CONDENSATION OF STEAM
15     C      AND BOILING OF AMMONIA), PIPING SYSTEM (TRANSPORTS AMMONIA
C      VAPOR OUT AND AMMONIA LIQUID FROM THE DRY COOLING TOWERS),
C      AND CIRCULAR TOWER SYSTEM (VERTICAL ONE-PASS HEAT EXCHANGERS
C      SITUATED IN CIRCULAR CONFIGURATIONS WITH COCURRENT AMMONIA
C      FLOW IN THE TUBES OF THE HEAT EXCHANGER).
20     DIMENSION PCST(8)
C      LOGICAL FIRST, FXTMP
C      COMMON
C      $ AFTR, ALPHA, ANG(3)
C      $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2,CAP
25     $ ,CBU, CTURB, CDANG, CLUVR, CHALLS, CVM
C      $ ,DANGLE, DFIN, DEEPL, DECVEL, DESVEL
C      $ ,FFFR
C      $ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
C      $ ,GBEFF
30     $ ,HXNR, HPCST
C      $ ,ITMAX, ITMIN
C      $ ,JCONS
C      $ ,KCONV, KALEXT
C      $ ,MXEXT
35     $ ,NTUCAL(2), NTA
C      COMMON
C      $ ,ODRI
C      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
C      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCU
40     $ ,RRP, REDUCE, REDUCV, ROOFLL
C      $ ,QRED, QREDUCE, QREDUCV
C      $ ,SIGMAG, SAAT
C      $ ,TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
C      $ ,TOD, TW
45     $ ,UCS, UWS
C      $ ,WFM
C      $ ,VAG(5)
C      $ ,XDEPA, XW, XD
C      COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
50     $ ,Q1V1, CLAN1, REA11, Z1, HFA2S, W41, UI, DEPW1, PPOW1,
C      $ ,FROM1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, HI1, HD1, T41,
C      $ ,REWA1, NW1, VI1, NP1, ZPLNC2, ZSIZ12, ZSPBD, SW41, SW31,
C      $ ,SP1, PTOT1, PLN131, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
C      $ ,B2MIN, N2MIN, TC1, DEPA1, DPWT1, DPWC1, CONBA1, XN1S1, VELO1
55     $ ,TLA1, UCON1, PNC1, FMC1, FBAC1, EFFC1, CHI, CA1, CS1
C      $ ,CLT1, CFC1, CPOC1, FITC1, CSC1, CEPRE1, DEPIP1, AST1, OLDCS1
C      $ ,CAPCS1, XNFAN1, BLDAN1, CPLEN1, DPFE1, WH1, HTTU1, AD11, ABL1

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60      S, WTHD1, WTER1, STRUC1, CFMPF1, HPPF1, TOTCF1, TPI, EFFIN1, ANTU1
      S, AIRFF1, WATFF1, XNMOO1, TCTPF1, FDCPF1, FMTRC1, ACCTP1, ADJTP1
      S, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1
      S, CSRI, WATER1, WSTRC1, CFOWN1, HUBD11, TOWLE1, NUMTOL, CTOWD1
      S, SQRJ1, SQRJ31, ATUBC1, CBA1, TT011, TT021, DELPS1, CSTLV1
      S, CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPC1, RPTPL1, SEPC1
      COMMON /SCALER/HRFAC1, ATUB, OPERA, SSCD, PLANC1, CASS1,
65      S, GAIR, FAIR, HPAIR, HPWAT, WLRT, PLANC1
      COMMON /SUPPLY/ VAL(5), CPLN, CRIP, CCOS, W3, COSM, EFF,
      S, QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
      S, FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
      S, REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
70      S, SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
      S, BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX
      S, TLAX, UCON, PMOST, FMCST, FBACC, EFFC, CH, CA, CS
      S, CLTC, CFC, CRCC, FITC, CSC, CEPREP, DELPIP, AST, OLDGST
75      S, CAPOST, XNFAN, OLDANG, CPEN, DPFEI, WHX, ATTUB, ADIA, ABLN
      S, WTHDR, WTERW, STRUC1, CFPERF, HOPERF, TOTCF, TPC, EFFIN, ANTU
      S, AIRFF, WATFF, XNMOD, TCTPF, FDCPF, FMTRC, ACCTP, ADJTP
      S, ACTRPD, ADJRPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
      S, CSRI, WATERW, WSTRCT, CFOWN, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S, SQRJ, SQRJ3, ATUBC, CBA, TT01, TT02, DELPS, CSTLVR
80      S, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
      COMMON /VARVAR/ TPER(16), TA(15)
      COMMON /INDIS/ DIST
      COMMON /INEX/ XNS, TLA, XNTS, ARPS, TT02CE, LINOR, XNP, XQUALY
81      FORMAT('ITD USED IN THE FOLLOWING CALCULATIONS IS =F8.3')
85      930 FORMAT(T02,"AMBIENT TURBINE", T29,"HEAT", T83,"COST TO",
      S, T93,"POWER COST", T105,"PCT TIME", T115,"PORTION OF")
      931 FORMAT(T04,"TEMP", T10,"OUTLET", T20,"BACK", T28,"RATE", T50,"HX"
      S, T57,"HX", T64,"POWER", T72,"CHANGE IN", T83,"REPLACE",
      S, T93,"AT AMBIENT", T104,"AT AMBIENT", T115,"INCREMENTAL")
90      932 FORMAT(T11,"TEMP", T18,"PRESSURE", T27,"FACTOR", T35,"RANGE"
      S, T42,"ITD", T49,"LMTD", T57,"ITD", T62,"GENERATED"
      S, T72,"FUEL COST", T83,"LOST CAP", T95,"TEMP", T106,"TEMP"
      S, T115,"POWER COST")
93      933 FORMAT(T02,T31(" "), T9," ", T17," ", T26," ", T33," ", T40," "
      S, T47," ", T54," ", T61," ", T71," ", T81," ", T92," ", T103," "
      S, T114," ")
94      934 FORMAT(T03,"DEG F", T11,"DEG F", T19,"IN. HG", T35,"DEG F"
      S, T41,"DEG F", T48,"DEG F", T56,"DEG F", T62,"MEGAWATTS"
      S, T72,"MILLS/KWH", T82,"MILLS/KWH", T93,"MILLS/KWH"
      S, T105,"PERCENT", T115,"MILLS/KWH")
100      944 FORMAT(140,T91,"FINAL INCREMENTAL COST",G11.5)
      945 FORMAT(140,T94,"CAPACITY CHARGE $",G15.0)
      FIRST=.TRUE.

C
C      READ IN THE EXTERNALLY FIXED VARIABLES OF THE AMMONIA
C      DRY COOLING TOWER SYSTEM AND THE INITIAL STARTING POINT FOR
C      THE OPTIMIZATION ROUTINE. A DESCRIPTION OF THE INPUT CARDS
C      IS GIVEN IN SUBROUTINE SETUP
C
110      CALLI SETUP(TSTAR,TEND)

C
C      INPUT SUMMARY AND CASE DESCRIPTION
C
      CALLI INPSUM

```

```

115      DO 7 IS=1,5
          7 VAR(IS)=0.0
          TD=ISTAR
          1 WRITE(5,81)TD
            K=4
120      C
          C      SCALE UP THE STEAM SUPPLY SYSTEM OF THE POWER PLANT BECAUSE
          C      OF OFF-RATING CONDITIONS
          C
          C      CALLI SRSCALE
125      C
          C      COARSE PATTERN SEARCH FOR OPTIMUM POINT
          C
          C      4 CALLI SHOT(1)
130      C
          C      IF LOWEST COST COOLING SYSTEM HAS INCREMENTAL COST ABOVE
          C      ZERO GO TO 5 IF IT IS LESS THAN ZERO REDUCE FRONTAL AREA
          C      OF THE HEAT EXCHANGER BY 75 PERCENT
          C
          C      IF(TCOS1.GT.0.0) GO TO 5
          C      VAS(4)=VAS(4)/4.
          C      GO TO 4
135      5 L=0
          C
          C      EXTEND THE AREA OF INVESTIGATION FOR THE FIVE VARIABLES
          C      IN THE SEARCH FOR ANOTHER MINIMUM
          C
          C      CALLI XTEND(L)
140      C
          C      IF A NEW MINIMUM HAS BEEN FOUND START WITH THE COARSE
          C      PATTERN SEARCH ONCE AGAIN
          C
          C      IF(L.EQ.1) GO TO 4
          C
          C      FINE PATTERN SEARCH FOR OPTIMUM POINT
150      C
          C      CALLI SHOT(2)
          C      2 JCONS=0
          C
          C      GRADIENT SEARCH FOR OPTIMUM POINT
155      C
          C      CALLI SERCH
          C
          C      IF SERCH HAS DETERMINED AN OPTIMUM GO TO 10 BUT IF IT
          C      HAS NOT FOUND AN OPTIMUM CALL SERCH AGAIN
160      C
          C      IF(JCONS.EQ.0) GO TO 10
          C      K=K+1
          C      IF(K.GT.0) GO TO 2
          C      10 CONTINUE
165      C
          C      PRINTOUT OF OPTIMUM DESIGN OF THE COOLING SYSTEM
          C
          C      CALLI OUT2(RBP,HRFAC1,SSCD,CASSS1,PLANCT1,PLANC1,C7URB,TCO)
          C      CALLI OUT4(1)
          C      CALLI OUT4(2)
          C      CALLI RPTHXD
170

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      CALL RPTHXC(AFR01)
      CALL RPTSUP(DESVELV, NUMT01, CTOWD1)
      CALL RETRET(CTOWD1, POHCIR, PSTAC1, PUFIT1, AMPCSI, RPTPL1,
175  * SEPCSI)
      CALL RORT2(EFFC1, CONMAT, CONMA2)
      CALL DPTFAN
      CALL EDRMSG(3)
      WRITE(4,100)
180 100 FORMAT(1H1)

      C
      C      PRINTOUT OF OPERATING PARAMETERS AND CONDITIONS OF THE
      C      PLANT VERSUS AMBIENT TEMPERATURE. ALSO PRINTOUT OF INCRE-
      C      MENTAL POWER PRODUCTION COSTS ATTRIBUTED TO EACH AMBIENT
185  C      TEMPERATURE AND THE TOTAL INCREMENTAL POWER PRODUCTION COSTS:
      C

      WRITE(4,930)
      WRITE(4,931)
      WRITE(4,932)
190  WRITE(4,933)
      WRITE(4,934)
      WRITE(4,935)
      CLSUM=0.0
      FCSUM=0.0
195  DO 3 I=1,NTA
      3 CALL VAPIT(TA(I), TPER(I), PCST(I), I, CLSUM, FCSUM)
      ACOS=0.0
      DO 4 I=1,NTA
      ACOS=ACOS+PCST(I)
200  4 CONTINUE
      WRITE(4,944) ACOS
      WRITE(4,945) CAPCSI
      TD=TD + 5.
      FIRST = .TRUE.
      KALEXT = 0
205  IF (TD.LE.TEND) GOTO 1
      5 CONTINUE

      C
      C      PRINTOUT OF THE CAPITAL AND UNIT ENERGY COSTS OF THE DRY
210  C      COOLING TOWER SYSTEM
      C

      CALL SUMCOS(FCR, PSIZE, CAPF, CCOS1, CPIP1, CONBA1, ATUBC1, CPLEN1
      * ,FBAC1, FMCS1, STRUC1, CFOUN1, CAPCS1, SPCO1, SSCD, HRFAC1
      * ,HRFAPS, YPRMIN, PLANC, CLAV1, CLSUM, FCSUM, COSM1, CSTLV1
215  * ,CSTH1, CFAN1*XNFAN1, CYLRN1*XNFAN1)
      WLRTP=WIDTH1/ELEN1
      END

```

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

SUBROUTINE CALC IS USED FOR THE ANALYSIS OF THE AMMONIA DRY COOLING SYSTEM. IN THIS SUBROUTINE THE CONDENSER/REBOILER, PIPING SYSTEM, HEAT EXCHANGER, AND TOWERS ARE DESIGNED. THE COSTS FOR ALL OF THESE SYSTEMS ARE FOUND ALONG WITH THE INCREMENTAL COST FOR OPERATING THE PLANT WITH THE DRY COOLING SYSTEM OVER THE ENTIRE YEAR.

THE FOLLOWING FIVE VARIABLES ARE THE FIVE INDEPENDENT VARIABLES THAT ARE USED TO DESIGN THE AMMONIA COOLING SYSTEM.

TT - TURBINE OUTLET TEMPERATURE (DEG F)
 TTD1 - TEMPERATURE DIFFERENCE BETWEEN THE OUTLET TEMPERATURE OF THE TURBINE AND THE TEMPERATURE OF THE AMMONIA IN THE CONDENSER/REBOILER (DEG F)
 RANGE - TEMPERATURE RANGE OF THE AIR THROUGH THE HEAT EXCHANGER (DEG F)
 AFRON - FRONTAL AREA OF THE HEAT EXCHANGER (SQ FT)
 WLRAT - WIDTH LENGTH RATIO OF THE HEAT EXCHANGER (FT/FT)

DEFINITION OF VARIABLES

AAIR - AIRSIDE AREA OF THE HEAT EXCHANGER (SQ FT)
 AMTU - NUMBER OF TRANSFER UNITS IN THE HEAT EXCHANGER (DIMENSIONLESS)
 ARPS - AREA PER SHELL OF THE CONDENSER/REBOILER (SQ FT)
 ATUB - SURFACE AREA OF THE BARE TUBES OF THE HEAT EXCHANGER (SQ FT)
 CDANG - ANGLE OF THE HEAT EXCHANGER BUNDLES FROM THE CIRCUMFERENCE OF THE COOLING TOWERS (DEGREES)
 CONF - THERMAL CONDUCTIVITY OF THE FINS IN THE HEAT EXCHANGER (BTU/HR-FT-DEG F)
 CONL - THERMAL CONDUCTIVITY OF THE TUBE LINER (BTU/HR-FT-DEG F)
 CPA - SPECIFIC HEAT OF THE AIR (BTU/LBM-DEG F)
 CPW - SPECIFIC HEAT OF THE AMMONIA (BTU/LBM-DEG F)
 CTOWD - DIAMETER OF CIRCULAR COOLING TOWERS (FT)
 DELPA - AIRSIDE PRESSURE DROP ACROSS THE HEAT EXCHANGER (LBF/SQ FT)
 DELPIP - PRESSURE DROP OF THE AMMONIA THROUGH THE SUPPLY AND RETURN PIPING (LBF/SQ FT)
 DELPR - PRESSURE DROP OF LIQUID FROM TOWERS TO TURBINE BUILDING (LBF/SQ FT)
 DELPS - PRESSURE DROP OF VAPOR FROM TURBINE BUILDING TO THE TOWERS (LBF/SQ FT)
 DELPW - PRESSURE DROP OF THE AMMONIA THROUGH THE WHOLE PIPING SYSTEM (LBF/SQ FT)
 DELPWC - PRESSURE DROP IN THE CONDENSER/REBOILER (LBF/SQ FT)
 DELPWT - PRESSURE DROP THROUGH THE TUBES OF THE HEAT EXCHANGER (LBF/SQ FT)
 DENAV - AVERAGE DENSITY OF THE AIR IN THE HEAT EXCHANGER (LBM/SQ FT)
 DENIN - DENSITY OF THE AIR ENTERING THE HEAT EXCHANGER (LBM/CU FT)
 DENOUT - DENSITY OF THE AIR LEAVING THE HEAT EXCHANGER

	C		(LBM/CU FT)
	C	DENSIV	- DENSITY OF AMMONIA VAPOR (LBM/CU FT)
60	C	DENSIW	- DENSITY OF AMMONIA LIQUID (LBM/CU FT)
	C	DEPTH	- DEPTH OF THE HEAT EXCHANGER (FT)
	C	DESVEL	- DESIGN VELOCITY OF AMMONIA LIQUID (FT/SEC)
	C	DESVELV	- DESIGN VELOCITY OF AMMONIA VAPOR (FT/SEC)
	C	DFIN	- FIN DIAMETER OF THE TUBES IN THE HEAT EXCHANGER
65	C		(IN)
	C	DI	- INSIDE DIAMETER OF THE TUBES IN THE HEAT EXCHANGER
	C		(IN)
	C	DIST	- DISTANCE FROM TURBINE BUILDING TO COOLING TOWERS
	C		(FT)
70	C	DPTINW	- AIRSIDE PRESSURE DROP ACROSS THE HEAT EXCHANGER
	C		(IN H ₂ O)
	C	EFF	- EFFECTIVENESS OF THE HEAT EXCHANGER (DIMENSIONLESS)
	C	EFFIN	- FIN EFFECTIVENESS OF THE TUBES IN THE HEAT
	C		EXCHANGER (DIMENSIONLESS)
75	C	ELENG	- LENGTH OF THE HEAT EXCHANGER TUBES (FT)
	C	ELEV	- ELEVATION OF THE PLANT SITE (FT)
	C	ENGTH	- LENGTH OF THE HEAT EXCHANGER TUBES (IN)
	C	FIAR	- FRICTION FACTOR OF THE AIR FLOW THROUGH THE
	C		HEAT EXCHANGER (DIMENSIONLESS)
80	C	GAIR	- MASS FLUX OF THE AIR IN THE HEAT EXCHANGER
	C		(LBM/HR-SQ FT)
	C	GWAT	- MASS FLUX OF THE AMMONIA ON THE INSIDE OF THE TUBES
	C		IN THE HEAT EXCHANGER (LBM/HR-SQ FT)
	C	HFG	- HEAT OF VAPORIZATION OF THE AMMONIA (BTU/LBM)
85	C	HGMAX	- AIRSIDE PRESSURE DROP OF THE HEAT EXCHANGER
	C		AT THE REFERENCE TEMPERATURE OF 70 DEG F
	C		(IN H ₂ O)
	C	HI	- INSIDE HEAT TRANSFER COEFFICIENT OF THE TUBES OF
	C		THE HEAT EXCHANGER (BTU/HR-SQ FT-DEG F)
90	C	HO	- OUTSIDE HEAT TRANSFER COEFFICIENT OF THE HEAT
	C		EXCHANGER (BTU/HR-SQ FT-DEG F)
	C	HPWAT	- HORSEPOWER LOSS FOR THE TOTAL PIPING SYSTEM (HP)
	C	HPWAT1	- HORSEPOWER LOSS THROUGH THE SUPPLY AND RETURN
	C		PIPING AND THE TUBES OF THE HEAT EXCHANGER (HP)
95	C	HPWAT2	- HORSEPOWER LOSS THROUGH THE TUBING OF THE CON-
	C		DENSER/REBOILER (HP)
	C	H5FAC2	- HEAT RATE FACTOR OF THE TURBINE (DIMENSIONLESS)
	C	HYDDIA	- HYDRAULIC DIAMETER OF THE TUBING ARRANGEMENT
	C		(IN)
100	C	NUMTOW	- NUMBER OF CIRCULAR COOLING TOWERS
	C		(DIMENSIONLESS)
	C	NW	- NUMBER OF TUBES IN WIDTH OF THE HEAT EXCHANGER
	C		(DIMENSIONLESS)
	C	ODL	- OUTSIDE DIAMETER OF THE TUBE LINER (IN)
105	C	ODR	- ROOT DIAMETER OF FINNED TUBE IN THE HEAT EXCHANGER
	C		(IN)
	C	P	- BACK PRESSURE OF THE TURBINE (IN HGA)
	C	PF	- FIN PITCH OF THE TUBES IN THE HEAT EXCHANGER (IN)
	C	PIPCSTL	- LIQUID PIPING COST (\$)
110	C	PIPCSTV	- VAPOR PIPING COST (\$)
	C	PL	- LONGITUDINAL PITCH OF THE TUBES (IN)
	C	PMP CST	- COST OF THE PUMPING SYSTEM (\$)
	C	PPOW	- PUMP POWER (HP)
	C	PRW	- PRANDTL NUMBER OF THE AMMONIA (DIMENSIONLESS)

115	C	PSIZE	- SIZE OF THE PLANT (MGW)
	C	QIN	- HEAT INPUT TO THE PLANT (BTU/HR)
	C	QREJ	- HEAT REJECTION TO THE ENVIRONMENT (BTU/HR)
	C	REAIR	- REYNOLDS NUMBER OF THE AIR IN THE HEAT EXCHANGER (DIMENSIONLESS)
120	C	REWAT	- REYNOLDS NUMBER OF THE AMMONIA FLOW THROUGH THE TUBES OF THE HEAT EXCHANGER (DIMENSIONLESS)
	C	RPTPL	- PUMP MOTOR ELECTRICAL COST (\$)
	C	SF	- SPACE BETWEEN THE FINS OF THE HEAT EXCHANGER (IN)
	C	TAIRAV	- AVERAGE TEMPERATURE OF THE AIR IN THE HEAT EXCHANGER (DEG F)
125	C	TCOS	- INCREMENTAL POWER PRODUCTION COST (\$/KWH)
	C	TCWPCS	- TOTAL COST OF THE PIPING SYSTEM (\$)
	C	TD	- AMBIENT DESIGN TEMPERATURE (DEG F)
	C	TEFF	- THERMAL EFFECTIVENESS OF THE PLANT AT THE DESIGN BACK PRESSURE (DIMENSIONLESS)
130	C	TEFFM	- THERMAL EFFECTIVENESS OF THE PLANT (DIMENSIONLESS)
	C	THCONW	- THERMAL CONDUCTIVITY OF THE AMMONIA LIQUID (BTU/HR-FT-DEG F)
	C	THFIN	- THICKNESS OF THE FINS OF THE TUBES IN THE HEAT EXCHANGER (IN)
135	C	TIN	- TEMPERATURE OF THE AMMONIA ENTERING THE SUPPLY PIPING (DEG F)
	C	TINHX	- TEMPERATURE OF AMMONIA ENTERING THE HEAT EXCHANGER (DEG F)
140	C	TLA	- LENGTH OF THE TUBES IN THE CONDENSER/REBOILER (FT)
	C	TTD1	- TEMPERATURE DIFFERENCE BETWEEN THE SATURATED STEAM AND AMMONIA IN THE CONDENSER/REBOILER (DEG F)
	C	TTD2	- TEMPERATURE DROP OF THE AMMONIA IN THE SUPPLY PIPING (DEG F)
145	C	TVATAV	- TEMPERATURE OF THE AMMONIA IN THE CONDENSER/REBOILER (DEG F)
	C	U	- OVERALL HEAT TRANSFER COEFFICIENT OF THE HEAT EXCHANGER (BTU/HR-SQ FT-DEG F)
	C	VAIR	- VELOCITY OF THE AIR IN THE HEAT EXCHANGER (FT/SEC)
150	C	VELD	- INLET VELOCITY OF THE AMMONIA ENTERING THE CONDENSER/REBOILER (FT/SEC)
	C	VELDO	- OUTLET VELOCITY OF THE AMMONIA LEAVING THE CONDENSER/REBOILER (FT/SEC)
	C	VISA	- VISCOSITY OF AIR IN THE HEAT EXCHANGER (LBM/FT-HR)
155	C	VISV	- VISCOSITY OF AMMONIA VAPOR (LBM/FT-HR)
	C	VISW	- VISCOSITY OF THE AMMONIA (LBM/FT-HR)
	C	VOL	- VOLUME OF THE HEAT EXCHANGER (CU FT)
	C	VVAT	- VAPOR VELOCITY OF THE AMMONIA IN THE ENTRANCE OF THE TUBES OF THE HEAT EXCHANGER (FT/SEC)
160	C	WB	- BUNDLE WIDTH OF HEAT EXCHANGER (FT)
	C	WIDTH	- WIDTH OF THE HEAT EXCHANGER (FT)
	C	W3	- MASS FLOW RATE OF THE AMMONIA (LBM/HR)
	C	W4	- MASS FLOW RATE OF THE AIR (LBM/HR)
	C	XDG	- DIAGONAL PITCH OF THE TUBES IN THE HEAT EXCHANGER (IN)
165	C	XNP	- NUMBER OF PASSES IN THE CONDENSER/REBOILER (DIMENSIONLESS)
	C	XNS	- NUMBER OF SHELLS IN THE CONDENSER/REBOILER (DIMENSIONLESS)
	C	XNTS	- NUMBER OF TUBES PER SHELL (DIMENSIONLESS)
170	C	XQUALY	- EXIT QUALITY OF THE AMMONIA LEAVING THE

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C      CONDENSER/REBOILER (DIMENSIONLESS)
C      XW      - TRANSVERSE PITCH OF THE TUBES (IN)
C      ZD      - TUBE DEPTH OF THE HEAT EXCHANGER (DIMENSIONLESS)
175  C
      LOGICAL FXTLNG
      LOGICAL FIRST, FXTFMP
      COMMON
180  $ AFTQ, ALPHA, ANG(3)
      $ ,CAFF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
      $ ,CRU, CTURB, CDANG, CLUVR, CHAILS, CVM
      $ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
      $ ,EFFP
185  $ ,FCR, FIRST, FIXL, FCOS, FFHX, FTEMP
      $ ,GBEFF
      $ ,HXNP, HPCST
      $ ,ITMAX, ITMIN
      $ ,JCONS
190  $ ,KCONV, KALEXT
      $ ,MXEXT
      $ ,NTJCAL(2), NTA
      COMMON
195  $ DDRI
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPLI
      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL
      $ ,RED, REDUCE, REDUCV, ROOFLI
      $ ,QREJ, QREDUCE, QREDUCV
      $ ,SIGMAG, SAAF
200  $ ,TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
      $ ,TCD, TW
      $ ,UCS, UWS
      $ ,WFW
      $ ,VAS(5)
205  $ ,XDEPA, XW, XD
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      $ QIN, CLAND, REAIR, Z,HRFAC2, W4, U, DELPW, PPOW,
      $ FPAW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
      $ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
210  $ SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPC2, PSIZ13, WT2,
      $ BP2, VW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX
      $ , TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
      $ , CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLDCST
      $ ,CAPOST, XNFAN, BLDANG, CPLEN, DPFEI, WHX, WTTUB, ADIA, ASLV
215  $ , WTHOR, WTERM, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFEN, ANTU
      $ , AIRFF, WATERF, XNMOD, TOTPF, FOCFF, FMTRC, ACCTP, ADJTP
      $ , ACTBD, ADJBD, ACTVH, ADJVT, ADJVP, THPKR, TOTF, AFCST
      $ , CSRJ, WATERW, WSTRCT, CFOWN, HJSDIA, TOWLEN, NUMTOW, CTOWD
      $ , SQRJ, SQRJS, ATURC, CBA, TTD1, TTD2, DELPS, CSTLVR
220  $ , CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
      COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
      $ QI1, CLAN1, REAI1, Z1,HRFA2S, W41, U1, DEPW1, PPOW1,
      $ FPOW1, DEFC1, WIDTH1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,
      $ REWAT1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPBP, SW41, SW31,
225  $ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFP4IN, SPC1, SPS13, WT2MIN,
      $ BP2MIN, VW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
      $ , TLAX1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CA1, CS1
      $ , CLTC1, CFC1, CPCC1, FITCO1, CSC1, CEPRE1, DEPIP1, AST1, OLDCS1
      $ ,CAPCS1, XNFAN1, BLDAN1, CPLEN1, DPFEI1, WH1, WTTU1, ADI1, ASL1

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230      S, WTHD1, WTRF1, STRUC1, CFMPF1, HPPF1, TOTCF1, TPI, EFFIN1, ANTU1
      S, AIRFF1, WATFF1, XNMOD1, TCTPF1, FOCPP1, FMTRC1, ACTTP1, ADJTP1
      S, ACTBP1, ADJBP1, ACTVH1, ADJH1, ADJPP1, THPA11, TCTF1, AFCST1
      S, CSR1, WATER1, WSTRC1, CFOJN1, HUBD11, TOWLE1, NJMT01, CTOWD1
      S, SQRJ1, SQRJ51, ATUBC1, CBA1, TTD11, TTD21, DELPS1, CSTLV1
535      S, CSTH1, CYLRN1, CFANC1, PSTAC1, PUFIT1, PMPDS1, RTTAL1, SEPCS1
      COMMON /SCALER/HRFAC1, ATUB, CPRA, SSCD, PLANCT1, CASSS1,
      S, GAIR, FAIR, HPAIR, HPWAT, WLRTP, PLANCT1
      COMMON/DJB/DI,XDG,SF
      COMMON /FLSW/ FXTLNG
      COMMON /INDIS/ DIST
240      COMMON /LACALL/ SRN
      COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2RE, LINOR, XNP, XQUALY
      COMMON /HEADX/ CHH,CN,CHM,CW,CWJ,CST,CMO,CSR,CSM,PITCHF,CPW,
1PRESS,HEDMAT,HEDTYP,NPASS,WB
      COMMON /SURFEX/ ODL,DUMBLST(15)
245      COMMON /HXD/ AI,ATOT
      LOGICAL LOOPER
      COMMON/FAN/ FANDAP(153,10),FANDAH(153,10),FMCPF,FBCPF,P2,R,S,
      S VELREC, AFC, ELEV, EHR, LOOPER, CTMAX
      COMMON /PROP/ CPW, THCONW, DENSIW, VISW, HFG,
250      * CPV, THCONV, DENSIW, VISV, SIGMA,
      * CPA, THCONA, DENSA, VISA
      DATA PI/3.14159/, GC/32.0/
1002  FORMAT(5X,"AI,PF,SFA,EFA,RFA =",5G12.6/5X,"ATOT,HXVOL,ART,AF,ACS =
      1",5G12.6/5X,"AFTR,ALPHA,SIGMA =",3G12.6/)
255      IF(FXTLNG.AND.LYC.EQ.M.AND.M.EQ.5) RETURN
      KCONV=.
      LOOPER = .FALSE.
      CTMAX = 0.0
      TTD1 = TTD
260
      C
      C      HEAT REJECTED BY THE TURBINE:
      C
      C      BACK PRESSURE OF TURBINE AS A FUNCTION OF THE SATURATION
      C      TEMPERATURE
265      P=EXP(17.168-9240./(T1+460.))
      RP2=P
      C
      C      HEAT RATE FACTOR OF THE PLANT AT THE DESIGN BACK PRESSURE:
      C      HRFAC2=TPO(1) +TPO(2)*P +TPO(3)*P**2 + TPO(4)*P**3
270      C
      C      EFFICIENCY OF THE PLANT AT THE DESIGN BACKPRESSURE:
      C      TEFFM=TEFF/HRFAC2
      C
      C      HEAT PUT IN BY THE BOILER (BTU/HR)
275      QIN=3413.*PSIZE*1000./TEFFM
      C
      C      HEAT REJECTED TO THE ENVIRONMENT (BTU/HR)
      QREJ=QIN*(1.-TEFFM)
      SQRJ = QREJ
280
      C
      C      CALCULATION OF AIR AND AMMONIA PROPERTIES
      C
      50  TAIRAV = TD + RANGE/2.0
      100 TWATAV = T1 - TTD1
285      CALL PPERT(TWATAV,TAIRAV,ELEV)

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      PRW = CPW*VISW/THCONW
      C
      C      MASS FLOW RATES OF AMMONIA AND AIR IN HEAT EXCHANGER
      C
300      W3 = QDEJ/HFG
      W4 = QDEJ/(CPA*RANGE)
      C
      C      *****UNIT GEOMETRIES OF THE HEAT EXCHANGER*****
      C
305      C      INSIDE AREA PER FOOT (FT**2/FT)
      AI = PI*DI*12.0/144.0
      C
      C      FIN PITCH (FINS/IN)
      PF = 1.0/(SF + THFIN)
310      C
      C      SIDE FIN AREA (FT**2/FT)
      SFA = 2.0*PF*PI*(DFIN**2 - ODR**2)/48.0
      C
      C      AREA AT THE ENDS OF THE FIN (FT**2/FT)
315      EFA = PF*PI*DFIN*THFIN/12.0
      C
      C      ROOT FIN AREA (FT**2/FT)
      RFA = PI*ODR*(1.00 - PF*THFIN)/12.0
320      C
      C      TOTAL SURFACE AREA (FT**2/FT)
      ATOT = SFA + EFA + RFA
      C
      C      HEAT EXCHANGER VOLUME (FT**2/FT)
      COSTH = XW/(2.0*XDG)
      SINTH = SQRT(1.0 - COSTH**2.0)
      SPACE = XDG*SINTH
      HXVOL = XW*SPACE*1.0/144.0
325      C
      C      CROSS-SECTIONAL ROOT TUBE AREA (FT**2/FT)
      ART = ODR/12.0
      C
      C      CROSS-SECTIONAL FIN TUBE AREA (FT**2/FT)
      AF = PF*(DFIN - ODR)*THFIN/12.0
330      C
      C      CROSS-SECTIONAL AREA (FT**2/FT)
      ACS = XW/12.0
      C
      C      AFTR = AIR SIDE FIN AREA/TOTAL AIR SIDE AREA
      AFTR = (SFA + EFA)/(SFA + EFA + RFA)
335      C
      C      ALPHA = AIR SIDE HEAT TRANSFER AREA/H. X. VOLUME
      ALPHA = ATOT/HXVOL
      C
      C      SIGMAG = FREE FLOW AREA/FRONTAL AREA
      SIGMAG = 1. + (ART + AF)/ACS
340      C
      C      IF(KDERUG.NE.0) WRITE(6,1002) AI, PF, SFA, EFA, RFA, ATOT, HXVOL,
      & ART, AF, ACS, AFTR, ALPHA, SIGMAG
      C
      C      HEAT EXCHANGER DIMENSIONS
      C
      C      WIDTH OF HEAT EXCHANGER

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150 IF(FXTLNG) WIDTH = AFRON/FIXL
   IF(.NOT. FXTLNG) WIDTH = SQRT(WLRAT*AFRON)
   NW = WIDTH/XW*12.0
C
C      LENGTH OF TUBES IN THE HEAT EXCHANGER
   IF(FXTLNG) ELENB = FIXL
   IF(.NOT. FXTLNG) ELENB = WIDTH/WLRAT
350 ENGB = ELENB*12.
   NW2 = NW
   WT2 = WIDTH
   IF (M.EQ. 5 .OR. M.EQ. 4) CALL PRPERT(TWATAV,TAIRAV,ELEV)
C
C      DESIGN OF THE CONDENSER/REBOILER
C
   CALL SPDES(T1,TTD1,XNS,XNP,GRU,TL4,XQUALY,VELD,VELDO,ARPS,XNTS,
10ELPWC,LINOR)
C
C      GUESS THE TEMPERATURE DROP IN THE PIPING FROM THE
C      CONDENSER/REBOILER TO THE HEAT EXCHANGER
C
   TTD2 = 2.
C
C      *****
C      *****BEGINNING OF ITERATION LOOP THAT DETERMINES THE HEAT *****
C      *****EXCHANGER, TOWER, AND FAN CONFIGURATIONS*****
C      *****
C
370 C      EFFECTIVENESS OF THE HEAT EXCHANGER
160 EFF = RANGE/(T1 - TTD1 - TTD2 - TD)
   IF(EFF.GE.1.) GO TO 250
C
C      NUMBER OF TRANSFER UNITS IN THE HEAT EXCHANGER
375 NTU = -ALOG(1.0 - EFF)
C
C      AIR SIDE FRICTION FACTOR AND HEAT TRANSFER COEFFICIENT
C      OF THE HEAT EXCHANGER
C
380 C      MAXIMUM AIR SIDE MASS FLUX IN THE HEAT EXCHANGER
   GAIR = W4/(AFRON*SIGMA)
C
C      MAXIMUM AIR SIDE VELOCITY IN THE HEAT EXCHANGER
385 VAIR = GAIR/(3600.0*DENSIA)
C
C      MAXIMUM AIR SIDE REYNOLDS NUMBER IN THE HEAT EXCHANGER
   REAIR = ODR*GAIR/(VISA*12.0)
   KK = 1
   PATIO = XDG/XW
390 IF(ABS(RATIO - 1.0) .GE. 1.00E-03) KK = 2
   IF (EFFX.EQ. "PFR"      ") CALL HXPER(ODR, REAIR, DFIN, PF,
3      THFIN, HO)
   IF (EFFX.EQ. "FRICHO"   ") CALL FRICHO(KK, FAIR, HO, ODR, DFIN,
3      XW, XDG, SF, THFIN, GAIR)
395 C
C      FIN EFFICIENCY OF THE FINNED TUBES OF THE HEAT EXCHANGER
   BFIN = (DFIN/ODR + 4.0/3.0)/7.0
   EFFIN = 1.0/(1.0 + (BFIN*HO*(DFIN - ODR)**2)/(24.0*CONF*THFIN))
C

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400      C      OVERALL SURFACE EFFICIENCY OF THE FINNED TUBES OF THE
      C      HEAT EXCHANGER
      C      EFS = 1.0 - AFTR*(1.0 - EFFIN)

      C
      C      *****
405      C      *****BEGINNING OF ITERATION LOOP THAT DETERMINES THE TUBE *****
      C      *****DEPTH OF THE HEAT EXCHANGER *****
      C      *****
      C
      C      KN = 0
410      C      ZD = 2

      C
      C      MASS FLUX OF AMMONIA IN TUBES OF THE HEAT EXCHANGER
225      C      GWAT = W3/((ZD/HXNP)*NW*PI*DI*DI/(4.*144.))

      C
415      C      VAPOR VELOCITY OF AMMONIA AT INLET OF THE TUBES OF THE
      C      HEAT EXCHANGER
      C      VWAT = GWAT/(DENSIV*3600.)

      C
      C      INSIDE AMMONIA HEAT TRANSFER COEFFICIENT OF THE TUBES
420      C      OF THE HEAT EXCHANGER
      C      CALL HTCLD(DI,ENGTH,ANG,GWAT,1.,0.,PRW,DENSIW,DENSIV,VISW*.41338,
      C      IVISV*.41338,THCONW,CPW,HI,HTC,HTB,HTN,HTK,REWAT)
      C      T4 = TD + RANGE

      C
425      C      OVERALL HEAT TRANSFER COEFFICIENT OF THE HEAT EXCHANGER
      C
      C      REFFI = ATOT/(2.0*PI)
      C      U = 1.0 / (1.0/(EFS*HO) +
430      C      * REFF*ALOG(ODL/DI)/CONL +
      C      * ATOT/(AI*HI))

      C
      C      AIRSIDE AREA OF THE HEAT EXCHANGER
      C      AAIR = ANTU*CPA*WA/U

435      C
      C      VOLUME OF THE HEAT EXCHANGER
      C      VOL = AAIR/ALPHA

      C
      C      TUBE DEPTH OF THE HEAT EXCHANGER
440      C      DEPTH = VOL/AFRON
      C      PZD = 70
      C      ZD = 12.0*DEPTH/XD

      C
      C      CONVERGENCE CRITERIA OF THE TUBE DEPTH OF THE HEAT
445      C      EXCHANGER
      C
      C      IF(ABS(ZD-PZD)/ZD .LT. .0001) GOTO 300
      C      KN = KN + 1
      C      IF(KN .GT. 70) WRITE(6,1000) KN, PZD, ZD, AFRON
1000      C      FORMAT(5X,"KN,PZD,ZD,AFRON =",I3,3G12.6/)
450      C      IF(KN .GT. 80) GO TO 250
      C      ZAAIR = AAIR
      C      Z = ZD
      C      GO TO 225

      C
455      C      *****
      C      *****END OF ITERATION LOOP FOR DETERMINING THE TUBE DEPTH *****

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C      *****OF THE HEAT EXCHANGER *****
C      *****
450      C      250 KCONV = 1
          C      LVC = "
          C      RETURN
C
C      LIMIT OF TUBE DEPTH EITHER ABOVE OR BELOW A SPECIFIED
465      C      LIMIT OR WITHIN A RANGE OF VALUES
C
C      300 IF (DEEPL .LT. 0.00) TEST = ".GT."
          C      IF (DEEPL .GT. 0.00) TEST = ".LT."
          C      IF (POMDPL .GT. 0.0 .AND. ABS(DEEPL) .GT. 0.0) TEST = ".EQ."
470      C      Z = ZD
          C      IF (TEST .EQ. ".GT." .AND. ZD .GT. ABS(DEEPL)) GO TO 250
          C      IF (TEST .EQ. ".LT." .AND. ZD .LT. DEEPL) GO TO 250
          C      IF (TEST .EQ. ".EQ." .AND. ABS(ZD-DEEPL) .GT. POMDPL) GO TO 250
C
C      AIR SIDE PRESSURE DROP ACROSS THE HEAT EXCHANGER
475      C
C      AVERAGE DENSITY OF THE AIR IN THE HEAT EXCHANGER
          C      DENOUT = FLUID(7,2,T4,ELEV,"CALC4")
          C      DENIN = FLUID(7,2,T0,ELEV,"CALC3")
480      C      DENAV = (DENIN + DENOUT)/2.0
C
C      MAXIMUM VELOCITY IN THE HEAT EXCHANGER BASED ON THE
          C      AVERAGE DENSITY OF THE AIR
          C      VAIR = GAIR/(3600.0*DENAV)
485      C
C      HYDRAULIC DIAMETER OF THE HEAT EXCHANGER TUBING
          C      PL = SQRT( XDG**2 - (XW/2.0)**2 )
          C      HYDDIA = 4.0 * ((ZD-1.0)*PL + DFIN) * (ACS - (ART*AF))/(ATOT*ZD)
          C      IF (FFHX .EQ. "PFR") CALL FPFH (HYDDIA,PL,GAIR,FAIR)
490      C      AIRFF = FAIR
C
C      PRESSURE DROP ACROSS THE HEAT EXCHANGER
          C      DELPA = DENAV * FAIR * ZD * VAIR**2 / GC
          C      OPTINW = DELPA/5.2022
495      C
C      DESIGN OF THE FAN SYSTEM
          C
          C      HGMAX = OPTINW*0.07495/DENOUT
          C      IF (HGMAX .GT. 1.35) RETURN
500      C
C      COST ANALYSIS OF THE HEAT EXCHANGER
          C      CALL COSTEX (AFRONT,ATOT)
C
C      DESIGN OF THE LEAST COST FAN SYSTEM FOR THE ABOVE HEAT
505      C      EXCHANGER DETERMINATION OF THE NUMBER AND DIAMETER
          C      OF THE TOWERS IS ALSO DONE
          C      CALL FAN (OPTINW,AFRONT)
          C      IF (.NOT. LOOPER .AND. AFC .EQ. 5LE+8) CALL ERRMSG(1)
          C      IF (LOOPER) CALL ERRMSG(2)
510      C
          C      IF AFC IS GREATER THAN .49E+9 IT MEANS NO SUITABLE FAN
          C      WAS FOUND BY SUBROUTINE FAN IF THIS EXISTS TCOS IS
          C      SET EQUAL TO A HIGH VALUE IN ORDER TO THROW OUT THIS

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515      C      POINT IN THE SEARCH FOR A MINIMUM
      IF(AFC .GT. .49E+9) TCOS = 1.E+38
      IF(AFC .GT. 49.0E+07) RETURN

      C
      C      DESIGN OF THE SUPPLY PIPING SYSTEM
      C
520      TIN = T1 - TTD1
      XTOW = NUMTOW
      DENSIV = FLUID(7,1,TIN,ELEV,"CALC5")
      VISV = FLUID(8,1,TIN,ELEV,"CALC5")
525      CALL PIPCLS(XTOW,CTOWD,W3,TIN,DIST,DESVELV,W3,REDUCV,QREDUCV,
      S ELENG, TINHX, DELPS, PIPCSTV, CDANG, POHCIR)

      C
      C      CONVERGENCE CRITERIA ON THE TEMPERATURE DROP OF THE
      C      SUPPLY PIPING
      C
530      TTD22 = T1 - TTD1 - TINHX
      TTD23 = TTD2
      TTD2 = TTD22
      IF(ABS(TTD23 - TTD22).LT.,1) GO TO 310
      CALL PPERT(TINHX,TAIRAV,ELEV)
535      PRW = CPW*VISV/THCONW
      GO TO 160

      C
      C      *****
      C      *****END OF ITERATION LOOP FOR DETERMINING THE HEAT EX- *****
540      C      *****CHANGER, TOWER, AND FAN CONFIGURATIONS *****
      C      *****
      C
      C      310 CONTINUE

      C
545      C      DESIGN OF THE RETURN PIPING SYSTEM
      C
      CALL PIPCLR(XTOW,CTOWD,W3,DIST,DESVEL,W3,REDUCE,QREDUCE,DELPR,
      S PIPCSTL, CDANG, POHCIR)

      C
550      C      PRESSURE DROP OF THE AMMONIA THROUGH THE TUBES OF THE
      C      HEAT EXCHANGER
      C
      CALL DPCON(GOSW,DI,ENGTH,ANG,GWAT,1.,0.,DENSIV,DENSIV,VISW,.41339,
555      S VISV,.41339,DELPWT,DPF,DPG,DPM,XLM,PHIL,PHIL2,VF,WATFF,RL,RV)
      DELPWT = DELPWT*144.

      C
      C      COST OF PUMPS TO CIRCULATE AMMONIA AROUND THE PIPING
      C
      CALL PUMPCST(W3, DELPS, DELPR, DELPWT, DELPWC, XQUALY, DESVEL,
560      S PUMPCST, PUFITC)
      TCWPCS = PIPCSTL + PIPCSTV + PUMPCST

      C
      C      HORSEPOWER DISSIPATED BY THE AMMONIA FLOWING THROUGH
      C      THE SYSTEM
      C
565      DELPIP = DELPS + DELPR
      DELPW = DELPWT + DELPWC + DELPS + DELPR
      HPWAT1 = (DELPWT + DELPS + DELPR)*W3/(DENSIV*3600.*550.)
      HPWAT2 = DELPWC*W3/(DENSIV*XQUALY*3600.*550.)
570      HPWAT = HPWAT1 + HPWAT2

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      C
      C      ELECTRICAL COST OF THE CIRCULATION PUMPS:
      C
      C      CALLI PUMLEC(POHLEC, HPWAT, DIST, EFFP, RPTPL)
575      C
      C      PUMP POWER REQUIRED TO DRIVE THE AMMONIA THROUGH THE
      C      SYSTEM
      C
      C      PPOW = HPWAT/(1.341*EFFP)
580      C      ATUB = (1.0 - AFTR)*AAIR
      C
      C      COSTING OF THE PLANT, LAND, PIPING, AND CONDENSER/
      C      REBOILER
      C
585      C      XN=Z
      C      CALLI SCALP(T1,RANGE,AFRDN,WLRAT,TCWFCS,NUMTOW)
      C      DENSIV = FLUID(7,1,TIN,ELEV,"CALC 7")
      C
      C      INCREASED COST OF OPERATING THE PLANT WITH THE ABOVE
590      C      DESIGNED COOLING SYSTEM THROUGHOUT THE WHOLE YEAR
      C      (INCREMENTAL COST)
      C      CALLI NOVART(TCOS,RANGE)
      C      LVC=M
      C
595      C      RETURN
      C      END

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SUBROUTINE CHNGE(M)

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

LOGICAL FXTLNG

DIMENSION DP(5),DV(5),VAJ(5)

COMMON /SCALER/HRFAC1, ATUR, CPERA, SSCD,PLANC1,CASSS1,

S, GAIR, FAIR, HPAIR, HPWAT, ALRTP, PLANC1

LOGICAL FIRST, FXTMP

COMMON

S, AFTR, ALPHA, ANG(3)

S, CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP

S, CBU, CTURR, CDANG, CLUVR, CHAITS, CVM

S, DANGLE, DFIN, DEEPL, DESVEL, DESVELV

S, EFFP

S, FCR, FIRST, FIXL, FCOS, FFHX, FXTMP

S, GBEFF

S, HXVP, HPCST

S, ITMAX, ITMIN

S, JCONS

S, KCONV, KALEXT

S, MXEXT

S, NTUCAL(2), NTA

COMMON

S, ODR

S, PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL

S, POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCC

S, RUP, REDUCE, REDUCV, ROOFLI

S, QREJ, QREDUCE, QREDUCV

S, SIGMAG, SAAF

S, TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TPIX

S, TCD, TW

S, UCS, UWS

S, WEFV

S, VAS(5)

S, XDEPA, XW, XD

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

S, QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,

S, FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,

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

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

S, BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTEX, VELDX

S, TLAX, UCON, PMOST, PMOST, FBACC, EFFC, CH, CA, CS

S, CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLDOST

S, CAPCST, XNFAN, BLDANG, CPLEN, DPFEI, WHX, WTTUB, ADIA, ABLN

S, WTHOR, WTERF, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU

S, AIRFF, WATER, XNMOO, TCTP, FOCPE, FMTRC, ACCTTP, ADJTP

S, ACTRBD, ADJRPD, ACTVH, ADJVM, ADJPPF, THPAIR, TCTP, AFCST

S, CSRD, WATERW, WSTRICT, CFOUND, HUSBIA, TOWLEN, NUMTOW, CTOWD

S, SGRU, SGRUS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR

S, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST

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

S, QIN1, CLAN1, REA11, Z1, HRFAC2S, W41, U1, DEPW1, PPOW1,

S, FPOW1, DELFC1, WIDTH1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,

S, REWAT1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPBP, SW41, SW31,

```

60      S SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCO1, SPS13, WT2MIN,
      S B2ZMIN, NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
      S , TLA1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CHI, CA1, CS1
      S , CLTC1, CFC1, CPCC1, FITC01, CSC1, CEPRE1, DEPIPI, AST1, OLDCS1
      S, CAPCS1, XNFANI, BLDANI, CPLEN1, DPFE1, WH1, WTTU1, ADI1, ABL1
      S, WTHN1, WTR1, STRUC1, CEMPF1, HPPF1, TOTCF1, TPI, EFFIN1, ANTU1
65      S, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTYP1, ADJTP1
      S, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1
      S, CSR1, WATER1, WSTRC1, CFJUN1, HURD11, TOWLE1, NUMTO1, CTOWD1
      S, SRRJ1, SRRJS1, ATUBC1, CBAL, TTD11, TTD21, DELPS1, CSTLM1
      S, CSTHS1, CYLRN1, CFANE1, STAC1, PUFIT1, PMPCS1, RPTFL1, SEPCSI
70      COMMON /FLSW/ FXTLNG
      COMMON /LACALL/SRN
      COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2GE, LENOR, XNP, XQUALY
      IDB=0
      L=0
      K1=0
75      DO 1 I=1,3
1      DV(I)=.05
      DO 2 I=1,2
2      DV(I+3)=.2
      DO 3 I=1,5
80      VAJ(I)=VAR(I)
3      VAL(I)=VAR(I)
4      VAL(M)=(1.+DV(M))*VAR(M)
      IF(FXTLNG) VAL(1) = TFIX
      IF(VAL(M).LE.0.0) GO TO 36
85      IF(M.GT.3) GO TO 10
      IF(VAL(1).LE.0.0) GOTO 36
10     SRN="/CHNGE-1/"
      CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),1)
      IF(KCONV.EQ.1) GO TO 36
90     PA=DELP
      PA1=DEPA1
      DP(M)=DELP-DEPA1
      IIB=1
      IF(FXTLNG) IIB=2
95     DO 35 II=IIB,5
      I=5-II
      IF(I.EQ.5.AND.DV(1).GT..005) GO TO 35
      IF(I.EQ.M) GO TO 35
100    11 VAL(I)=(1.+DV(I))*VAR(I)
      IF(VAL(I).LE.0.0) GO TO 34
      VAJ(I)=VAL(I)
      IF(FXTLNG) VAJ(1) = TFIX
      IF(I.GT.3) GO TO 17
      IF(VAJ(1).LE.0.0) GOTO 12
105    GO TO 17
12     VAJ(I)=VAR(I)
      GO TO 34
17     J=I
      IF(M.LT.I) J=M
110    SRN="/CHNGE-2/"
      CALL CALC(VAJ(1),VAJ(2),VAJ(3),VAJ(4),VAJ(5),J)
      VAJ(I)=VAR(I)
      IF(KCONV.EQ.1) GO TO 34
      PA=DELP

```

```

115      PA1=DEPA1
        DP(1)=DELPA-DEPA1
        E=0.
        C=1.
        D=1.
120      18 VAL(I)=(1.+DV(I))*(E-DP(M))/DP(I))*VAR(I)
        IF (FXTEMP) VAL(1) = TFIX
        IF (VAL(I).LE.0.0) GO TO 34
        IF (I.GT.3) GO TO 24
        IF (VAL(1).LE.0.0) GOTO 34
125      24 SRN="/CHNGE-3/"
        CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),J)
        IF (KCONV.EQ.1) GO TO 34
        IF (DELPA.GE.XDEPA.AND.DELPA.LE.1.01*XDEPA) GO TO 25
        IF (DELPA.GE.1.01*XDEPA) GO TO 25
130      C=D/10.
        IF (C.LT..001) GO TO 34
        E=E+C
        GO TO 18
135      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
140      L=1
        DO 27 IJ=1,5
145      27 VAJ(IJ)=VAR(IJ)
        VAL(M)=(1.+DV(M))*VAR(M)
        IF (FXTEMP) VAJ(1) = TFIX
        IF (FXTEMP) VAL(1) = TFIX
        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.110.1 GO TO 36.
150      33 SRN="/CHNGE-4/"
        CALL CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
        IF (KCONV.EQ.1) GO TO 36
        PA1=DEPA1
        PA=DELPA
        DP(M)=DELPA-DEPA1
155      GO TO 11
        34 VAL(I)=VAR(I)
        35 CONTINUE
        36 DO 37 I=1,5
160      37 DV(I)=-DV(I)
        K1=K1+1
        IF (K1.EQ.1) GO TO 4
        K1=0
        IF (DV(I).LE..005) GO TO 39
        DO 38 I=1,5
165      38 DV(I)=DV(I)/5.
        GO TO 4
        39 IF (L.EQ.1.AND.ID3.NE.0) RETURN
170      103 FORMAT("          AND CHANGES MADE")
        RETURN
        END

```



```

C      FUNCTION CMARTIN(XMART,JMART,KMART)
C
C      FUNCTION CMARTIN SUPPLIES THE MARTINELLI COEFFICIENTS FOR
C      TWO-PHASE FLOW
5      DIMENSION PHI(9,6,2)
C
C      DEFINITION OF MARTINELLI INDICES FOR DATA SUPPLY
C
10     PHI(IMART,JMART,KMART)
C      IMART - COEFFICIENTS OF CURVE FITS (1 - 9)
C
C      JMART - FLOW REGIME (1 - 4)
C      1 -- VISCOUS - VISCOUS
15     C      2 -- TURBULENT - VISCOUS
C      3 -- VISCOUS - TURBULENT
C      4 -- TURBULENT - TURBULENT
C      HOLDUP CORRELATIONS (5 - 6)
C      5 -- MARTINELLI PARAMETER (X) LESS THAN ONE
20     C      6 -- MARTINELLI PARAMETER (X) GREATER THAN ONE
C
C      KMART - FLUID
C      1 -- LIQUID
C      2 -- VAPOR
25
C      MARTINELLI FUNCTIONAL COEFFICIENTS FOR THE LIQUID
C
C      DATA((PHI(IMART,JMART,1), IMART = 1, 9), JMART = 1, 6)/
C      VISCOUS - VISCOUS
30     * 0.97995 , -0.42951 , 0.09563 , -0.00547 , 0.00142 , 0.00011 ,
C      * 0.00000 , 0.00000 , 0.00000 ,
C      TURBULENT - VISCOUS
C      * 1.24907 , -0.44314 , 0.05680 , -0.00521 , -0.00057 , 0.00012 ,
35     * 0.00000 , 0.00000 , 0.00000 ,
C      VISCOUS - TURBULENT
C      * 1.23807 , -0.45844 , 0.07139 , -0.00444 , -0.00070 , 0.00012 ,
C      * 0.00000 , 0.00000 , 0.00000 ,
C      TURBULENT - TURBULENT
40     * 1.44065 , -0.50445 , 0.06212 , -0.00106 , -0.00101 , 0.00003 ,
C      * 0.00000 , 0.00000 , 0.00000 ,
C      RL HOLDUP CORRELATION - MARTINELLI PARAMETER LESS
C      THAN ONE
C      * 0.22206 , 0.04251 , -0.00127 , 0.00002 , 0.00000 , 0.00000 ,
45     * 0.00000 , 0.00000 , 0.00000 ,
C      RL HOLDUP CORRELATION - MARTINELLI PARAMETER
C      GREATER THAN ONE
C      * 0.22918 , 0.11270 , 0.01113 , -0.00431 , 0.00050 , 0.00099 ,
50     * -0.00613 , -0.00007 , 0.00001 /
C
C      MARTINELLI FUNCTIONAL COEFFICIENTS FOR THE VAPOR
C
C
C      DATA((PHI(IMART,JMART,2), IMART = 1, 9), JMART = 1, 6)/
C      VISCOUS - VISCOUS
55     * 1.19310 , 1.49456 , -0.01132 , 0.00014 , 0.00000 , 0.00000 ,
C      * 0.00000 , 0.00000 , 0.00000 ,
C      TURBULENT - VISCOUS

```

```

60      * 1.24906 , -0.55672 , 0.06678 , -0.00518 , -0.00057 , 0.00012 ,
      * 0.00000 , 0.00000 , 0.00000 ,
      C      VISCOUS - TURBULENT
      * 1.23450 , 0.53139 , 0.07181 , -0.00442 , -0.00069 , 0.00012 ,
      * 0.00000 , 0.00000 , 0.00000 ,
      C      TURBULENT - TURBULENT
65      * 1.44105 , 0.49541 , 0.06153 , -0.00113 , -0.00095 , 0.00003 ,
      * 0.00002 , 0.00000 , 0.00000 ,
      C      RG HOLDUP CORRELATION - MARTINELLI PARAMETER LESS
      C      THAN ONE
      * -0.25522 , -0.10583 , -0.02893 , -0.00884 , 0.00000 , 0.00000 ,
      * 0.00000 , 0.00000 , 0.00000 ,
70      C      MARTINELLI PARAMETER GREATER THAN ONE
      * -0.25522 , -0.10573 , -0.02893 , -0.00884 , 0.00000 , 0.00000 ,
      * 0.00000 , 0.00000 , 0.00000 /
      C
      C      MARTINELLI PARAMETER CALCULATION
75      C
      IMART = 9
      J = JMART
      K = KMART
      SUM = 0.00
80      IF(J.EQ. 1 .AND. K.EQ. 2) GO TO 75
      IF(J.EQ. 5 .AND. K.EQ. 1) GO TO 75
      DO 50 I = 1, IMART
      SUM = SUM + PHI(I,J,K)*ALOG(XMART)**(I - 1)
50      CONTINUE
85      CMARTIN = EXP(SUM)
      IF(J.EQ. 6 .AND. K.EQ. 1) CMARTIN = SUM
      RETURN
75      DO 100 I = 1, IMART
      SUM = SUM + PHI(I,J,K)*XMART**(I - 1)
90      CONTINUE
      CMARTIN = SUM
      RETURN
      END

```

SUBROUTINE DPCON(GOWS,DTI,DL,ANG,GT,XI,XO,DENL,DENV,VISL,VISV,DP,
1 DPF,DPG,OPM,XLM,PHIL,PHIL2,VF,FL,RL,RV)

```

C
C
5  C      SUBROUTINE DPCON CALCULATES THE TWO PHASE PRESSURE DROP
C      INSIDE TUBES WHETHER IT BE CONDENSATION OR BOILING. THE
C      PRESSURE DROP IS CALCULATED ACCORDING TO THE METHOD OF
C      LOCKHART AND MARTINELLI
C
C      DEFINITION OF VARIABLES
10  C
C      ANG(2)  - THE SIN OF THE ANGLE THE TUBE MAKES FROM THE
C               HORIZONTAL (DIMENSIONLESS)
C      DENL    - DENSITY OF THE LIQUID PHASE OF THE TWO PHASE FLOW
C      DENV    - DENSITY OF THE VAPOR PHASE OF THE TWO PHASE FLOW
15  C      DL    - LENGTH OF THE TUBE (IN)
C      DP      - TOTAL PRESSURE DROP IN THE TUBE (LBF/SQ IN)
C      DPF     - PRESSURE DROP DUE TO FRICTION (LBF/SQ IN)
C      DPG     - PRESSURE INCREASE DUE TO GRAVITY (LBF/SQ IN)
C      OPM     - PRESSURE DROP OR INCREASE DUE TO MOMENTUM LOSS OR
20  C             GAIN (LBF/SQ IN)
C      DR      - DENSITY RATIO (LIQUID/VAPOR) (DIMENSIONLESS)
C      DTI     - INSIDE DIAMETER OF THE TUBING (IN)
C      FL      - LIQUID FANNING FRICTION FACTOR BASED ON THE VAPOR
C               QUALITY AND THE INSIDE DIAMETER ON THE TUBE (DIM-
25  C             ENSIONLESS)
C      GT      - MASS FLUX OF FLUID IN THE TUBE (LBM/HR-SQ FT)
C      PHIL    - MARTINELLI FUNCTION (DIMENSIONLESS)
C      PHIL2   - MARTINELLI FUNCTION SQUARED (DIMENSIONLESS)
C      RL      - REYNOLDS NUMBER LIQUID FRACTION (DIMENSIONLESS)
30  C      RV    - REYNOLDS NUMBER VAPOR FRACTION (DIMENSIONLESS)
C      SN      - NUMBER OF DIVISIONS IN THE LENGTH OF THE TUBE
C               (DIMENSIONLESS)
C      VISL    - VISCOSITY OF THE LIQUID (CENTIPOSE)
C      VISV    - VISCOSITY OF THE VAPOR (CENTIPOSE)
35  C      X1    - AVERAGE VAPOR QUALITY IN EACH SECTION OF THE TUBE
C               (DIMENSIONLESS)
C      XAV     - AVERAGE VAPOR QUALITY IN THE TUBE
C      XD      - CHANGE IN VAPOR QUALITY FROM ONE END OF THE TUBE
C               TO THE NEXT OR FOR EACH SECTION OF TUBE
40  C             (DIMENSIONLESS)
C      XI      - INLET VAPOR QUALITY (DIMENSIONLESS)
C      XLM     - LOCKHART-MARTINELLI PARAMETER (DIMENSIONLESS)
C      XO      - EXIT VAPOR QUALITY (DIMENSIONLESS)
C
45  C      DIMENSION ANG(3)
C      DHOMO(X)=(1.0-X)/DENL*X/DENV
C      DPG = 0.0
C      OPM = 0.0
C
50  C      PRESSURE DROP AS A RESULT OF FRICTION
C
C      SETUP OF VARIABLES FOR CALCULATION OF PRESSURE DROP
C      INCREMENTALLY ALONG THE LENGTH OF THE TUBE
C
55  C      DR = DENL/DENV
C      XD = ABS(XI-XO)
C      XAV = 0.5*(XI+XO)
C      N = XD*.01

```

```

      N = N + 1
      SN = N
60      XD = XD/SN
      SUM = 0.0
      SUG = 0.0
      XA = XI + XD*.5
      IF(XI.LT.XD) XA = XI - XD*.5
65      C
      C      PRESSURE DROP INCREMENTALLY CALCULATED ALONG THE LENGTH
      C      OF THE PIPE
      DO 10 I = 1,N
      IF(XD.LT.XI) XA = XA - XD
70      IF(XI.LT.XD) XA = XA + XD
      XV = AMAX1(0.10,XA)
      C
      C      DETERMINATION OF MARTINELLI FUNCTION
      CALL DPLMNB(DTI,GT,XV,DR,VISL,VISV,PHIL,PHIL2,FL,XLM,RL,RV)
75      SUG = SUG + 1./PHIL
      C
      C      DETERMINATION OF THE SUM OF THE VARIABLE PARTS IN FRONT
      C      OF THE TWO PHASE PRESSURE DROP EQUATION
80      10 SUM = SUM + (1.0 - XV)**2*FL*PHIL2
      C
      C      PRESSURE DROP INCURRED BY THE TWO PHASE FLOW IN THE PIPE
      C      DUE TO FRICTION
      OPF = .333E-10 * DL*GT**2*SUM/(DTI*DENL*SN)
85      C
      C      INCREASE IN PRESSURE DUE TO GRAVITY
      C
      20 VF = 1. - SUG/SN
      C      OPG = -ANG(2)*DL*(DENV*VF + DENL*(1.-VF))/1728.
      C
      C      INCREASE OR DROP IN PRESSURE DUE TO CHANGES IN MOMENTUM
      C      THE MODEL IS BASED ON A HOMOGENEOUS MODEL THAT ASSUMES
      C      THE CHANGE IN MOMENTUM APPLIES JUST TO THE VAPOR
90      C
      30 OPH = GT**2/6.E10*(DHOMO(XD)-DHOMO(XI))
85      OPM = OPM*XA**2
      C
      C      TOTAL PRESSURE DROP
      C
90      DP = OPF + OPG + OPM
100      RETURN
      END

```

```
      SUBROUTINE DPFFF(RE,FF,ILT)
C
C      SUBROUTINE DPFFF DETERMINES THE FANNING FRICTION FACTOR
C      FOR SMOOTH TUBES
5
C      DEFINITION OF VARIABLES
C
C      RE      - REYNOLDS NUMBER (DIMENSIONLESS)
C      FF      - FANNING FRICTION FACTOR (DIMENSIONLESS)
10
C
C      ILT = 2
C      IF (RE - 1600.) 30,30,10
10 IF (RE - 3950.) 40,40,20
20 IF (RE - 52000.) 50,50,60
15
C      LAMINAR FLOW REGIME
C
30 FF = 16./RE
C      ILT = 1
C      GO TO 70
20
C      TRANSITION FLOW REGIME
C
40 FF = 0.010
C      IF (RE.LT.2000.) ILT = 1
C      GO TO 70
25
C      TURBULENT FLOW REGIME
C
50 FF = 0.0791/RE**0.25
C      GO TO 70
60 FF = 0.0460/RE**0.20
30
70 RETURN
END
```

SUBROUTINE DPLMNB(DTI,GT,XD,DR,VISL,VISV,PHIL,PHIL2,FL,XLM,RL,RV)

SUBROUTINE DPLMNB DETERMINES THE MARTINELLI FUNCTION FOR
BOILING INSIDE OF TUBES BY CURVE FITS OF THE LOCKHART-
MARTINELLI PARAMETER

DEFINITION OF VARIABLES

DR - DENSITY RATIO (LIQUID/VAPOR) (DIMENSIONLESS)
DTI - INSIDE DIAMETER OF THE TUBING (IN)
FL - LIQUID FANNING FRICTION FACTOR (DIMENSIONLESS)
FV - VAPOR FANNING FRICTION FACTOR (DIMENSIONLESS)
GT - MASS FLUX OF FLUID IN THE TUBE (LBM/(HR-SQ FT))
PHIL - MARTINELLI FUNCTION (DIMENSIONLESS)
PHIL2 - MARTINELLI FUNCTION SQUARED (DIMENSIONLESS)
RL - REYNOLDS NUMBER LIQUID FRACTION
RV - REYNOLDS NUMBER VAPOR FRACTION
VISL - VISCOSITY OF THE LIQUID (CENTIPOSE)
VISV - VISCOSITY OF THE LIQUID VAPOR (CENTIPOSE)
XA - VAPOR QUALITY OF THE FLUID (DIMENSIONLESS)
XLM - LOCKHART-MARTINELLI PARAMETER (DIMENSIONLESS)

XA = PMLIM(1.E-9,.9999,XD)

LIQUID REYNOLDS NUMBER
RL = DTI*GT*(1.-XA)/(VISL*29.)

VAPOR REYNOLDS NUMBER
RV = DTI*GT*XA/(VISV*29.)

FANNING FRICTION FACTOR FOR THE LIQUID
CALL DFFFF(RL,FL,ILTL)

FANNING FRICTION FACTOR FOR THE VAPOR
CALL DFFFF(RV,FV,ILTV)

LOCKHART-MARTINELLI PARAMETER
XLM = SQRT(FL/(FV*DR)) * (1.-XA)/XA

VISCOUS FLOW LIQUID - VISCOUS FLOW VAPOR
IF(ILTL.EQ.1.AND.ILTV.EQ.1) JMART = 1

TURBULENT FLOW LIQUID - VISCOUS FLOW VAPOR
IF(ILTL.EQ.2.AND.ILTV.EQ.1) JMART = 2

VISCOUS FLOW LIQUID - TURBULENT FLOW VAPOR
IF(ILTL.EQ.1.AND.ILTV.EQ.2) JMART = 3

TURBULENT FLOW LIQUID - TURBULENT FLOW VAPOR
IF(ILTL.EQ.2.AND.ILTV.EQ.2) JMART = 4

MARTINELLI FUNCTION
PHIL = CMARTIN(XLM,JMART,1)

MARTINELLI FUNCTION SQUARED
PHIL2 = PHIL*PHIL
RETURN

END

FUNCTION PNLIM

74/74 OPT=1

FTN 4.2+74351

12/18/66

```
      FUNCTION PNLIM(AMIN,AMAX,AFUNC)
      C
      C      FUNCTION PNLIM LIMITS AFUNC BETWEEN AMIN AND AMAX
      C
      C      PNLIM=AFUNC
      C
      C      IF AFUNC IS LESS THAN AMIN SET PNLIM EQUAL TO AMIN
      C      IF (AFUNC-AMIN) 10,10,20
10      PNLIM=AMIN
      GO TO 50
      C
      C      IF AMAX IS LESS THAN AMIN JUST SET PNLIM EQUAL TO AFUNC
      C      20 IF (AMAX-AMIN) 50,50,30
      C
      C      IF AFUNC IS GREATER THAN AMAX SET PNLIM EQUAL TO AMAX
      C      30 IF (AFUNC-AMAX) 50,50,40
      C      40 PNLIM=AMAX
      C      50 RETJRN
      C      END
```

```

FUNCTION FLUID(NPROP,NFLUID,TEMP,ALITD,LOCAT)
DIMENSION LOCAT(2)
DIMENSION COLLAJ(12,8,2)
DIMENSION FLU(2), PROP(12,3)
LOGICAL WARN
IFLAG3 = 1

```

FLUID 5

```

SUBROUTINE FLUID DETERMINES THE THERMODYNAMIC AND PHYSICAL
PROPERTIES OF SATURATED AMMONIA AND AIR. THE VALUES ARE
DETERMINED BY CURVE FITS OF THE PROPERTIES VERSES TEMPERATURE.
THE LIQUID PROPERTIES OF AMMONIA ARE FOR SATURATED AMMONIA.
THE THERMODYNAMIC PROPERTIES FOR AMMONIA GAS ARE FOR ATMOS-
PHERIC PRESSURE WHILE THE PHYSICAL PROPERTIES ARE FOR
SATURATED AMMONIA GAS.

```

COLLAJ(NFLUID, NPROP, ICLA)

FLUID 10
FLUID 11
FLUID 12

NFLUID - FLUID INDEX

= 1 - AMMONIA
= 2 - AIR

NPROP - PROPERTY INDEX

= 1 - SPECIFIC HEAT (LIQUID) (BTU/LBM-DEG F)
= 2 - THERMAL CONDUCTIVITY (LIQUID) (BTU/HR-FT-DEG F)
= 3 - DENSITY (LIQUID) (LBM/CU FT)
= 4 - VISCOSITY (LIQUID) (LBM/FT-HR)
= 5 - SPECIFIC HEAT (GAS) (BTU/LBM-DEG F)
= 6 - THERMAL CONDUCTIVITY (GAS) (BTU/HR-FT-DEG F)
= 7 - DENSITY (GAS) (LBM/CU FT)
= 8 - VISCOSITY (GAS) (LBM/FT-HR)
= 9 - HEAT OF VAPORIZATION (BTU/LBM)
= 10 - PRESSURE AS A FUNCTION OF TEMPERATURE (PSI)
= 11 - TEMPERATURE AS A FUNCTION OF PRESSURE (DEG F)
= 12 - SURFACE TENSION (LBF/FT)

ICLA - COEFFICIENTS, LIMITS AND ADJUSTMENT FACTORS:

= 1 - FIRST COEFFICIENT
= 2 - SECOND COEFFICIENT
= 3 - THIRD COEFFICIENT
= 4 - FOURTH COEFFICIENT
= 5 - LOWER TEMPERATURE LIMIT
= 6 - UPPER TEMPERATURE LIMIT
= 7 - FIRST ADJUSTMENT FACTOR, ADDED TO TEMPERATURE
= 8 - SECOND ADJUSTMENT FACTOR, DIVIDED INTO TEMPERATURE

FLUID 53

DATA VALUES FOR AMMONIA

FLUID 55

```

DATA((COLLAJ(I,J,1), J = 1,8), I = 1, 9)/
      LIQUID SPECIFIC HEAT (1,J,1)
* 1.0880 , -4.15152E-05, 7.349495E-06, 0.0 , 0.0 ,
* 200.0 , 0.00 , 1.000,
      LIQUID THERMAL CONDUCTIVITY (2,J,1)

```

```

      * 3.348732E-01, -7.24969E-04, -7.37431E-09, 0.0      , 9.0 ,
      * 100.0      , 0.00      , 1.000,
      C      LIQUID DENSITY (3,J,1)
      * 41.256      , -3.93362E-02, -3.16190E-05, 0.0      , 0.0 ,
      * 200.0      , 0.00      , 1.000,
      C      LIQUID VISCOSITY (4,J,1)
      * 5.370135E-01, -3.05263E-03, 5.727532E-06, 0.0      , 9.0 ,
      * 100.0      , 0.00      , 1.000,
      C      SPECIFIC HEAT OF GAS (5,J,1)
      * 4.853433E-01, 1.716071E-04, 1.398809E-07, 0.0      , 50.0 ,
      * 100.0      , 0.00      , 1.000,
      C      THERMAL CONDUCTIVITY OF GAS (6,J,1)
      * 1.161067E-02, 3.020539E-05, 2.398301E-08, 0.0      , 50.0 ,
      * 100.0      , 0.00      , 1.000,
      C      DENSITY OF GAS (7,J,1)
      * 9.059293E-02, 5.588934E-03, -4.04296E-05, 4.343057E-07, 0.0 ,
      * 200.0      , 0.00      , 1.000,
      C      VISCOSITY OF GAS (8,J,1)
      * 2.375058E-02, 4.175724E-05, 8.421106E-09, 0.0      , 9.0 ,
      * 100.0      , 0.00      , 1.000,
      C      HEAT OF VAPORIZATION (9,J,1)
      * 5.567073E+02, -5.09783E-01, -2.75342E-03, 0.0      , 0.0 ,
      * 200.0      , 0.00      , 1.000,
      DATA((COLLAJ(I,J,1), J = 1, 9), I = 10, 12)/
      C      PRESSURE AS A FUNCTION OF TEMPERATURE (10,U,1)
      * 2.983273E+01, 8.155492E-01, 5.019419E-03, 4.990946E-05, 0.0 ,
      * 100.0      , 0.00      , 1.000,
      C      TEMPERATURE AS A FUNCTION OF PRESSURE (11,U,1)
      * -1.50307E+01, 7.921579E-01, -1.33280E-03, 8.885735E-07, 30.0 ,
      * 710.0      , 0.00      , 1.000,
      C      SURFACE TENSION (12,J,1)
      * 2.0213E-03 , -8.1309E-06 , 0.0 , 0.0 , 30.0 ,
      * 200.0      , 0.00      , 1.000/

```

FLUID 81

DATA VALUES FOR AIR (PRESSURE OF ONE ATMOSPHERE)

```

      DATA((COLLAJ(I,J,2), J = 1, 8), I = 1, 8)/
      C      LIQUID SPECIFIC HEAT (1,J,2)
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      C      LIQUID THERMAL CONDUCTIVITY (2,J,2)
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      C      LIQUID DENSITY (3,J,2)
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      C      LIQUID VISCOSITY (4,J,2)
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      * 0.0      , 0.0      , 0.0      , 0.0      , 0.0 ,
      C      SPECIFIC HEAT OF GAS (5,J,2)
      * 2.403053E-01, 6.7987568E-7, 1.3005827E-8, 7.041570E-11, -40.0 ,
      * 140.0      , 0.0      , 1.0      , 0.0      , 0.0 ,
      C      THERMAL CONDUCTIVITY OF GAS (6,J,2)
      * 1.3069044E-2, 2.6570901E-5, 5.0393357E-8, -4.11082E-10, -40.0 ,
      * 140.0      , 0.0      , 1.0      , 0.0      , 0.0 ,
      C      DENSITY OF GAS (7,J,2)

```

```

115      * 8.5353904E-2, -1.874752E-4, 3.7316434E-7, -4.66929E-10, -40.0 ,
      * 140.0 , 0.0 , 1.0 ,
      C      VISCOSITY OF GAS (8,J,2)
      * 3.3387711E-2, 6.8722417E-5, -3.483392E-8, 2.452409E-11, -40.0 ,
      * 140.0 , 0.0 , 1.0 /
120      C
      C      DATA (FLU(I), I = 1, 2)/"WATER","AIR"/
      C
      C      DATA FOR PRINTING OF ERROR MESSAGES
125      C
      C      DATA((PROP(I,J), J = 1, 3), I = 1, 12)/
      * "SPECIFIC H","HEAT OF LIQ","JID",
130      * "THERMAL CON","DUCTIVITY"," OF LIQUID",
      * "DENSITY OF"," LIQUID ",",",
      * "VISCOSITY ","OF LIQUID ",",",
      * "SPECIFIC H","HEAT OF GAS",",",
      * "THERMAL CON","DUCTIVITY"," OF GAS ",",",
      * "DENSITY OF"," GAS ",",",
135      * "VISCOSITY ","OF GAS ",",",
      * "HEAT OF VA","PORIZATION",",",
      * "PRESSURE A","S A FUNCTI","ON OF T ",",
      * "TEMPERATUR","E AS A FUN","CTION OF P",
      * "SURFACE TE","NSION AS A"," FUNCTION"/
140      C
      C      DETERMINATION OF ERROR IN INPUTS
      C
      IF(NFLUID .GT. 2) RETURN
      NF = NFLUID
      NP = NPROP
145      C
      C      AIR PROPERTIES NOT AVAILABLE
      IF(NF .EQ. 2 .AND. NP .LE. 4) GO TO 50
      WARN = .FALSE.
150      C
      C      PROPERTIES ASKED FOR OUTSIDE THE RANGE OF TEMPERATURES
      C      ALLOWED FOR
      IF (TEMP .LT. COLLAJ(NP,5,NF)) WARN = .TRUE.
      IF (TEMP .GT. COLLAJ(NP,6,NF)) WARN = .TRUE.
155      C
      C      FLUID PROPERTY CALCULATION
      C
      T = (TEMP + COLLAJ(NP,7,NF))/COLLAJ(NP,8,NF)
      FLUID = COLLAJ(NP,1,NF) + COLLAJ(NP,2,NF)*T + COLLAJ(NP,3,NF)*T**2
160      * + COLLAJ(NP,4,NF)*T**3
      C
      C      ALTITUDE CORRECTION FOR DENSITY OF AIR
      C
      IF(NF .EQ. 2 .AND. NP .EQ. 7) FLUID =
165      * 1.325 * EXP(3.39853 - 3.81835E-5 * ALTID) / (TEMP + 459.67)
      C
      C      PRINTING OF ERRORS
      C
      IF(.NOT. WARN) RETURN
170      IF(IFLAG3 .EQ. 0) RETURN
      C

```

FLUID495

FLUID498

FLUID500

FLUID501

FLUID502

FLUID503

FLUID504

FLUID505

FLUID506

FLUID513

FLUID514

FLUID541

FUNCTION FLUID

74/74 OPT=1

FTN 4.2+74351

12/18/66

```

C      TEMPERATURE LIMITS EXCEEDED ERROR PRINTOUT
      WRITE(4,1) TEMP, (PROP(NPROP,I),I=1,3), FLUID, FLU(NFLUID),
      * COLLAJ(NP,5,NF), COLLAJ(NP,6,NF), LOCAT
175 1 FORMAT("0***WARNING***"/
      * " THE INPUT TEMPERATURE (" ,F8.3," ) FOR DETERMINING THE " ,3A10,
      * " (" ,F8.3," )"/
      * " FOR " ,A9," IS OUTSIDE THE RANGE OF " ,F8.3," TO " , F8.3/
      * " THE CALL TO FLUID WAS IN " ,2A10//)
      RETURN
180
C
C      AIR PROPERTY ERROR PRINTOUT
50 WRITE(4,60) NP
60 FORMAT(5X,"THIS PROPERTY OF AIR IS NOT AVAILABLE IN FUNCTION FLUID"
185 * *** WARNING *** NP = " ,I2/)
      FLUID = 0.000
C
      RETURN
      END
```

FLUID548.
FLUID549.
FLUID550
FLUID551
FLUID552.

SUBROUTINE COSTEX (AFRONTOT)

```

C
C
C
5 C      SUBROUTINE COSTEX DETERMINES THE COST OF THE HEAT EXCHANGER
C      BUNDLES OF THE DRY COOLING TOWERS. THE COST OF THE HEAT
C      EXCHANGER BUNDLE IS BROKEN DOWN INTO SEVERAL SUBCOMPONENTS
C      1. HEADER
C      2. TUBING
C      3. TUBING SEALANT
C      4. SPACERS
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      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
C      EXCHANGER (DECIMAL)
20 C      CA - BUNDLE ASSEMBLY AND FRAME COSTS ($)
C      CRA - BUNDLE ASSEMBLY COST ($)
C      CRJ - COST OF BOLTED HEADER JOINT ($/FT)
C      CELAST - COST OF THE ELASTOMER ($/LBF)
C      CEPREP - COST OF END PREPARATION FOR EACH TUBE ($/TUBE)
25 C      CFS - UNIT FRAME COSTS ($/LBF)
C      CH - COST OF THE HEADER FOR EACH BUNDLE
C      CHC - STEEL HEADER COSTS ($/LBF)
C      CHF - BUNDLE FRAME COST ($)
C      CHX - COST OF THE HEAT EXCHANGER ($)
30 C      COATC - COST OF COATING THE AIR SIDE SURFACE AREA
C      ($/SQ FT)
C      CPCC - COST OF COATING THE HEAT EXCHANGER TUBES ($)
C      CRJ - COST OF ROLLED JOINTS FOR THE HEADER ($/TUBE)
C      CS - COOLING SURFACE COST ($)
35 C      CSC - TUBE SPACER COSTS ($/TUBE-SPACER)
C      CSEALP - COST OF SEAL PLATE ($/LBF)
C      CWJ - COST OF WELDED JOINT FOR THE HEADER ($/TUBE)
C      OFIN - OUTSIDE DIAMETER OF FIN (IN)
C      DI - INSIDE DIAMETER OF TUBE (IN)
40 C      ELENG - LENGTH OF THE HEAT EXCHANGER TUBES (FT)
C      EPREPC - END PREPARATION COSTS ($/TUBE)
C      FA - TOTAL TUBE FLOW AREA PER PASS SQ (IN)
C      FACT - HEADER FACTOR WHICH DEPENDS ON THE TYPE OF HEADER
C      (DIMENSIONLESS)
45 C      FITCO - TUBING COST ($/FT)
C      FB - PRESSURE FACTOR (DIMENSIONLESS)
C      FI - HEADER DEPTH MATERIAL FACTOR (IN)
C      FR - HEADER WIDTH MATERIAL FACTOR (IN)
C      HD - HEADER DEPTH PER PASS (IN)
50 C      HFORMAT - TYPE OF HEADER MATERIAL (DIMENSIONLESS)
C      HFTUB - NUMBER OF TUBES PER HEADER
C      HFTYP - TYPE OF HEADER
C      HEDVOL - HEADER VOLUME (CU FT)
C      HF - FIN HEIGHT (IN)
55 C      HW - HEADER WIDTH (IN)
C      HXNP - NUMBER OF PASSES THROUGH THE HEAT EXCHANGER
C      (DIMENSIONLESS)

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C      NW      - NUMBER OF HEAT EXCHANGER TUBES IN WIDTH
C              (DIMENSIONLESS)
60  C      ODL      - OUTSIDE DIAMETER OF TUBE (IN)
C      ODLIN     - OUTSIDE DIAMETER OF THE LINER (IN)
C      PCF      - PROCURMENT COST FACTOR (DECIMAL)
C      POHBAF    - INDIRECT CONSTRUCTION COST FOR HEAT EXCHANGER
C      PF        - FIN PITCH (FINS/IN)
65  C              BUNDLE (DECIMAL)
C      ROEL      - TUBING MATERIAL DENSITY (LBM/CU IN)
C      SF        - SPACING BETWEEN FINS (IN)
C      SS        - SPACING BETWEEN SPACERS (FT)
C      THFIN     - FIN THICKNESS (IN)
70  C      TR      - THICKNESS OF THE FIN AT THE ROOT OF THE FIN (IN)
C      TUBVOL    - VOLUME OF WATER INSIDE THE TUBES (CU FT)
C      TW        - THICKNESS OF THE HEADER WALLS (IN)
C      WATERW    - TOTAL WEIGHT OF THE WATER IN THE HEAT EXCHANGER
C                  BUNDLE (LBF)
75  C      WR      - WIDTH OF THE HEAT EXCHANGER BUNDLE (F)
C      WF        - WEIGHT OF THE FINS OF THE HEAT EXCHANGER (LBF)
C      WHX       - WEIGHT OF MATERIAL MAKING UP THE EXCHANGER (LBF)
C      WL        - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
C      WTRFM     - WEIGHT OF THE HEAT EXCHANGER FRAME (LBF)
80  C      WTHDR   - WEIGHT OF THE HEAT EXCHANGER HEADER (LBF)
C      WTTUB     - WEIGHT OF THE TUBES IN THE HEAT EXCHANGER (LBF)
C      XD        - LONGITUDINAL TUBE SPACING BETWEEN TUBE ROWS (IN)
C      XNBUN     - NUMBER OF HEAT EXCHANGER BUNDLES (DIMENSIONLESS)
C      XW        - TRANSVERSE TUBE PITCH NORMAL TO AIR FLOW (IN)
85  C      Z        - NUMBER OF HEAT EXCHANGER TUBES IN DEPTH
C                  (DIMENSIONLESS)
C      ZINCC     - COST OF THE ZINC FOR THE TUBE SPACERS ($/LBM)
C
C      ARRAYS
90  C      TUBMA   - LINER MATERIAL
C      CL        - LINER FIXED COSTS ($)
C      CLM       - LINER MATERIAL COSTS ($/LB)
C      ROEL      - DENSITY OF LINER MATERIALS (LB/CU IN)
C      GAGLI     - LINER GAGE
95  C      THKLIN  - THICKNESS OF LINER (IN)
C      FINTY     - TYPE OF FIN
C      CFM       - FIN MATERIAL COSTS ($/LB)
C      CF        - FINNING FIXED COSTS ($/FT)
C      ODLIN     - COMMON DIAMETERS OF LINER (IN)
100 C      MAXFH   - MAXIMUM FIN HEIGHT (IN)
C      STANFT    - STANDARD FIN THICKNESS (IN)
C      FPL      - LOWEST FIN PITCH (FPI)
C      FPH      - HIGHEST FIN PITCH (FPI)
C      HEDTY    - TYPE OF HEADER
105 C      HEDMA   - HEADER MATERIAL
C      ROEHM     - HEADER MATERIAL DENSITY (LB/CU IN)
C      CHM       - COST OF HEADER MATERIAL ($/LB)
C      CMW      - COST OF HEADER MACHINING AND WELDING ($/FT)
C      CM       - NOZZEL AND ATTACHING COST ($/HOLE)
110 C      CHH     - TUBE AND PLUGHOLE PREPARATION ($/HOLE)
C      FF       - COST LENGTH FACTOR FOR TUBES (DIMENSIONLESS)
C      FINMA    - TYPE OF FIN MATERIAL
C      FPL      - LOWER LIMIT ON STANDARD FIN PITCHES THAT ARE
C                  COMMERCIALY AVAILABLE (FINS/IN)

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115      C      FPH - UPPER LIMIT ON STANDARD FIN PITCHES THAT ARE
      C      COMMERCIALY AVAILABLE (FINS/IN)
      C      MAXFH - MAXIMUM FIN HEIGHT FOUND COMMERCIALY (IN)
      C      ROEF - DENSITY OF FIN MATERIAL (LBM/CU IN)
      C      STANFT- FIN THICKNESS LIMITS FOUND COMMERCIALY (IN)
120      C
      C      REAL NTUB
      C
      LOGICAL FIRST, FXTMP
125      COMMON
      S AETR, ALPHA, ANG(3)
      S CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAPF
      S CRJ, CTURB, CDANG, CLUVR, CHAHS, CVM
130      S DANGLE, DFIN, DEEPL, DESVEL, DESVELV
      S EFFF
      S FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
      S GBEFF
      S HXMP, HPCST
135      S ITMAX, ITMIN
      S JCONC
      S KCONV, KALEXT
      S MXEXT
      S NTUCAL(2), NTA
      COMMON
140      S ODR
      S PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      S POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POWSTC, POWSCH
      S REP, REDUCE, REDUCV, ROOFLL
145      S QRED, QREDUCE, QREDUCV
      S SIGMA3, SAAF
      S TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
      S TCO, TW
      S UCS, UWS
      S WEF
150      S VAS(5)
      S XDSPA, XW, XD
      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      S QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
155      S FPOW, DELEC, WIDTH, ELENG, VAIR, VWAT, HT, HO, T4,
      S REWAT, NW, NT, NP, PLANC2, PSIZ12, SPAP, SW4, SW3,
      S SPC, PTOTAL, PLANC3, GAIRON, GAIR, YFP, SPCO, PSIZ13, WT2,
      S BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
      S TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
160      S CLTC, CFC, CPEC, FITCO, USC, CEPREP, DELPIP, AST, OLDOST
      S CAPCST, XNFAN, BLDANG, CPLEN, DPFL, WHX, ATTUB, ADIA, ABLN
      S WTHOR, WTRM, STRUCC, CPERF, HPERF, TOTCF, TPC, EFFIN, ANTU
      S AIRFF, WATFF, XNMOD, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      S ACTBPO, ADJBPD, ACTV4, ADJV4, ADJPPF, THPAIR, TCTF, AFCST
165      S CSRD, WATERPW, WSTRCT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S SRJ, SRJG, ATURC, CRA, TTD1, TTD2, DELPS, CSTLVR
      S CSTHC, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
      COMMON /DJB/ DI, XDG, SF
      COMMON /PLCOST/ WPL
      COMMON /FLSW/ FXTNG
170      COMMON /SCALER/ HRFAC1, ATUB, CPERA, SSCD, PLANC1, CASS1, GAIR, FAIR,
      + HPAIR, HPWAT, WLRTF

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G-35

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230      S,6*0.0
      S,6*0.0
      S,6*0.0
      S,.3125, .37500, .50000, 3*.625
      S,.3125, .37500, .50000, 3*.625
      S,6*0.0
235      S,.3125, .37500, .50000, 3*.625
      S /
      DATA (((STANFT(I,J,K),I=1,6),J=1,7),K=1,2) / 42* .016, 42* .030 /
      DATA (((FPL(I,J,K),I=1,6),J=1,7),K=1,2) /
      S 5*2.0,18*7.0,18*5.0,18*0.0,6*7.0,18*5.0/
240      DATA (((FPH(I,J,K),I=1,6),J=1,7),K=1,2) /
      S 5*27., 36*11., 18*0.0, 6*9.0, 18*11.0 /
      DATA FPMMA / "ALUMINUM " , "STEEL " /
      DATA RREF / 0.09751, 0.2840 /

245      C
      C      TABLE V
      C      HEADER FABRICATION COSTS
      C
      DATA HEDTY / "WELD REMOV", "WELD PLUG ", "FORM REMOV",
      *      "FORM PLUG " /
250      DATA (HEDMA(I),I=1,3)/"STEEL " , "ALUMINUM " , "GALVANIZED"/
      DATA RREFM / .284, .09751, .284/
      DATA CWMAT / .53, 1.3, .57/
      DATA CHC / 1.05, 1.00, 0.95, 0.90 /

255      C
      C      TABLE VI
      C      TUBING LENGTH PENALTIES
      C
      C      FOR COPPER ALLOYS
260      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 /
      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 /

265      C
      C      FOR ALUMINUM
      DATA (FF(5,J),J=1,6) / 1.00, 1.05, 1.10, 1.14, 1.18, 1.22 /

270      C
      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 /

275      C
      C      FOR STAINLESS STEEL
      DATA (FF(8,J),J=1,6) / 1.00, 1.00, 1.04, 1.08, 1.12, 1.15 /

      C
      C      DEFINING THE TYPE OF TUBING UNDER CONSIDERATION
      C
      IF(.NOT.FIRST) GOTO 55
      DO 10 I=1,8
      ITUBMA = I
280      IF (TUBMAT .EQ. TUBMA(I)) GO TO 15
10  CONTINUE
      PRINT 11
      STOP
285      11 FORMAT(5X,"NO MATCH FOR LINER MATERIAL")
      15 DO 20 J=1,13

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      IGAGLI = J
      IF (ABS(GAGLIN-GAGLI(J)).LT..001) GOTO 25
20  CONTINUE
      PRINT 21
290  21  FORMAT(5X,"NO MATCH FOR LINER GAGE")
      STOP
25  DO 30 K=1,7
      IFINTY = K
      IF (IFINTY.EQ. FINTY(K)) GO TO 35
295  30  CONTINUE
      PRINT 31
31  FORMAT(5X,"NO MATCH FOR TYPE OF FIN")
35  DO 40 L=1,2
      IFINMA = L
300  40  IF (FINMAT.EQ. FINMA(L)) GO TO 45
      40  CONTINUE
      PRINT 41
41  FORMAT(5X,"NO MATCH FOR FIN MATERIAL")
45  IF (IFINTY.EQ. 7) GOTO 59
305  DO 50 I=1,6
      IODLIN = I
      IF (ODL.EQ. ODLIN(I)) GO TO 55
50  CONTINUE
      PRINT 51
310  51  FORMAT(5X,"NO MATCH FOR OUTSIDE DIAMETER OF LINER")
      STOP
55  CONTINUE
      IF (IFINTY.EQ. 7) GOTO 59
      IF (FIRST) GOTO 59
315  C
      C***** FINNED TUBE COSTS
      C
      C LINER TUBING COSTS
      C
320  WL = 37.69511*ROEL(ITUBMA)*(ODL+THKLIN(IGAGLI))*THKLIN(IGAGLI)
      C
      LI=5
      DO 57 I=3,8
      IF (ELFNG.GE.(10*I)) LI=I-2
325  57  CONTINUE
      F=FF(ITUBMA,LI)
      ADDER=0.0
      IF (ITUBMA.LT.5) ADDER = F
      IF (ITUBMA.LT.5) F=1.0
330  CLTC = (CLM(ITUBMA) * WL + CLN(ITUBMA)) * F + ADDER
      PCF = 1.10
      CLTC = CLTC*PCF
      C
      C FINNING COSTS
      C
335  PF = 1./(SF + THFIN)
      GOTO (40,70,80,90,100,110,105) , IFINTY
      C
      C FIN WEIGHTS
      C
340  C
      C STRAIGHT FIN
      60 ODR=ODL

```

```

      HF=(DFIN-ODR)/2.0
      WF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
345      GO TO 120
    C
    C      FOOTED FIN
      70 ODR=ODL + 2.*THFIN
      HF=(DFIN-ODR)/2.0
350      WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
      WF = WSF-(SF-1./PF)*WSF/HF
      GO TO 120
    C
    C      DOUBLE FOOTED FIN
355      80 ODR= ODL + 4.*THFIN
      HF=(DFIN-ODR)/2.0
      WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
      WF = WSF-(SF-2./PF)*WSF/HF
      GO TO 120
360    C
    C      EMBEDDED FIN
      90 ODR=ODL
      HF=(DFIN-ODR)/2.0
365      WSF = 37.69911*ROEF(IFINMA)*THFIN*ODL*PF*HF
      WF = 0.94*WSF
      GOTO 120
    C
    C      EXTRUDED FINS
370      100 CONTINUE
      TR = 0.035
      ODR=ODL + 2.*TR
      HF=(DFIN-ODR)/2.
      WF=37.69911*ROEF(IFINMA)*(THFIN*PF*HF*(ODR+HF)+(ODL*TR)*TR)
      GO TO 120
375    C
    C      EXTRUDED FINS WITHOUT LIVER
      105 TR = THKLN(IGAGLI)
      ODR = ODL
      HF = (DFIN-ODR) / 2.
380      WF =37.69911*ROEF(IFINMA)*(THFIN*PF*HF*(ODR+HF) + (ODL-TR) * TR)
      GOTO 120
    C
    C      PLATE FINS
385      110 ODR=ODL+2.*THFIN
      IF (IFINTY.EQ. 6) GO TO 120
      IF (HF.GT. MAXFH(10DLIN,IFINTY,IFINMA)) PRINT 115
390      115 FORMAT(5X,"HEIGHT OF FIN IS LARGER THAN THE MAXIMUM ALLOWABLE VALU
      +E")
      IF (THFIN.LT. STANFT(10DLIN,IFINTY,1)) PRINT 116
      116 FORMAT(5X,"FIN THICKNESS IS LESS THAN THE SPECIFIED LIMIT")
      IF (THFIN.GT. STANFT(10DLIN,IFINTY,2)) PRINT 117
      117 FORMAT(5X,"FIN THICKNESS IS GREATER THAN THE SPECIFIED LIMIT")
      IF (PF.LT. FPL(10DLIN,IFINTY,IFINMA)) PRINT 118
      118 FORMAT(5X,"FIN PITCH IS LESS THAN THE SPECIFIED LIMIT")
      IF (PF.GT. FPH(10DLIN,IFINTY,IFINMA)) PRINT 119
395      119 FORMAT(5X,"FIN PITCH IS GREATER THAN THE SPECIFIED LIMIT")
      APLATE = XW*X0
      WF=37.69911*ROEF(IFINMA)*(APLATE*THFIN*PF+3.14159*ODR *THFIN)
      120 AB = 37.69911*ODL*PF*THFIN

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```

400      IF (FIRST) GOTO 125
      C
      C      COST OF BONDING THE FIN TO THE TUBING - IF THERE IS NO
      C      BONDING TO BE DONE, CFB SHOULD BE EQUAL TO ZERO
      CFC = CFM(IFINTY*IFINMA)*WF+(CFR(IFINTY)+CFB*AB)
405      C
      C      PROTECTIVE COATING COSTS
      C
      C      IF A PROTECTIVE COATING IS NOT WANTED, COATC IS SET
      C      EQUAL TO ZERO IN THE INPUT
410      C
      AS = ATOT * ELENG * Z * NW
      CPCC = COATC*AS
      C
      C      COST OF THE TUBING AND FINS PER FOOT
415      C
      FITCO = CLTC+CFC+CPCC
      C
      C***** TUBE SPACER COSTS
      C
420      CSC = ZINCC * 0.1 * (XW**2 - DOR**2) * CASTC
      C
      C***** END PREPARATION COSTS
      C
      CEPREP = EPREPC
425      C
      C***** TOTAL COOLING SURFACE COSTS
      C
      CS = Z*NW*(FITCO*ELENG+CSC*((ELENG**5*SS)/SS)+CEPREP)
      CS = CS * POMBAF
430      C
      C      DEFINING THE CASE FOR THE HEADER
      C
      125 IF (.NOT. FIRST) GOTO 145
      DO 130 I=1,4
435      IHEDTY = I
      IF (HEDTYP.EQ. HEDTY(I)) GO TO 135
      130 CONTINUE
      PRINT 131
      STOP
440      131 FORMAT(5X,"NO MATCH FOR HEADER TYPE")
      135 DO 140 I=1,3
      IHEDMA=I
      IF (HEDMAT.EQ.HEDMA(I)) GOTO 142
445      140 CONTINUE
      PRINT 141
      STOP
      141 FORMAT(5X,"NO MATCH FOR HEADER MATERIAL")
      142 FIRST=.FALSE.
      RETURN
450      C
      C***** HEADER AND NOZZEL COSTS
      C
      145 DI=ODL-2.*THKLIN(IGAGLI)
      C
455      C      NUMBER OF BUNDLES IN COOLING TOWERS
      C
      XNRJN = NW*XW/(12.0*WB)

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```

      XNMOD = XNBUN/8.0
C
C      NUMBER OF TUBES PER BUNDLE
460 HEDTUB = 12.*Z *WB/XW
      ABC=1.0
      IF(IHEDTY.EQ.2.OR.IHEDTY.EQ.4) ABC=2.0
      FP=1.00
      IF(PRESS.GT.150) FP=1.05
465 IF(PRESS.GT.250) FP=1.10
      FA = .785398*DI*DI*HEDTUB/HXNP
C
C      HEADER DEPTH AND WIDTH
      HD = XD * (Z/HXNP) + 1.0
      HW = FA / (2.0 * HD) + 2.0
470 F1 = 2.0 * HXNP * HXNP * HD / 10.0
      F2 = 2.0 * HXNP*FA/(20.0*HD)
      IF(IHEDTY.EQ.1.OR.IHEDTY.EQ.2) FACT=2.*F1+4.
      IF(IHEDTY.EQ.3.OR.IHEDTY.EQ.4) FACT=2.*F1
475
C
C      COST OF HEADERS
C
      CHM= CHMAT(IHEDMA)
      CH=(CHM*ROEHM(IHEDMA)*(12.*WB*TW*(2.*F1*HD +(F2+2.)*HW)+F1*FA*
480 $ TW) + CMW*(FACT*WB + (4.0*F1*HD + 2.0*(F2 + 2.0) * HW) /12.0) +
      $ 4.0 * CRJ* (HXNP*HD/12. + WB) +
      1CHH*(24.0*ABC*Z*WB/XW) + 4.0*CN*SQRT(FA/3.14159))*XNBUN*FP
      CH = CH * PCHBAF
      IF (WB .GT. 14.0) PRINT 150
485 150 FORMAT(5X,"THE SPECIFIED HEADER LENGTH IS BEYOND THE PRACTICAL LIM
      +IT")
C
C***** BUNDLE ASSEMBLE AND FRAME COSTS
C
490 CA = HEDTUB*(CRJ+CWJ)+20.*ELEN*(2.0*WB/(2.*SS))*SQRT(Z/6.)*CST
      CA = CA * XNBUN * PCHBAF
C
C***** WEIGHT OF HEAT EXCHANGER
C
495 C      MATERIAL TUBE WEIGHT OF THE COOLING TOWER
      WTTUB = Z*NW*ELEN*(WL + WF)
C
C      MATERIAL HEADER WEIGHT OF THE COOLING TOWER
      WTHDR = ROEHM(IHEDMA) * (12.*WB*TW * (2.*F1*HD+(F2+2.)*HW) +
500 $ F1*FA*TW) * XNBUN
C
C      TOTAL FRAME WEIGHT OF THE HEAT EXCHANGER
      WTFRM = 20. * ELEN * (2.*WB/(2.*SS)) * SQRT(Z/6.)*XNBUN
C
C      TOTAL WEIGHT OF WATER IN THE HEAT EXCHANGER
505 TURVOL = Z*NW*ELEN*3.14159*DI*DI/(144.0*4.0)
      HEDVOL = 2.0 * HXNP * HD * HW * WB / 144. * XNBUN
      WATERW = TURVOL*DENSIV + (HEDVOL/2.)*DENSIV + (HEDVOL/2.)*DENSIV
C
C      WEIGHT OF THE HEAT EXCHANGER
510 WHX = WTTUB + WTHDR + WTFRM
C
C***** TOTAL COST OF THE HEAT EXCHANGER

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SUBROUTINE COSTEX 74/74 OPT=1

FTN 4.2+70351

12/19/66

515 BSECF = 1.12
 CHX = BSECF * (CA + CH + CS)
 RETURN
 END

SUBROUTINE FAN(DPTINH, AFRON)

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C      SUBROUTINE FAN SELECTS THE OPTIMUM FAN SYSTEM FOR THE PARTICULAR
C      ULAR HEAT EXCHANGER GEOMETRY SELECTED. FOR THE PARTICULAR
5      FAN SYSTEM THE FOLLOWING PARAMETER ARE SPECIFIED-
C      1. BLADE DIAMETER
C      2. HUB DIAMETER
C      3. NUMBER OF BLADES PER FAN
C      4. BLADE ANGLE
10     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     IN THIS SUBROUTINE THERE ARE TWO ARRAYS WHICH CONTAIN DATA
C      FOR THE FOLLOWING FAN DIAMETERS (24,26,28,30,40,60). FOR
C      EACH FAN DIAMETER THERE IS PERFORMANCE DATA FOR FANS WITH
C      DIFFERENT NUMBER OF BLADES AND BLADE ANGLES. THE DATA
C      ARRAYS FANDAP CONTAINS THE FOLLOWING INFORMATION-
20     FANDAP(I,J)
C      J=1,5 - COEFFICIENTS FOR THIRD ORDER CURVE FIT OF VOLUMETRIC
C      FLOW RATE VERSUS TOTAL PRESSURE DROP ACROSS
C      THE FAN
C      J=6 - LOWER PRESSURE DROP LIMIT (IN WATER)
25     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=1,53 - DIFFERENT SETS OF DATA FOR EACH FAN AND
30     PERFORMANCE POINT
C      THE DATA ARRAY FANDAH CONTAINS THE FOLLOWING INFORMATION-
C      FANDAH(I,J)
C      J=1,5 - COEFFICIENTS FOR FOURTH ORDER CURVE FIT OF
C      HORSEPOWER VERSUS VOLUMETRIC FLOW RATE
35     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     J=9 - NUMBER OF BLADES PER FAN
C      J=10 - BLADE ANGLE (DEGREES)
C
C      DEFINITION OF VARIABLES
C      A - AIR FLOW AREA OF THE FAN (SQ FT)
45     ARLN - NUMBER OF FAN BLADES (DIMENSIONLESS)
C      ADIA - FAN DIAMETER (FT)
C      ANFCOS - ANNUAL FAN COSTS ($)
C      ANSFPC - ANNUAL CAPITAL COST OF PLENUM, FOUNDATION, AND
C      STRUCTURES ($)
50     ANSFPF - TOTAL ANNUAL COST OF THE FAN SYSTEM AND STRUCTURE
C      BAR - BAROMETRIC PRESSURE (IN HGA)
C      BLDANG - FAN BLADE ANGLE (DEGREES)
C      CAPF - PERCENTAGE OF TIME THE PLANT IS PRODUCING POWER
C      (PERCENT)
55     CDANG - COSINE OF THE ANGLE FOR THE DELTA HEAT EXCHANGER
C      ARRANGEMENT (DIMENSIONLESS)
C      CFM - ESTIMATE OF THE VOLUMETRIC FLOW RATE OF AIR THROUGH

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      C      EACH FAN (CU FT/MIN)
      C      CFROS - FAN STACK COSTS WITH AND WITHOUT VELOCITY RECOVERY
60      C      ($)
      C      CI - CONVERGENCE PARAMETER FOR THE VOLUMETRIC FLOW RATE
      C      THROUGH EACH FAN (DIMENSIONLESS)
      C      CINC - INCREMENTAL VOLUMETRIC FLOW RATE OF AIR USED IN
      C      DETERMINING THE FAN PERFORMANCE POINT (CU FT/MIN)
65      C      CMOT - COST OF FAN MOTORS PER FAN ($)
      C      CPL - COST OF PLENUM FOR THE ENTIRE TOWER SYSTEM ($)
      C      CPM - COST OF PLENUM MATERIAL ($/LBM)
      C      CSR - COST OF THE SPEED REDUCER ($)
      C      CVM - FAN RING MATERIAL UNIT COST ($/LBF)
70      C      DIST - DISTANCE FROM THE CONDENSER ROOM TO THE FIRST
      C      CIRCULAR TOWER (FT)
      C      OPTINW - PRESSURE DROP ACROSS THE HEAT EXCHANGER (IN H2O)
      C      DRGTM - DISTANCE FROM THE SWITCH GEAR TO THE MOTOR (FT)
      C      DTOW - DIAMETER OF THE CIRCULAR TOWERS (FT)
75      C      DTTSG - DISTANCE FROM THE TOWER TO THE SWITCH GEAR (FT)
      C      EFCSE - ESCALATION FACTOR FOR FAN COST (DIMENSIONLESS)
      C      EHR - HEAT RATE OF PLANT (BTU/KW-HR)
      C      ELENG - LENGTH OF HEAT EXCHANGER TUBES (FT)
      C      ELEV - PLANT ELEVATION FROM SEA LEVEL (FT)
80      C      FIAD - FAN DIAMETER (FT)
      C      FANLEC - ELECTRICAL WIRING COSTS FOR THE FAN SYSTEM ($)
      C      FFOCS - PLANT FUEL COST (CENTS/MMBTU)
      C      FCR - FIXED CHARGE RATE ON CAPITAL FOR ONE
      C      YEAR (FRACTIONAL)
85      C      FCST - CAPITAL COST OF THE FAN ($)
      C      FMC - FAN MOTOR COST PER HORSEPOWER FOR MOTORS OF SMALL
      C      HORSEPOWER ($/HP)
      C      FNDG - FOUNDATION COSTS FOR THE CIRCULAR TOWERS ($)
      C      FPOW - POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
90      C      GREFF - GEAR BOX EFFICIENCY OF THE FAN SYSTEM (PERCENT)
      C      H0 -
      C      HER - HEIGHT OF THE FAN RING (FT)
      C      HPAIR - HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
      C      HPPF - HORSEPOWER REQUIREMENTS OF EACH FAN (HP)
85      C      HUBDIA - DIAMETER OF THE FAN HUB (FT)
      C      I - PERFORMANCE POINT OF A FAN (DIMENSIONLESS)
      C      ITMAX - MAXIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
      C      (DIMENSIONLESS)
      C      ITMIN - N
100      C      ITMIN - MINIMUM NUMBER OF TOWERS ALLOWED BY INPUT VARIABLE
      C      (DIMENSIONLESS)
      C      ITOWN - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
      C      LRF,LFE - VARIABLES USED IN SPECIFYING WHICH FANS ARE TO BE
105      C      CONSIDERED FOR USE IN THE FAN SYSTEM
      C      (DIMENSIONLESS)
      C      NOF - NUMBER OF FANS MAKING UP THE FAN SYSTEM
      C      (DIMENSIONLESS)
      C      PFACT - PACKING FACTOR, RATIO OF CIRCULAR TOWER ROOF AREA
110      C      TO FAN SWEEP AREA (DIMENSIONLESS)
      C      PLANC - BASE PLANT COSTS ($/KW)
      C      POHFAN - INDIRECT COST FACTOR FOR FANS (DECIMAL)
      C      POHSTC - INDIRECT COST FACTOR FOR CIRCULAR TOWER STRUCTURES
      C      (DECIMAL)
      C      ROOFL - CIRCULAR TOWER ROOF LOAD (LBF/SQ FT)

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SUBROUTINE FAN

74/74 OPT=1

FTN 4.2+74351

12/18/76

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115      C      SAAF - SHIPPING AND ASSEMBLY FACTOR (DECIMAL)
          C      SPVOL - SPECIFIC VOLUME OF THE AIR EXITING THE HEAT
          C            EXCHANGER (LBM/CU FT)
          C      STRUCC - CIRCULAR TOWER STRUCTURE COST ($)
          C      TAN19 - TANGENT OF 19 DEGREES TO BE USED IN COSTING OF
120      C            ENTRY BELL TO THE FAN (DECIMAL)
          C      TAN 8 - TANGENT OF 8 DEGREES TO BE USED IN COSTING OF EXIT
          C            STACK FROM THE FAN (DECIMAL)
          C      TCSTF - TOTAL COST OF THE FAN SYSTEM ($)
          C      TCSTPF - TOTAL COST OF A FAN ($)
125      C      TOTCFM - TOTAL VOLUMETRIC FLOW RATE FOR THE AIR THROUGH
          C            THE FAN SYSTEM (CU FT/MIN)
          C      TOTHP - TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM (HP)
          C      TP - TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN (IN H2O)
          C      T4 - AIR EXIT TEMPERATURE FROM THE HEAT EXCHANGER
130      C            (DEG F)
          C      UCS - UNIT COST OF THE STACK ($/LBF)
          C      UWS - UNIT WEIGHT OF THE STACK (LBF/CU FT)
          C      VEL - AVERAGE VELOCITY OF THE AIR LEAVING THE FAN
          C            (FT/SEC)
135      C      VELREC - SPECIFIES WHETHER VELOCITY RECOVERY STACKS ARE
          C            GOING TO BE USED OR NOT (DIMENSIONLESS)
          C      V0 - NON RECOVERABLE AIR VELOCITY HEAT EXITING THE FAN
          C            (IN H2O)
          C      WATERW - WEIGHT OF WATER IN THE HEAT EXCHANGER TUBES AND
140      C            BUNDLES (LBF)
          C      WEV - UNIT WEIGHT OF THE ENTRY BELL (LBF/SQ FT)
          C      WEX - 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      W4 - MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER
          C            (LBM/HR)
          C      XNFAN - NUMBER OF FANS (DIMENSIONLESS)

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150      REAL NOF
          LOGICAL LOOPER
          COMMON/FAN/ FANDAP(153,10),FANDAH(153,10),FMCPP,FBCPP,P2,R,S,
          $ VELREC, AFC, ELEV, SHR, LOOPER, CTMAX
          LOGICAL FIRST, FTEMP
          COMMON
155      $ AFTR, ALPHA, ANG(3)
          $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONM42,CAFI
          $ ,CBU, CTURB, CDANG, CLUVR, CHALS, CVM
          $ ,DANGLE, OFIN, DEEPL, DESVEL, DESVELV
          $ ,EFPF
160      $ ,FCR, FIRST, FIXL, FCOS, FFHX, FTEMP
          $ ,GBEFP
          $ ,HXNP, HPCST
          $ ,ITMAX, ITMIN
          $ ,JCONS
165      $ ,KCONV, KALEXT
          $ ,MXEXT
          $ ,NTUCAL(2), NTA
          COMMON
          $ DOR
170      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
          $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC

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$ , RSP, REDUCE, REDUCV, ROOFL
$ , PREJ, QREDUCE, QREDUCV
$ , SIGMAG, SAAF
175 $ , TJ, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
$ , TCD, TW
$ , UCS, UWS
$ , WFW
$ , VAS(5)
180 $ , XJED, XW, XD
COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOs, W3, COSM, EFF,
$ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
$ FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
185 $ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
$ SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCO, PSIZ13, WT2,
$ B02, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
$ , TLAX, UCON, FMCST, FMCST, KHACC, EFFC, CH, CA, CS
$ , CLTC, CFC, CPOC, FITC, CSC, CEPREP, DELPIP, AST, OLDCST
190 $ , CAPCST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTTUB, ADIA, ABLN
$ , WTHDR, WTERM, STRUCC, CPERF, HPERF, TOTCF, TPC, EFFIN, ANTU
$ , AIRFF, WATFF, XNMOD, TCTPF, FDCPF, FMTRC, ACCTP, ADJTP
$ , ACTRBD, ADJBD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTP, AFCST
$ , CSR0, WATERW, WSTRCT, CFOJND, HUBDIA, TOWLEN, NUMTOW, CTOWD
195 $ , SQRJ, SQRJS, ATUBC, CBA, ITD1, ITD2, DELPS, CSTLVR
$ , CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
COMMON /SCALER/ HRFAC1, ATUB, CPERA, SSCO, PLANC1, CASSS1,
$ GAIR, FAIR, HPAIR, HPWAT, WLRTT, PLANC1
COMMON /HEADEX/ CHH, CN, CHM, CMW, CRJ, CWJ, CST, CMO, CSR, CSM, PITCHF, CPM,
$ PRESS, HEDMAT, HEDTYP, NPASS, WB
200 COMMON /ENLOOP/ LFR, LFE
COMMON /PLCOST/ WPL
COMMON /INDIS/ DIST
COMMON /PME/ PMELEC
205 DATA (FANDAP( 1,J),J=1,10) /
$ .7961 ,.6520 ,-.6.316 ,.11.944 ,-.8.252 ,
$ .13 ,.625 ,.24. , 5. , 6. /
DATA (FANDAP( 2,J),J=1,10) /
210 $ 1.059 ,-.8172 ,-.1262 ,.2533 ,-.2331 ,
$ .25 ,.765 ,.24. , 6. , 8. /
DATA (FANDAP( 3,J),J=1,10) /
$ 1.346 ,-.1.635 ,1.585 ,-.1.666 ,.5886 ,
$ .31 ,.91 ,.24. , 6. , 10. /
DATA (FANDAP( 4,J),J=1,10) /
215 $ .5943 ,4.692 ,-.14.335 ,.15.960 ,-.6.562 ,
$ .365 ,.94 ,.24. , 6. , 12. /
DATA (FANDAP( 5,J),J=1,10) /
$ .4015 ,5.087 ,-.16.629 ,.17.327 ,-.6.713 ,
$ .42 ,.98 ,.24. , 6. , 14. /
DATA (FANDAP( 6,J),J=1,10) /
220 $ 1.337 ,.9315 ,-.4.655 ,.5.368 ,-.2.424 ,
$ .477 ,.95 ,.24. , 6. , 16. /
DATA (FANDAP( 7,J),J=1,10) /
$ -3.074 ,26.409 ,-.57.905 ,.54.455 ,-.19.277 ,
$ .532 ,1.01 ,.24. , 6. , 18. /
DATA (FANDAP( 8,J),J=1,10) /
225 $ 1.226 ,.3.829 ,-.11.905 ,.12.904 ,-.5.303 ,
$ .605 ,.98 ,.24. , 6. , 20. /
DATA (FANDAP( 9,J),J=1,10) /

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230      $ -17.129 ,96.0 , -132.414 ,152.343 , -47.879 ,
      $ .59 ,1.015 , 24. , 6. , 22. /
      DATA (FANDAP( 10,J),J=1,10) /
      $ .9109 ,-.6216 ,-.0575 ,.09596 ,-.0758 ,
      $ .205 ,.795 , 24. , 8. , 6. /
235      DATA (FANDAP( 11,J),J=1,10) /
      $ 1.069 ,-.7222 ,.0581 ,.0384 ,-.0676 ,
      $ .254 ,.969 , 24. , 8. , 5. /
      DATA (FANDAP( 12,J),J=1,10) /
      $ 1.194 ,-.6385 ,-.0933 ,.01957 ,-.00947 ,
      $ .327 ,1.139 , 24. , 8. , 10. /
240      DATA (FANDAP( 13,J),J=1,10) /
      $ 1.442 ,-.1399 ,1.550 , -1.419 ,.4356 ,
      $ .393 ,1.12 , 24. , 8. , 12. /
      DATA (FANDAP( 14,J),J=1,10) /
245      $ .4597 ,4.639 , -10.373 ,3.728 , -2.719 ,
      $ .445 ,1.21 , 24. , 8. , 14. /
      DATA (FANDAP( 15,J),J=1,10) /
      $ 1.532 ,-.5932 ,-.5343 ,.6805 ,-.3261 ,
      $ .529 ,1.14 , 24. , 8. , 16. /
250      DATA (FANDAP( 16,J),J=1,10) /
      $ .244 ,7.202 , -14.895 ,12.133 , -3.683 ,
      $ .612 ,1.25 , 24. , 8. , 18. /
      DATA (FANDAP( 17,J),J=1,10) /
255      $ 2.321 , -2.232 ,1.862 ,-.7451 ,-.0714 ,
      $ .634 ,1.15 , 24. , 8. , 20. /
      DATA (FANDAP( 18,J),J=1,10) /
      $ -12.149 ,55.65 , -33.947 ,55.657 , -13.939 ,
      $ .766 ,1.24 , 24. , 8. , 22. /
260      DATA (FANDAP( 19,J),J=1,10) /
      $ .8525 ,-.2121 ,-.6814 ,.5934 ,-.1894 ,
      $ .214 ,.95 , 24. , 10. , 6. /
      DATA (FANDAP( 20,J),J=1,10) /
265      $ 1.307 , -2.057 ,3.129 , -2.760 ,.8712 ,
      $ .275 ,1.15 , 24. , 10. , 8. /
      DATA (FANDAP( 21,J),J=1,10) /
      $ 1.140 ,-.3050 ,-.4077 ,.2543 ,-.0612 ,
      $ .34 ,1.365 , 24. , 10. , 10. /
270      DATA (FANDAP( 22,J),J=1,10) /
      $ 1.511 ,-.1516 ,-.5855 ,.3418 ,-.07576 ,
      $ .397 ,1.34 , 24. , 10. , 12. /
      DATA (FANDAP( 23,J),J=1,10) /
275      $ 1.247 ,.0813 ,-.5502 ,.1955 ,-.01166 ,
      $ .465 ,1.4 , 24. , 10. , 14. /
      DATA (FANDAP( 24,J),J=1,10) /
      $ 1.314 ,.5641 , -1.534 ,.8592 ,-.1989 ,
      $ .55 ,1.37 , 24. , 10. , 16. /
280      DATA (FANDAP( 25,J),J=1,10) /
      $ .5757 ,4.363 , -7.5248 ,4.961 , -1.231 ,
      $ .652 ,1.53 , 24. , 10. , 18. /
      DATA (FANDAP( 26,J),J=1,10) /
285      $ -.075 ,6.982 , -10.783 ,6.833 , -1.667 ,
      $ .745 ,1.44 , 24. , 10. , 20. /
      DATA (FANDAP( 27,J),J=1,10) /
      $ -158.296 ,548.34 , -659.02 ,350.82 , -69.909 ,
      $ 1.02 ,1.48 , 24. , 10. , 22. /
      DATA (FANDAP( 28,J),J=1,10) /

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$ 1.090      ,1.005      ,.2432      ,.1717      ,1.515
$ .205      ,.55      , 26. , 6. , 6. /
  DATA (FANDAP( 29,J),J=1,10) /
590 $ 1.144      ,-.0621      ,3.590      ,5.245      ,4.382
$ .248      ,.66      , 26. , 6. , 8. /
  DATA (FANDAP( 30,J),J=1,10) /
$ 1.196      ,.1327      ,2.291      ,1.492      ,.2797
$ .235      ,.778      , 26. , 6. , 10. /
  DATA (FANDAP( 31,J),J=1,10) /
595 $ 1.376      ,1.413      ,1.077      ,.8904      ,.2331
$ .35      ,.84      , 26. , 6. , 12. /
  DATA (FANDAP( 32,J),J=1,10) /
$ -.3974      ,13.678      ,38.403      ,44.263      ,19.254
$ .41      ,.87      , 26. , 6. , 14. /
  DATA (FANDAP( 33,J),J=1,10) /
300 $ 2.497      ,4.479      ,5.789      ,2.571      ,1.061
$ .456      ,.85      , 26. , 6. , 16. /
  DATA (FANDAP( 34,J),J=1,10) /
$ -31.553      ,200.29      ,450.42      ,445.5      ,164.67
305 $ .525      ,.89      , 26. , 6. , 18. /
  DATA (FANDAP( 35,J),J=1,10) /
$ -37.986      ,229.06      ,493.08      ,468.48      ,166.93
$ .585      ,.88      , 26. , 6. , 20. /
  DATA (FANDAP( 36,J),J=1,10) /
310 $ 199.88      ,940.76      ,1563.3      ,1295.8      ,373.75
$ .65      ,.99      , 26. , 6. , 22. /
  DATA (FANDAP( 37,J),J=1,10) /
$ 1.166      ,1.456      ,2.750      ,4.222      ,1.818
$ .22      ,.605      , 26. , 8. , 6. /
  DATA (FANDAP( 38,J),J=1,10) /
315 $ 1.178      ,-.1032      ,2.070      ,3.033      ,1.935
$ .275      ,.755      , 26. , 8. , 8. /
  DATA (FANDAP( 39,J),J=1,10) /
$ 1.431      ,-.9074      ,.04604      ,.5361      ,.6993
320 $ .333      ,.885      , 26. , 8. , 10. /
  DATA (FANDAP( 40,J),J=1,10) /
$ 1.330      ,.5823      ,3.195      ,3.499      ,1.643
$ .39      ,.985      , 26. , 8. , 12. /
  DATA (FANDAP( 41,J),J=1,10) /
325 $ .8602      ,3.760      ,8.974      ,7.814      ,2.768
$ .45      ,1.083      , 26. , 8. , 14. /
  DATA (FANDAP( 42,J),J=1,10) /
$ 1.929      ,-.6431      ,.5595      ,.9619      ,.6993
$ .518      ,1.03      , 26. , 8. , 16. /
  DATA (FANDAP( 43,J),J=1,10) /
330 $ -6.905      ,44.885      ,87.056      ,72.668      ,22.635
$ .586      ,1.14      , 26. , 8. , 18. /
  DATA (FANDAP( 44,J),J=1,10) /
$ -13.827      ,76.312      ,138.97      ,111.051      ,33.333
335 $ .65      ,1.06      , 26. , 8. , 20. /
  DATA (FANDAP( 45,J),J=1,10) /
$ -14.507      ,68.914      ,108.62      ,75.63      ,20.0
$ .74      ,1.125      , 26. , 8. , 22. /
  DATA (FANDAP( 46,J),J=1,10) /
340 $ 1.084      ,-.5941      ,.3743      ,.5713      ,.2083
$ .23      ,.78      , 26. , 11. , 6. /
  DATA (FANDAP( 47,J),J=1,10) /

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      $ 1.284      ,-.9293      ,.9885      ,-.10506      ,.303      ,
      $ .29      ,.98      , 25.      , 11.      , 8. /
345      DATA (FANDAP( 48,J),J=1,10) /
      $ 1.320      ,-.09006      ,-.1.233      ,.1.396      ,-.6345      ,
      $ .255      ,.1.15      , 26.      , 11.      , 10. /
      DATA (FANDAP( 49,J),J=1,10) /
350      $ 1.385      ,.3155      ,-.1.958      ,.1.880      ,-.7164      ,
      $ .415      ,.1.28      , 26.      , 11.      , 12. /
      DATA (FANDAP( 50,J),J=1,10) /
      $ 1.376      ,.7735      ,-.2.250      ,.1.701      ,-.5449      ,
      $ .49      ,.1.415      , 26.      , 11.      , 14. /
      DATA (FANDAP( 51,J),J=1,10) /
355      $ .4584      ,.5.911      ,-.11.267      ,.8.504      ,-.2.414      ,
      $ .57      ,.1.444      , 26.      , 11.      , 16. /
      DATA (FANDAP( 52,J),J=1,10) /
      $ -.6.273      ,.34.035      ,-.53.2655      ,.35.675      ,-.8.8359      ,
      $ .63      ,.1.525      , 26.      , 11.      , 18. /
      DATA (FANDAP( 53,J),J=1,10) /
360      $ -.25.743      ,.103.427      ,-.144.837      ,.89.298      ,-.20.622      ,
      $ .75      ,.1.38      , 25.      , 11.      , 20. /
      DATA (FANDAP( 54,J),J=1,10) /
365      $ -.67.994      ,.225.328      ,-.273.144      ,.146.373      ,-.29.455      ,
      $ 1.11      ,.1.46      , 26.      , 11.      , 22. /
      DATA (FANDAP( 55,J),J=1,10) /
      $ 1.141      ,-.331      ,-.1.453      ,-.1.591      ,.2.453      ,
      $ .19      ,.54      , 28.      , 6.      , 6. /
      DATA (FANDAP( 56,J),J=1,10) /
370      $ 1.045      ,.2.745      ,-.16.574      ,.30.038      ,-.20.517      ,
      $ .23      ,.63      , 28.      , 5.      , 9. /
      DATA (FANDAP( 57,J),J=1,10) /
      $ .9281      ,.5.303      ,-.23.573      ,.36.246      ,-.20.781      ,
      $ .23      ,.71      , 28.      , 5.      , 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) /
380      $ -.3.092      ,.37.837      ,-.111.734      ,.139.178      ,-.64.532      ,
      $ .39      ,.78      , 28.      , 6.      , 14. /
      DATA (FANDAP( 60,J),J=1,10) /
      $ -.1.430      ,.26.222      ,-.79.847      ,.102.926      ,-.50.00      ,
      $ .435      ,.72      , 28.      , 5.      , 16. /
      DATA (FANDAP( 61,J),J=1,10) /
385      $ -.22.914      ,.167.722      ,-.422.735      ,.467.633      ,-.193.335      ,
      $ .49      ,.785      , 28.      , 6.      , 18. /
      DATA (FANDAP( 62,J),J=1,10) /
      $ -.4.125      ,.46.711      ,-.131.308      ,.158.511      ,-.71.4578      ,
      $ .53      ,.73      , 28.      , 5.      , 20. /
      DATA (FANDAP( 63,J),J=1,10) /
390      $ -.99.242      ,.607.746      ,-.1365.6      ,.1350.4      ,-.508.349      ,
      $ .59      ,.79      , 28.      , 6.      , 22. /
      DATA (FANDAP( 64,J),J=1,10) /
395      $ 1.149      ,-.0283      ,-.3.051      ,.3.750      ,-.1.911      ,
      $ .20      ,.67      , 28.      , 9.      , 6. /
      DATA (FANDAP( 65,J),J=1,10) /
      $ 1.336      ,-.4003      ,-.2.450      ,.3.275      ,-.1.655      ,
      $ .235      ,.79      , 28.      , 8.      , 8. /
      DATA (FANDAP( 66,J),J=1,10) /

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400      $ 1.479      ,-.4131      ,-.8639      ,5.0806      ,.3017      ,
      $ .3          ,.9          , 28. , 8. , 10. /
      DATA (FANDAP( 67,J),J=1,10) /
      $ 1.542      ,1.115      ,-.6.369      ,9.507      ,-.4.843      ,
      $ .35        ,.9          , 28. , 8. , 12. /
405      DATA (FANDAP( 68,J),J=1,10) /
      $ .4543      ,9.668      ,-.26.857      ,28.991      ,-.11.655      ,
      $ .44        ,.98        , 28. , 9. , 14. /
      DATA (FANDAP( 69,J),J=1,10) /
      $ -.1495      ,13.991      ,-.36.402      ,38.619      ,-.15.385      ,
410      $ .49      ,.94      , 28. , 8. , 15. /
      DATA (FANDAP( 70,J),J=1,10) /
      $ -1.626      ,22.206      ,-.51.295      ,49.975      ,-.18.322      ,
      $ .557      ,.98      , 28. , 8. , 18. /
      DATA (FANDAP( 71,J),J=1,10) /
415      $ -15.419      ,94.430      ,-.191.291      ,170.303      ,-.56.97      ,
      $ .6          ,.96        , 28. , 8. , 20. /
      DATA (FANDAP( 72,J),J=1,10) /
      $ -132.795      ,850.555      ,-.1466.4      ,1121.9      ,-.321.938      ,
      $ .8          ,1.01        , 28. , 8. , 22. /
420      DATA (FANDAP( 73,J),J=1,10) /
      $ 1.907      ,-.8.155      ,26.542      ,-.39.870      ,20.833      ,
      $ .203      ,.72      , 23. , 9. , 5. /
      DATA (FANDAP( 74,J),J=1,10) /
      $ 1.707      ,-.2.471      ,.5.482      ,-.7.257      ,-.3.078      ,
425      $ .3          ,.1.025      , 28. , 9. , 10. /
      DATA (FANDAP( 75,J),J=1,10) /
      $ -5.491      ,43.171      ,-.95.661      ,90.264      ,-.31.495      ,
      $ .443      ,1.045      , 28. , 9. , 14. /
      DATA (FANDAP( 76,J),J=1,10) /
430      $ -11.476      ,71.058      ,-.139.528      ,119.048      ,-.37.792      ,
      $ .355      ,1.08      , 28. , 9. , 18. /
      DATA (FANDAP( 77,J),J=1,10) /
      $ -111.138      ,485.02      ,-.778.16      ,553.442      ,-.147.595      ,
      $ .67      ,1.11      , 28. , 9. , 22. /
435      DATA (FANDAP( 78,J),J=1,10) /
      $ .9182      ,-.6397      ,.1263      ,-.1.283      ,1.08      ,
      $ .118      ,.54      , 28. , 10. , 2. /
      DATA (FANDAP( 79,J),J=1,10) /
      $ 1.191      ,-.5515      ,-.046      ,-.974      ,.6976      ,
440      $ .2          ,.8          , 28. , 10. , 5. /
      DATA (FANDAP( 80,J),J=1,10) /
      $ 1.478      ,-.2616      ,-.2.549      ,3.408      ,-.1.70      ,
      $ .31      ,1.03      , 28. , 10. , 10. /
      DATA (FANDAP( 81,J),J=1,10) /
445      $ 0.4844      ,8.207      ,-.20.171      ,19.338      ,-.6.894      ,
      $ .45      ,1.15      , 28. , 10. , 14. /
      DATA (FANDAP( 82,J),J=1,10) /
      $ -12.855      ,75.341      ,-.141.915      ,115.921      ,-.35.119      ,
      $ .53      ,1.17      , 28. , 10. , 18. /
450      DATA (FANDAP( 83,J),J=1,10) /
      $ -131.140      ,528.522      ,-.784.764      ,516.323      ,-.127.273      ,
      $ .71      ,1.21      , 28. , 10. , 22. /
      DATA (FANDAP( 84,J),J=1,10) /
      $ .9124      ,-.6355      ,.3496      ,-.1.159      ,.7755      ,
455      $ .122      ,.64      , 28. , 12. , 2. /
      DATA (FANDAP( 85,J),J=1,10) /

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      $ 1.205      ,-.51      ,.1897      ,-.1.018      ,.6163      ,
      $ .215      ,.94      , 28. , 12. , 6. /
      DATA (FANDAP( 86,J),J=1,10) /
460  $ 1.504      ,-.1562      ,-.1.506      ,.1.699      ,-.7334      ,
      $ .33      ,1.2      , 28. , 12. , 10. /
      DATA (FANDAP( 87,J),J=1,10) /
      $ .6086      ,6.967      ,-.15.551      ,.13.341      ,-.4.216      ,
465  $ .49      ,1.32      , 28. , 12. , 14. /
      DATA (FANDAP( 88,J),J=1,10) /
      $ 1.227      ,4.415      ,-.9.275      ,.7.309      ,-.2.178      ,
      $ .62      ,1.44      , 28. , 12. , 18. /
      DATA (FANDAP( 89,J),J=1,10) /
470  $ 1.036      ,-.4416      ,-.6.142      ,.15.126      ,-.14.698      ,
      $ .12      ,.38      , 30. , 8. , 2. /
      DATA (FANDAP( 90,J),J=1,10) /
      $ 2.034      ,-.5.822      ,.13.159      ,-.16.404      ,.6.562      ,
      $ .22      ,.64      , 30. , 9. , 6. /
      DATA (FANDAP( 91,J),J=1,10) /
475  $ 1.109      ,6.519      ,-.26.233      ,.35.842      ,-.18.121      ,
      $ .32      ,.79      , 30. , 8. , 10. /
      DATA (FANDAP( 92,J),J=1,10) /
      $ -9.482      ,76.036      ,-.183.916      ,.190.216      ,-.73.502      ,
480  $ .49      ,.85      , 30. , 8. , 14. /
      DATA (FANDAP( 93,J),J=1,10) /
      $ -1009.5      ,5246.17      ,-.10189.02      ,.8781.48      ,-.2836.03      ,
      $ .7      ,.88      , 30. , 8. , 18. /
      DATA (FANDAP( 94,J),J=1,10) /
485  $ 5.9445      ,-.4.875      ,.0.      ,.0.      ,.0.      ,
      $ .88      ,.91      , 30. , 8. , 22. /
      DATA (FANDAP( 95,J),J=1,10) /
      $ 1.055      ,-.7416      ,-.2.354      ,.5.096      ,-.6.699      ,
      $ .12      ,.4      , 30. , 10. , 2. /
      DATA (FANDAP( 96,J),J=1,10) /
490  $ 1.511      ,-.1.705      ,.1.163      ,-.1.643      ,.7516      ,
      $ .23      ,.7      , 30. , 10. , 6. /
      DATA (FANDAP( 97,J),J=1,10) /
      $ .5192      ,3.050      ,-.26.526      ,.29.287      ,-.12.683      ,
495  $ .34      ,.9      , 30. , 10. , 10. /
      DATA (FANDAP( 98,J),J=1,10) /
      $ -9.716      ,71.057      ,-.157.956      ,.150.679      ,-.53.458      ,
      $ .46      ,1.0      , 30. , 10. , 14. /
      DATA (FANDAP( 99,J),J=1,10) /
500  $ -504.715      ,2239.6      ,-.3604.36      ,.2607.84      ,-.706.956      ,
      $ .82      ,1.045      , 30. , 10. , 18. /
      DATA (FANDAP(100,J),J=1,10) /
      $ -3515.6      ,13939.07      ,-.20708.7      ,.13672.5      ,-.3385.42      ,
      $ .97      ,1.08      , 30. , 10. , 22. /
      DATA (FANDAP(101,J),J=1,10) /
505  $ 1.076      ,-.9295      ,-.3826      ,.4669      ,-.8643      ,
      $ .12      ,.44      , 30. , 11. , 2. /
      DATA (FANDAP(102,J),J=1,10) /
      $ 1.555      ,-.1.09      ,-.4653      ,.5259      ,-.2670      ,
510  $ .24      ,.765      , 30. , 11. , 6. /
      DATA (FANDAP(103,J),J=1,10) /
      $ .9216      ,6.142      ,-.18.702      ,.18.968      ,-.7.415      ,
      $ .35      ,.98      , 30. , 11. , 10. /
      DATA (FANDAP(104,J),J=1,10) /

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515      $ -13.274 ,109.841 , -218.930 ,188.787 , -60.351 ,
      $ .576 ,1.07 , , 30. , 11. , 14. /
      DATA (FANDAP(105,J),J=1,10) /
      $ -3000.2 ,12053.9 , -18124.3 ,12096.4 , -3024.19 ,
      $ .917 ,1.11 , , 30. , 11. , 18. /
      DATA (FANDAP(106,J),J=1,10) /
520      $ -39.918 ,78.558 , -36.938 ,0.0 , 0.0 ,
      $ 1.07 ,1.16 , , 30. , 11. , 22. /
      DATA (FANDAP(107,J),J=1,10) /
      $ 1.032 , -2723 , -3.275 ,5.874 , -5.731 ,
      $ .125 ,.485 , , 30. , 12. , 2. /
525      DATA (FANDAP(108,J),J=1,10) /
      $ 1.523 , -8049 , -869 ,.9265 , -397 ,
      $ .245 ,.83 , , 30. , 12. , 5. /
      DATA (FANDAP(109,J),J=1,10) /
530      $ 1.151 ,.4199 , -12.180 ,11.996 , -4.465 ,
      $ .35 ,1.05 , , 30. , 12. , 10. /
      DATA (FANDAP(110,J),J=1,10) /
      $ -14.085 ,93.829 , -160.649 ,132.788 , -40.673 ,
      $ .51 ,1.14 , , 30. , 12. , 14. /
      DATA (FANDAP(111,J),J=1,10) /
535      $ -4789.04 ,17939.56 , -25154.2 ,15654.5 , -3648.91 ,
      $ .978 ,1.19 , , 30. , 12. , 18. /
      DATA (FANDAP(112,J),J=1,10) /
      $ 1.376 , -1365 , -15.858 ,53.187 , -69.015 ,
      $ .13 ,.365 , , 30. , 12. , 2. /
540      DATA (FANDAP(113,J),J=1,10) /
      $ 2.508 , -2.762 ,5.513 , -15.566 ,9.394 ,
      $ .225 ,.64 , , 40. , 8. , 6. /
      DATA (FANDAP(114,J),J=1,10) /
545      $ 1.969 ,6.766 , -22.052 ,24.257 , -11.119 ,
      $ .32 ,.83 , , 40. , 8. , 10. /
      DATA (FANDAP(115,J),J=1,10) /
      $ -6.169 ,63.616 , -156.602 ,163.373 , -63.846 ,
      $ .447 ,.91 , , 40. , 8. , 14. /
      DATA (FANDAP(116,J),J=1,10) /
550      $ -5.464 ,55.577 , -127.737 ,128.57 , -49.557 ,
      $ .54 ,.96 , , 40. , 8. , 18. /
      DATA (FANDAP(117,J),J=1,10) /
      $ -191.005 ,955.903 , -1748.194 ,1419.63 , -433.33 ,
      $ .675 ,1.0 , , 40. , 8. , 22. /
555      DATA (FANDAP(118,J),J=1,10) /
      $ 1.802 ,.454 , -11.977 ,27.924 , -27.683 ,
      $ .14 ,.38 , , 40. , 10. , 2. /
      DATA (FANDAP(119,J),J=1,10) /
560      $ 2.222 ,2.029 , -9.762 ,10.841 , -5.528 ,
      $ .253 ,.72 , , 40. , 10. , 6. /
      DATA (FANDAP(120,J),J=1,10) /
      $ 1.717 ,10.358 , -31.846 ,36.638 , -16.245 ,
      $ .357 ,.92 , , 40. , 10. , 10. /
      DATA (FANDAP(121,J),J=1,10) /
565      $ -10.728 ,85.651 , -189.552 ,179.696 , -63.371 ,
      $ .495 ,1.02 , , 40. , 10. , 14. /
      DATA (FANDAP(122,J),J=1,10) /
      $ -90.812 ,472.054 , -875.215 ,713.056 , -216.564 ,
      $ .59 ,1.073 , , 40. , 10. , 18. /
570      DATA (FANDAP(123,J),J=1,10) /

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$ -251.345 ,1060.7 , -1650.93 ,1141.51 , -296.667 ,
$ .80 ,1.127 , 40. , 10. , 22. /
DATA (FANDAP(124,J),J=1,10) /
575 $ 1.920 , -1.695 ,3.019 , -8.274 ,3.907 ,
$ .14 ,.44 , 40. , 12. , 2. /
DATA (FANDAP(125,J),J=1,10) /
$ 2.561 , -1.195 ,.1299 ,.1.262 ,.399 ,
$ .255 ,.84 , 40. , 12. , 6. /
DATA (FANDAP(126,J),J=1,10) /
580 $ .4204 ,17.453 , -43.194 ,42.370 , -15.566 ,
$ .39 ,1.06 , 40. , 12. , 10. /
DATA (FANDAP(127,J),J=1,10) /
$ -11.44 ,76.814 , -145.243 ,117.676 , -35.539 ,
$ .52 ,1.17 , 40. , 12. , 14. /
DATA (FANDAP(128,J),J=1,10) /
585 $ -7.134 ,51.677 , -90.399 ,58.768 , -19.929 ,
$ .635 ,1.24 , 40. , 12. , 18. /
DATA (FANDAP(129,J),J=1,10) /
$ -448.199 ,1598.46 , -2116.83 ,1245.43 , -275.191 ,
590 $ .99 ,1.3 , 40. , 12. , 22. /
DATA (FANDAP(130,J),J=1,10) /
$ 1.843 , -0.7846 , -6.985 ,17.722 , -17.908 ,
$ .145 ,.48 , 40. , 14. , 2. /
DATA (FANDAP(131,J),J=1,10) /
595 $ 2.525 ,1.142 ,.7597 , -2.214 ,1.017 ,
$ .27 ,.93 , 40. , 14. , 6. /
DATA (FANDAP(132,J),J=1,10) /
$ .9452 ,13.03 , -29.035 ,25.619 , -8.539 ,
$ .40 ,1.19 , 40. , 14. , 10. /
DATA (FANDAP(133,J),J=1,10) /
600 $ -3.555 ,39.492 , -78.853 ,64.69 , -19.54 ,
$ .573 ,1.28 , 40. , 14. , 14. /
DATA (FANDAP(134,J),J=1,10) /
$ -39.196 ,178.576 , -272.965 ,181.609 , -44.911 ,
605 $ .68 ,1.35 , 40. , 14. , 18. /
DATA (FANDAP(135,J),J=1,10) /
$ -118.82 ,406.731 , -504.396 ,278.236 , -57.944 ,
$ .85 ,1.435 , 40. , 14. , 22. /
DATA (FANDAP(136,J),J=1,10) /
610 $ 4.988 , -2.081 , -24.207 ,55.248 , -45.947 ,
$ .155 ,.492 , 60. , 12. , 4. /
DATA (FANDAP(137,J),J=1,10) /
$ 5.529 , -2.277 , -27.832 ,50.082 , -33.677 ,
$ .195 ,.59 , 60. , 12. , 6. /
DATA (FANDAP(138,J),J=1,10) /
615 $ 2.058 ,39.609 , -157.75 ,240.715 , -137.116 ,
$ .235 ,.66 , 60. , 12. , 8. /
DATA (FANDAP(139,J),J=1,10) /
$ 2.544 ,37.353 , -146.207 ,215.777 , -119.45 ,
620 $ .28 ,.73 , 60. , 12. , 10. /
DATA (FANDAP(140,J),J=1,10) /
$ -41.658 ,396.76 , -1195.8 ,1548.1 , -740.92 ,
$ .333 ,.744 , 50. , 12. , 12. /
DATA (FANDAP(141,J),J=1,10) /
625 $ -7.944 ,124.78 , -369.35 ,456.25 , -210.91 ,
$ .397 ,.76 , 60. , 12. , 14. /
DATA (FANDAP(142,J),J=1,10) /

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      $ -40.774 ,349.5 , -929.9 ,1076.8 , -468.43 ,
      $ .43 , .76 , 60. , 12. , 16. /
630 DATA (FANDAP(143,J),J=1,10) /
      $ -1519.9 ,9661.7 , -21438.7 ,21080.3 , -7758.4 ,
      $ .51 , .786 , 60. , 12. , 18. /
      DATA (FANDAP(144,J),J=1,10) /
635 $ 4.129 , -3.795 , .7758 , -8.697 , 8.977 ,
      $ .12 , .48 , 60. , 16. , 2. /
      DATA (FANDAP(145,J),J=1,10) /
      $ 4.304 , -3.225 , -1.142 , -3.317 , 2.953 ,
      $ .134 , .52 , 60. , 16. , 4. /
      DATA (FANDAP(146,J),J=1,10) /
640 $ 5.296 , -8.809 , -9.21 , 8.711 , -3.366 ,
      $ .232 , .76 , 60. , 16. , 6. /
      DATA (FANDAP(147,J),J=1,10) /
      $ 6.2175 , -3.071 , -1.696 , -2.459 , 2.489 ,
      $ .25 , .76 , 60. , 16. , 8. /
645 DATA (FANDAP(148,J),J=1,10) /
      $ 5.008 , 14.169 , -55.056 , 68.651 , -31.903 ,
      $ .31 , .93 , 60. , 16. , 10. /
      DATA (FANDAP(149,J),J=1,10) /
650 $ 5.304 , 13.941 , -45.551 , 47.755 , -19.574 ,
      $ .356 , .90 , 60. , 16. , 12. /
      DATA (FANDAP(150,J),J=1,10) /
      $ -34.33 , 265.14 , -612.11 , 604.01 , -220.51 ,
      $ .435 , .98 , 60. , 16. , 14. /
655 DATA (FANDAP(151,J),J=1,10) /
      $ 25.353 , -96.07 , 197.51 , -185.15 , 62.299 ,
      $ .43 , .91 , 60. , 16. , 16. /
      DATA (FANDAP(152,J),J=1,10) /
660 $ -220.25 , 1153.5 , -2169. , 1802.6 , -562.09 ,
      $ .55 , .98 , 60. , 16. , 18. /
      DATA (FANDAP(153,J),J=1,10) /
      $ -390.836 , 841.7 , -445.22 , 0.0 , 0.0 ,
      $ .95 , 1.0 , 60. , 16. , 22. /
665 DATA (FANDAH( 1,J),J=1,10) /
      $ -93.866 , 983.678 , -2376.14 , 2520.20 , -1060.61 ,
      $ 400000. , 760000. , 24. , 6. , 6. /
      DATA (FANDAH( 2,J),J=1,10) /
      $ 7.793 , 288.38 , -481.24 , 349.65 , -139.86 ,
      $ 400000. , 860000. , 24. , 6. , 8. /
670 DATA (FANDAH( 3,J),J=1,10) /
      $ -115.79 , 1005.09 , -1846.07 , 1498.74 , -486.6 ,
      $ 400000. , 950000. , 24. , 6. , 10. /
      DATA (FANDAH( 4,J),J=1,10) /
      $ 30.754 , -163.62 , 729.59 , -848.42 , 281.78 ,
      $ 400000. , 1025000. , 24. , 6. , 12. /
675 DATA (FANDAH( 5,J),J=1,10) /
      $ 155.94 , -527.75 , 1464.58 , -1447.9 , 460.03 ,
      $ 400000. , 1100000. , 24. , 6. , 14. /
      DATA (FANDAH( 6,J),J=1,10) /
680 $ -195.42 , 1138.28 , -1400.75 , 749.91 , -163.17 ,
      $ 650000. , 1180000. , 24. , 6. , 16. /
      DATA (FANDAH( 7,J),J=1,10) /
      $ 205.61 , -579.29 , 1312.33 , -1087.12 , 295.36 ,
      $ 500000. , 1250000. , 24. , 6. , 18. /
      DATA (FANDAH( 8,J),J=1,10) /

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485      $ 705.77      , -2402.05 , 3785.21      , -2521.68 , 601.4      ,
      $ 800000.      , 1330000.      , 24.      , 6.      , 20. /
      DATA (FANDAH( 9,J),J=1,10) /
      $ 721.32      , -2194.49 , 3143.5      , -1889.81 , 405.8      ,
      $ 750000.      , 1400000.      , 24.      , 6.      , 22. /
690      DATA (FANDAH( 10,J),J=1,10) /
      $ 177.57      , -697.3      , 1776.89      , -2005.05 , 757.58      ,
      $ 400000.      , 780000.      , 24.      , 8.      , 5. /
      DATA (FANDAH( 11,J),J=1,10) /
      $ 185.52      , -582.33      , 1372.23      , -1437.06 , 501.17      ,
695      $ 400000.      , 880000.      , 24.      , 8.      , 8. /
      DATA (FANDAH( 12,J),J=1,10) /
      $ 143.97      , -192.78      , 439.12      , -444.8      , 119.45      ,
      $ 400000.      , 970000.      , 24.      , 8.      , 10. /
      DATA (FANDAH( 13,J),J=1,10) /
700      $ 169.15      , -256.19      , 512.11      , -361.99      , 36.131      ,
      $ 500000.      , 1050000.      , 24.      , 8.      , 12. /
      DATA (FANDAH( 14,J),J=1,10) /
      $ -77.675      , 1050.7      , -1876.53      , 1567.15      , -530.3      ,
      $ 500000.      , 1140000.      , 24.      , 8.      , 14. /
705      DATA (FANDAH( 15,J),J=1,10) /
      $ 143.09      , -168.6      , 627.63      , -604.74      , 160.84      ,
      $ 700000.      , 1240000.      , 24.      , 8.      , 16. /
      DATA (FANDAH( 16,J),J=1,10) /
      $ 142.97      , -189.66      , 756.1      , -749.69      , 204.99      ,
710      $ 550000.      , 1330000.      , 24.      , 8.      , 18. /
      DATA (FANDAH( 17,J),J=1,10) /
      $ -235.24      , 1539.71      , -2094.92      , 1360.06      , -354.31      ,
      $ 900000.      , 1400000.      , 24.      , 8.      , 20. /
      DATA (FANDAH( 18,J),J=1,10) /
715      $ -112.06      , 849.65      , -956.93      , 564.88      , -163.17      ,
      $ 900000.      , 1400000.      , 24.      , 8.      , 22. /
      DATA (FANDAH( 19,J),J=1,10) /
      $ 22.074      , 483.11      , -1316.1      , 1603.54      , -833.33      ,
      $ 400000.      , 780000.      , 24.      , 10.      , 6. /
720      DATA (FANDAH( 20,J),J=1,10) /
      $ 58.107      , 431.89      , -1131.33      , 1196.97      , -524.48      ,
      $ 400000.      , 880000.      , 24.      , 10.      , 8. /
      DATA (FANDAH( 21,J),J=1,10) /
      $ 112.44      , 139.49      , -323.24      , 300.12      , -145.69      ,
725      $ 400000.      , 970000.      , 24.      , 10.      , 10. /
      DATA (FANDAH( 22,J),J=1,10) /
      $ -100.05      , 1045.91      , -2651.05      , 2365.19      , -839.16      ,
      $ 550000.      , 1060000.      , 24.      , 10.      , 12. /
      DATA (FANDAH( 23,J),J=1,10) /
730      $ -196.47      , 1864.5      , -3537.84      , 3051.97      , -1031.47      ,
      $ 580000.      , 1140000.      , 24.      , 10.      , 14. /
      DATA (FANDAH( 24,J),J=1,10) /
      $ -436.44      , 2801.51      , -4681.25      , 3571.12      , -1051.86      ,
      $ 720000.      , 1250000.      , 24.      , 10.      , 16. /
735      DATA (FANDAH( 25,J),J=1,10) /
      $ -27.599      , 620.01      , -769.57      , 558.36      , -191.62      ,
      $ 550000.      , 1330000.      , 24.      , 10.      , 18. /
      DATA (FANDAH( 26,J),J=1,10) /
      $ -752.28      , 3309.25      , -4177.96      , 2502.21      , -599.65      ,
740      $ 850000.      , 1400000.      , 24.      , 10.      , 20. /
      DATA (FANDAH( 27,J),J=1,10) /

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$ -279.38 ,1653.67 , -2140.73 ,1475.52 , -414.92 ,
$ 900000. ,1400000. , 24. , 10. , 22. /
DATA (FANDAH( 28,J),J=1,10) /
745 $ -59.966 ,641.02 , -1263.85 ,1123.39 , -414.92 ,
$ 500000. ,900000. , 26. , 6. , 6. /
DATA (FANDAH( 29,J),J=1,10) /
$ 147.46 , -436.19 ,915.07 , -784.62 ,209.79 ,
$ 500000. ,990000. , 26. , 6. , 8. /
750 DATA (FANDAH( 30,J),J=1,10) /
$ 46.138 ,166.75 , -282.52 ,272.1 , -126.46 ,
$ 500000. ,1080000. , 26. , 5. , 10. /
DATA (FANDAH( 31,J),J=1,10) /
755 $ 138.96 , -252.12 ,498.13 , -354.08 ,67.873 ,
$ 500000. ,1180000. , 26. , 5. , 12. /
DATA (FANDAH( 32,J),J=1,10) /
$ 172.97 , -372.85 ,722.82 , -517.47 ,114.80 ,
$ 500000. ,1270000. , 26. , 6. , 14. /
DATA (FANDAH( 33,J),J=1,10) /
760 $ -3206 ,452.26 , -648.81 ,493.49 , -156.59 ,
$ 750000. ,1350000. , 26. , 6. , 16. /
DATA (FANDAH( 34,J),J=1,10) /
$ 130.3 , -92.296 ,235.95 , -117.56 ,2.759 ,
$ 700000. ,1430000. , 26. , 6. , 18. /
765 DATA (FANDAH( 35,J),J=1,10) /
$ 162.10 , -194.34 ,432.03 , -278.64 ,53.34 ,
$ 900000. ,1500000. , 26. , 6. , 20. /
DATA (FANDAH( 36,J),J=1,10) /
770 $ 322.67 , -447.74 ,423.14 , -95.091 , -15.494 ,
$ 940000. ,1500000. , 26. , 6. , 22. /
DATA (FANDAH( 37,J),J=1,10) /
$ -350.23 ,2212.31 , -4250. ,3636.36 , -1212.12 ,
$ 600000. ,940000. , 26. , 8. , 6. /
DATA (FANDAH( 38,J),J=1,10) /
775 $ 83.709 ,7433 ,115.75 , -152.03 ,23.31 ,
$ 600000. ,1040000. , 26. , 8. , 8. /
DATA (FANDAH( 39,J),J=1,10) /
$ 160.09 , -245.62 ,483.82 , -364.34 ,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) /
785 $ 175.30 , -257.33 ,583.44 , -449.33 ,100.18 ,
$ 600000. ,1340000. , 26. , 8. , 14. /
DATA (FANDAH( 42,J),J=1,10) /
$ -474.23 ,2189.22 , -2769.16 ,1597.82 , -363.64 ,
$ 840000. ,1440000. , 26. , 8. , 16. /
DATA (FANDAH( 43,J),J=1,10) /
790 $ 193.55 , -288.44 ,678.44 , -479.25 ,100.02 ,
$ 600000. ,1520000. , 26. , 8. , 18. /
DATA (FANDAH( 44,J),J=1,10) /
$ -559.74 ,2354.58 , -2794.35 ,1546.54 , -335.66 ,
$ 1050000. ,1570000. , 26. , 8. , 20. /
795 DATA (FANDAH( 45,J),J=1,10) /
$ -4347.74 ,13226.42 , -14504.09 ,7162.39 , -1342.66 ,
$ 1150000. ,1600000. , 26. , 8. , 22. /
DATA (FANDAH( 46,J),J=1,10) /

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      $ -324.08 ,2261.12 , -4454.17 ,3924.24 , -1363.64 ,
000 $ 600000. ,970000. , 26. , 11. , 5. /
      DATA (FANDAH( 47,J),J=1,10) /
      $ 297.40 , -674.34 ,923.08 , -453.77 ,0.0 ,
      $ 600000. ,1080000. , 26. , 11. , 8. /
      DATA (FANDAH( 48,J),J=1,10) /
005 $ 165.74 , -105.07 ,169.43 , -24.391 , -71.678 ,
      $ 600000. ,1190000. , 26. , 11. , 10. /
      DATA (FANDAH( 49,J),J=1,10) /
      $ -121.21 ,1158.54 , -1704.69 ,1170.09 , -335.11 ,
      $ 600000. ,1300000. , 26. , 11. , 12. /
010 $ -34.067 ,818.08 , -1115.29 ,756.02 , -230.43 ,
      $ 600000. ,1390000. , 26. , 11. , 14. /
      DATA (FANDAH( 51,J),J=1,10) /
      $ 12.917 ,592.92 , -670.08 ,415.16 , -126.02 ,
015 $ 600000. ,1500000. , 26. , 11. , 16. /
      DATA (FANDAH( 52,J),J=1,10) /
      $ 223.46 , -0.085 ,80.012 ,1.166 , -34.965 ,
      $ 600000. ,1600000. , 26. , 11. , 18. /
      DATA (FANDAH( 53,J),J=1,10) /
020 $ -3.229 ,1038.49 , -1360.42 ,947.22 , -208.33 ,
      $ 1000000. ,1600000. , 26. , 11. , 20. /
      DATA (FANDAH( 54,J),J=1,10) /
      $ -3555.68 ,11081.15 , -11777.08 ,5652.78 , -1047.67 ,
      $ 1170000. ,1600000. , 26. , 11. , 22. /
025 $ 32.974 ,97.99 , -185.85 ,213.99 , -116.55 ,
      $ 600000. ,1020000. , 28. , 6. , 6. /
      DATA (FANDAH( 56,J),J=1,10) /
      $ 80.295 , -71.86 ,154.45 , -110.7 ,11.083 ,
030 $ 600000. ,1110000. , 28. , 5. , 8. /
      DATA (FANDAH( 57,J),J=1,10) /
      $ 85.09 , -39.55 ,76.619 , -26.452 , -17.992 ,
      $ 600000. ,1220000. , 28. , 5. , 10. /
      DATA (FANDAH( 58,J),J=1,10) /
035 $ 163.72 , -352.71 ,598.45 , -352.27 ,56.819 ,
      $ 730000. ,1330000. , 28. , 5. , 12. /
      DATA (FANDAH( 59,J),J=1,10) /
      $ -30.521 ,391.0 , -386.5 ,205.0 , -55.028 ,
      $ 600000. ,1450000. , 28. , 5. , 14. /
040 $ 522.91 , -1352.27 ,1663.48 , -841.6 ,145.26 ,
      $ 1030000. ,1560000. , 28. , 5. , 16. /
      DATA (FANDAH( 61,J),J=1,10) /
      $ 744.20 , -1905.75 ,2170. , -1022.22 ,166.67 ,
045 $ 1000000. ,1630000. , 28. , 6. , 18. /
      DATA (FANDAH( 62,J),J=1,10) /
      $ 557.31 , -1015.79 ,914.44 , -298.92 ,21.461 ,
      $ 1250000. ,1700000. , 28. , 5. , 20. /
      DATA (FANDAH( 63,J),J=1,10) /
050 $ -190.67 ,1135.05 , -1362.37 ,760.4 , -159.56 ,
      $ 1290000. ,1760000. , 28. , 5. , 22. /
      DATA (FANDAH( 64,J),J=1,10) /
      $ -51.432 ,688.46 , -1395.44 ,1273.01 , -461.14 ,
      $ 600000. ,1050000. , 28. , 8. , 6. /
055 $ 500000. ,1050000. , 28. , 8. , 6. /
      DATA (FANDAH( 65,J),J=1,10) /

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$ 27.126 ,271.6 , -455.19 ,391.06 , -143.96 ,
$ 530000. ,1180000. , 28. , 8. , 8. /
DATA (FANDAH( 66,J),J=1,10) /
$ 157.20 , -318.65 ,623.34 , -446.78 ,91.05 ,
$ 550000. ,1280000. , 28. , 8. , 10. /
DATA (FANDAH( 67,J),J=1,10) /
$ 297.63 , -973.37 ,1501.19 , -1021.21 ,231.07 ,
$ 550000. ,1400000. , 28. , 8. , 12. /
DATA (FANDAH( 68,J),J=1,10) /
$ 177.36 , -395.03 ,389.59 , -672.74 ,160.98 ,
$ 600000. ,1540000. , 28. , 8. , 14. /
DATA (FANDAH( 69,J),J=1,10) /
$ 79.603 , -25.755 ,395.79 , -348.17 ,80.492 ,
$ 900000. ,1600000. , 28. , 8. , 16. /
DATA (FANDAH( 70,J),J=1,10) /
$ 250.75 , -520.49 ,949.34 , -600.17 ,122.39 ,
$ 930000. ,1700000. , 28. , 8. , 18. /
DATA (FANDAH( 71,J),J=1,10) /
$ 311.62 , -376.48 ,398.49 , -114.14 , -4.087 ,
$ 1200000. ,1750000. , 28. , 8. , 20. /
DATA (FANDAH( 72,J),J=1,10) /
$ -257.36 ,1167.2 , -1145.64 ,581.78 , -120.54 ,
$ 1250000. ,1770000. , 28. , 8. , 22. /
DATA (FANDAH( 73,J),J=1,10) /
$ -13.151 ,483.04 , -928.15 ,703.03 , -274.70 ,
$ 500000. ,1050000. , 28. , 9. , 6. /
DATA (FANDAH( 74,J),J=1,10) /
$ 102.65 ,7.178 ,39.104 ,39.954 , -66.374 ,
$ 500000. ,1290000. , 28. , 9. , 10. /
DATA (FANDAH( 75,J),J=1,10) /
$ 125.18 , -50.834 ,318.54 , -260.86 ,51.636 ,
$ 600000. ,1570000. , 28. , 9. , 14. /
DATA (FANDAH( 76,J),J=1,10) /
$ 188.11 , -95.277 ,404.55 , -307.01 ,61.861 ,
$ 950000. ,1770000. , 28. , 9. , 18. /
DATA (FANDAH( 77,J),J=1,10) /
$ -73.4.5 ,19307.41 , -18251.29 ,7656.64 , -1207.28 ,
$ 1250000. ,1770000. , 28. , 9. , 22. /
DATA (FANDAH( 78,J),J=1,10) /
$ 1416.84 , -8770.24 ,21006.06 , -22060.6 ,8484.84 ,
$ 500000. ,830000. , 28. , 10. , 2. /
DATA (FANDAH( 79,J),J=1,10) /
$ -89.9 ,810.41 , -1370.82 ,1144.03 , -422. ,
$ 550000. ,1070000. , 28. , 10. , 6. /
DATA (FANDAH( 80,J),J=1,10) /
$ 131.94 , -73.389 ,191.66 , -68.245 , -48.595 ,
$ 570000. ,1320000. , 28. , 10. , 10. /
DATA (FANDAH( 81,J),J=1,10) /
$ 224.02 , -284.12 ,540.09 , -336.88 ,55.138 ,
$ 500000. ,1580000. , 28. , 10. , 14. /
DATA (FANDAH( 82,J),J=1,10) /
$ 718.7 , -1798.52 ,2459.25 , -1336.48 ,259.29 ,
$ 850000. ,1770000. , 28. , 10. , 18. /
DATA (FANDAH( 83,J),J=1,10) /
$ -1153.75 ,4181.1 , -4529.62 ,2243.76 , -426.4 ,
$ 1200000. ,1770000. , 28. , 10. , 22. /
DATA (FANDAH( 84,J),J=1,10) /

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915      S 1161.37 , -6675.67 , 14312.2 , -14463.5 , 5109.47 ,
        S 500000. , 360000. , 28. , 12. , 2. /
        DATA (FANDAH( 85,J),J=1,10) /
        S -257.57 , 1727.79 , -2934.3 , 2274.14 , -724.96 ,
        S 550000. , 1180000. , 28. , 12. , 6. /
        DATA (FANDAH( 86,J),J=1,10) /
        S 90.637 , 287.08 , -415.77 , 341.86 , -146.78 ,
920      S 570000. , 1340000. , 28. , 12. , 10. /
        DATA (FANDAH( 87,J),J=1,10) /
        S 454.87 , -1066. , 1726.52 , -1108.2 , 233.1 ,
        S 500000. , 1630000. , 28. , 12. , 14. /
        DATA (FANDAH( 88,J),J=1,10) /
925      S 555.85 , -920.47 , 1271.54 , -674.16 , 103.39 ,
        S 650000. , 1770000. , 26. , 12. , 18. /
        DATA (FANDAH( 89,J),J=1,10) /
        S 71.003 , -131.14 , 292.2 , -256.88 , 66.078 ,
        S 500000. , 920000. , 30. , 8. , 2. /
930      DATA (FANDAH( 90,J),J=1,10) /
        S .6923 , 399.64 , -784.08 , 706.5 , -243.37 ,
        S 500000. , 1220000. , 30. , 8. , 6. /
        DATA (FANDAH( 91,J),J=1,10) /
935      S 140.32 , -267.98 , 605.71 , -460.68 , 109.65 ,
        S 500000. , 1490000. , 30. , 8. , 10. /
        DATA (FANDAH( 92,J),J=1,10) /
        S 223.24 , -353.83 , 529.46 , -270.74 , 40.356 ,
        S 500000. , 1770000. , 30. , 8. , 14. /
        DATA (FANDAH( 93,J),J=1,10) /
940      S -459.74 , 1952.01 , -2176.9 , 1114.75 , -216.07 ,
        S 1000000. , 1770000. , 30. , 8. , 18. /
        DATA (FANDAH( 94,J),J=1,10) /
        S -2790.78 , 7918.48 , -7719.53 , 3355.91 , -546.08 ,
        S 1400000. , 1770000. , 30. , 8. , 22. /
945      DATA (FANDAH( 95,J),J=1,10) /
        S -2115.64 , 11983.3 , -24400. , 21818.2 , -7272.73 ,
        S 600000. , 940000. , 30. , 10. , 2. /
        DATA (FANDAH( 96,J),J=1,10) /
950      S -155.27 , 1062. , -1749.98 , 1364.18 , -420.48 ,
        S 600000. , 1260000. , 30. , 10. , 6. /
        DATA (FANDAH( 97,J),J=1,10) /
        S 70.014 , 278.3 , -479.95 , 404.31 , -128.79 ,
        S 600000. , 1530000. , 30. , 10. , 10. /
        DATA (FANDAH( 98,J),J=1,10) /
955      S 48.684 , 424.58 , -556.3 , 368.77 , -94.019 ,
        S 600000. , 1870000. , 30. , 10. , 14. /
        DATA (FANDAH( 99,J),J=1,10) /
        S 1838.82 , -4735.59 , 5146.6 , -2386.56 , 400.67 ,
        S 1110000. , 1870000. , 30. , 10. , 18. /
960      DATA (FANDAH(100,J),J=1,10) /
        S 3840.5 , -8553.07 , 7718.76 , -3055.38 , 449.55 ,
        S 1440000. , 1870000. , 30. , 10. , 22. /
        DATA (FANDAH(101,J),J=1,10) /
965      S 573.84 , -2682.76 , 5269.32 , -4489.9 , 1363.64 ,
        S 600000. , 250000. , 30. , 11. , 2. /
        DATA (FANDAH(102,J),J=1,10) /
        S 104.31 , -77.393 , 150.7 , -29.572 , -47.348 ,
        S 500000. , 1290000. , 30. , 11. , 6. /
        DATA (FANDAH(103,J),J=1,10) /

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970      $ -156.28 ,1106.85 , -1431.07 ,844.31 , -197.5 ,
      $ 600000. ,1560000. , 30. , 11. , 10. /
      DATA (FANDAH(104,J),J=1,10) /
      $ 108.35 ,142.38 , -19.254 , -15.095 , -2.55 ,
      $ 700000. ,1870000. , 30. , 11. , 14. /
975      DATA (FANDAH(105,J),J=1,10) /
      $ 1252.38 , -3070.33 ,3409.94 , -1571.34 ,255.68 ,
      $ 1040000. ,1870000. , 30. , 11. , 18. /
      DATA (FANDAH(106,J),J=1,10) /
      $ 6428.32 , -14958.6 ,13695. , -5504.54 ,821.78 ,
980      $ 1450000. ,1870000. , 30. , 11. , 22. /
      DATA (FANDAH(107,J),J=1,10) /
      $ -53.06 ,308.5 ,102.27 , -616.16 ,303.03 ,
      $ 600000. ,950000. , 30. , 12. , 2. /
      DATA (FANDAH(108,J),J=1,10) /
985      $ -272.65 ,1420.3 , -1840.91 ,1030.3 , -227.27 ,
      $ 600000. ,1290000. , 30. , 12. , 6. /
      DATA (FANDAH(109,J),J=1,10) /
      $ -107.44 ,844.15 , -980.16 ,527. , -119.46 ,
990      $ 600000. ,1580000. , 30. , 12. , 10. /
      DATA (FANDAH(110,J),J=1,10) /
      $ 172.04 , -76.343 ,334.06 , -244.14 ,48.077 ,
      $ 700000. ,1870000. , 30. , 12. , 14. /
      DATA (FANDAH(111,J),J=1,10) /
995      $ 867.44 , -1854.72 ,2097.31 , -952.54 ,148.6 ,
      $ 1050000. ,1870000. , 30. , 12. , 18. /
      DATA (FANDAH(112,J),J=1,10) /
      $ 642.59 , -1667.56 ,1862.69 , -928.03 ,170.45 ,
      $ 1000000. ,1620000. , 40. , 8. , 2. /
      DATA (FANDAH(113,J),J=1,10) /
1000     $ -234.4 ,936.78 , -837.06 ,339.56 , -55.0 ,
      $ 1000000. ,2160000. , 40. , 8. , 6. /
      DATA (FANDAH(114,J),J=1,10) /
      $ 59.02 ,212.2 , -81.972 ,14.603 , -2.878 ,
      $ 1000000. ,2570000. , 40. , 8. , 10. /
1005     DATA (FANDAH(115,J),J=1,10) /
      $ 420.1 , -458.47 ,450.55 , -159.26 ,18.324 ,
      $ 1200000. ,3040000. , 40. , 8. , 14. /
      DATA (FANDAH(116,J),J=1,10) /
1010     $ 502.04 , -434.25 ,352.16 , -95.755 ,7.843 ,
      $ 1700000. ,3320000. , 40. , 8. , 18. /
      DATA (FANDAH(117,J),J=1,10) /
      $ -256.24 ,1014.48 , -557.16 ,149.48 , -15.597 ,
      $ 2200000. ,3550000. , 40. , 8. , 22. /
      DATA (FANDAH(118,J),J=1,10) /
1015     $ 2875.11 , -7683.44 ,8025.69 , -3689.81 ,625.0 ,
      $ 1200000. ,1700000. , 40. , 10. , 2. /
      DATA (FANDAH(119,J),J=1,10) /
      $ -904.63 ,2572.63 , -2225.35 ,866.9 , -130.21 ,
      $ 1200000. ,2260000. , 40. , 10. , 6. /
1020     DATA (FANDAH(120,J),J=1,10) /
      $ 29.542 ,465.32 , -341.49 ,132.62 , -22.035 ,
      $ 1200000. ,2740000. , 40. , 10. , 10. /
      DATA (FANDAH(121,J),J=1,10) /
1025     $ -536.8 ,1461.13 , -834.02 ,221.53 , -23.765 ,
      $ 1270000. ,3180000. , 40. , 10. , 14. /
      DATA (FANDAH(122,J),J=1,10) /

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$ 621.15 , -428.07 , 299.22 , -60.185 , 1.457 ,
$ 1800000. , 3460000. , 40. , 10. , 18. /
DATA (FANDAH(123,J),J=1,10) /
1630 $ 9056.43 , -11236.6 , 5513.37 , -1173.03 , 91.146 ,
$ 2500000. , 3740000. , 40. , 10. , 22. /
DATA (FANDAH(124,J),J=1,10) /
$ -230.79 , 658.96 , -336.11 , 37.037 , 0.0 ,
$ 1200000. , 1720000. , 40. , 12. , 2. /
1635 DATA (FANDAH(125,J),J=1,10) /
$ -254.45 , 908.1 , -574.52 , 157.2 , -18.939 ,
$ 1200000. , 2330000. , 40. , 12. , 6. /
DATA (FANDAH(126,J),J=1,10) /
1640 $ -151.19 , 779.21 , -444.03 , 119.08 , -14.569 ,
$ 1200000. , 2830000. , 40. , 12. , 10. /
DATA (FANDAH(127,J),J=1,10) /
$ 543.7 , -459.81 , 452.62 , -152.95 , 16.208 ,
$ 1300000. , 3270000. , 40. , 12. , 14. /
DATA (FANDAH(128,J),J=1,10) /
1645 $ 1111.47 , -1181.9 , 794.01 , -202.17 , 16.754 ,
$ 1860000. , 3610000. , 40. , 12. , 18. /
DATA (FANDAH(129,J),J=1,10) /
$ -13201.1 , 17641.5 , -8397.4 , 1786.5 , -143.23 ,
$ 2540000. , 3750000. , 40. , 12. , 22. /
1650 DATA (FANDAH(130,J),J=1,10) /
$ -6179.5 , 17637.9 , -18314.5 , 8430.56 , -1458.33 ,
$ 1200000. , 1730000. , 40. , 14. , 2. /
DATA (FANDAH(131,J),J=1,10) /
$ 227.15 , 112.24 , -105.4 , 60.29 , -16.572 ,
$ 1200000. , 2330000. , 40. , 14. , 6. /
1655 DATA (FANDAH(132,J),J=1,10) /
$ 181.38 , 234.11 , -57.838 , 7284 , -1.093 ,
$ 1200000. , 2870000. , 40. , 14. , 10. /
DATA (FANDAH(133,J),J=1,10) /
1660 $ -103.26 , 346.19 , -428.34 , 105.65 , -11.837 ,
$ 1270000. , 3360000. , 40. , 14. , 14. /
DATA (FANDAH(134,J),J=1,10) /
$ 754.94 , -702.92 , 618.55 , -182.21 , 16.936 ,
$ 1920000. , 3720000. , 40. , 14. , 18. /
1665 DATA (FANDAH(135,J),J=1,10) /
$ 1717.77 , -1161.5 , 466.83 , -55.358 , -8156 ,
$ 2640000. , 3750000. , 40. , 14. , 22. /
DATA (FANDAH(136,J),J=1,10) /
1670 $ -27.579 , 253.49 , -106.3 , 21.961 , -2.126 ,
$ 2000000. , 4250000. , 60. , 12. , 4. /
DATA (FANDAH(137,J),J=1,10) /
$ -15.889 , 293.64 , -122.47 , 25.347 , -2.262 ,
$ 2000000. , 4750000. , 60. , 12. , 6. /
DATA (FANDAH(138,J),J=1,10) /
1675 $ 253.5 , -26.009 , 41.5 , -9.273 , 4242 ,
$ 2000000. , 5220000. , 60. , 12. , 8. /
DATA (FANDAH(139,J),J=1,10) /
$ 218.06 , 37.044 , 29.83 , -8.833 , 5606 ,
$ 2000000. , 5650000. , 60. , 12. , 10. /
1680 DATA (FANDAH(140,J),J=1,10) /
$ 417. , -96.1665 , 67.171 , -11.709 , 5361 ,
$ 2250000. , 6170000. , 60. , 12. , 12. /
DATA (FANDAH(141,J),J=1,10) /

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1085      $ -750.65 ,915.56 , -243.21 ,30.626 , -1.575 ,
      $ 3250000. ,5700000. , 60. , 12. , 14. /
      DATA (FANDAH(142,J),J=1,10) /
      $ -1483.86 ,1518.16 , -419.53 ,53.4 , -2.615 ,
      $ 4100000. ,7000000. , 60. , 12. , 16. /
      DATA (FANDAH(143,J),J=1,10) /
1090      $ 2257.4 , -1224.36 ,330.67 , -36. , 1.33 ,
      $ 4500000. ,7000000. , 60. , 12. , 18. /
      DATA (FANDAH(144,J),J=1,10) /
      $ -165.08 ,544.46 , -304.19 ,79.677 , -8.727 ,
      $ 2000000. ,3700000. , 60. , 15. , 2. /
1095      DATA (FANDAH(145,J),J=1,10) /
      $ -75.05 ,442.02 , -203.99 ,41.82 , -3.628 ,
      $ 2000000. ,4250000. , 60. , 15. , 4. /
      DATA (FANDAH(146,J),J=1,10) /
      $ 70.414 ,251.15 , -86.013 ,14.516 , -1.285 ,
1100      $ 2000000. ,4850000. , 60. , 15. , 6. /
      DATA (FANDAH(147,J),J=1,10) /
      $ -94.021 ,440.34 , -147.36 ,24.961 , -1.903 ,
      $ 2700000. ,5250000. , 60. , 15. , 8. /
      DATA (FANDAH(148,J),J=1,10) /
1105      $ -20.122 ,394.28 , -107.34 ,14.133 , -0.9016 ,
      $ 2000000. ,5930000. , 60. , 15. , 10. /
      DATA (FANDAH(149,J),J=1,10) /
      $ 502.50 , -132.89 ,102.98 , -19.495 , 1.03 ,
      $ 3170000. ,6370000. , 60. , 15. , 12. /
1110      DATA (FANDAH(150,J),J=1,10) /
      $ 390.34 ,84.842 ,12.235 , -3.344 , 0.0746 ,
      $ 2500000. ,7000000. , 60. , 15. , 14. /
      DATA (FANDAH(151,J),J=1,10) /
1115      $ -1498.49 ,1558.69 , -401.72 ,48.621 , -2.346 ,
      $ 4700000. ,7000000. , 60. , 15. , 15. /
      DATA (FANDAH(152,J),J=1,10) /
      $ 5655.16 , -3754.3 ,1080.28 , -133.41 , 6. ,
      $ 4200000. ,7000000. , 60. , 15. , 18. /
      DATA (FANDAH(153,J),J=1,10) /
1120      $ 1251.03 , -90.429 ,13.143 , 0.0 , 0.0 ,
      $ 5250000. ,7000000. , 60. , 15. , 22. /
      DATA PT /3,14159265/
      DATA TAN8 /.1405/, TAN19/.344/, HB/5./
1123      FORMAT(1X,4G12.4)
1125      10 FORMAT(5F10.4,2F10.5,3F3.0)
      15 FORMAT(5F10.4,2F10.1,3F3.0)

C
C      SPECIFIC VOLUME OF AIR LEAVING THE HEAT EXCHANGER AT THE
C      ELEVATION SPECIFIED FOR THE PLANT
1130      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
1135      TOTCFM=W4*SPVOL/60.
      AFC=5.E09
      AC=0.
      AHP=0.
1140

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      ADIA=0.
      ABLN=0.
      ABLA=0.
      ANF=0.
1145  AVEL=0.
      IF(LFE.LT.1) LFE = 153.
      IF(LFB.LT.1) LFB = 1
      C
      C      PART OF ITERATIVE LOOP FOR DETERMINING THE OPTIMUM FAN
1150  C      SYSTEM
      C
      DO 400 I=LFB,LFE
      C
      C      INITIALIZATION OF FAN OPTIMIZATION PARAMETERS
1155  C
      TP=0.
      RCFMPF=0.
      CFMPF=0.
      NOF=0.
1160  HPPF=0.
      TOTHP=0.
      FCST=0.
      CMOT=0.
      CSR=0.
1165  CFD=0.
      CEC=0.
      CPL=0.
      TCSTPF=0.
      TCSTF=0.
1170  VEL=0.
      CINC=50000.
      CFM=400000.
      FLOVP=0.
      TP=0.
1175  DF=0.
      CI=0.
      C
      C      CROSS-SECTIONAL FLOW AREA FOR THE FAN DEPENDING ON THE FAN
      C      DIAMETER
1180  C
      IF(I.LE.27) A=429.08
      IF(I.GT.27.AND.I.LE.54) A=495.96
      IF(I.GT.54.AND.I.LE.88) A=584.5
      IF(I.GT.88.AND.I.LE.111) A=638.37
1185  IF(I.GT.111.AND.I.LE.135) A=1123.91
      IF(I.GT.135) A=2680.4
      C
      C      DETERMINE THE NUMBER FANS, THE VOLUMETRIC FLOW RATE THROUGH
      C      EACH FAN, AND THE TOTAL PRESSURE DROP ACROSS EACH FAN
1190  C
      K=0
      50 CONTINUE
      K=K+1
      IF(K.GT.100) GO TO 59
1195  C
      C      THE PRESSURE DIFFERENTIAL ACROSS EACH FAN IS DEPENDENT UPON
      C      THE METHOD OF AIR DISCHARGE FROM THE FAN, WITH OR WITHOUT

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      C      VELOCITY RECOVERY STACKS
      C      VELREC=0      NO VELOCITY RECOVERY
1200      C      VELREC=1      VELOCITY RECOVERY
      C
      C      THE VELOCITY RECOVERY IS BASED ON 13 FT HIGH STACKS WITH
      C      8 DEGREE SIDESAND FOR A 28 FT DIAMETER FAN THE EFFECTIVE-
      C      NESS OF THE STACK HAS BEEN TAKEN TO BE 80 PERCENT
1205      IF (VELREC.EQ. 0.) VEL=CFM/60./A
      FAND = FANDAP(I,9)
      IF (VELREC.EQ.1.) VEL=CFM/60./(FAND+2.*13./28.*FAND*.14054)**2*4./
      *3.1416
      C
1210      C      VELOCITY EXITING THE FAN OR STACK NEW LINE VELOCITY HEAD
      C      EXITING THE FAN OR STACK
      FLOVP=CFM/1000000.
      IF (VELREC.EQ. 0.) VP=VEL**2/4452.852
1215      IF (VELREC.EQ. 1.) VP=0.2*((CFM/60./A)**2/4452.852+4.*VEL**2/4452.
      *852)
      C
      C      TOTAL PRESSURE DIFFERENTIAL ACROSS THE FAN
      TP=OPTINW*.07495*SPVOL+VP
      C
1220      C      CHECK IF PRESSURE DIFFERENTIAL AND VOLUMETRIC FLOW RATE ARE
      C      WITHIN SPECIFIED LIMITS
      IF (TP.GT.FANDAP(I,7)) GO TO 52
      IF (CFM.GT.FANDAH(I,7)) GO TO 54
1225      IF (CFM.LT.FANDAH(I,6)) GO TO 55
      IF (TP.LT.FANDAP(I,6)) GO TO 55
      IF (VP.GT.FANDAP(I,6)) GO TO 54
      C
      C      CALCULATION OF VOLUMETRIC FLOW RATE THROUGH THE FAN FOR THE
      C      SPECIFIED PRESSURE DIFFERENTIAL ACROSS THE FAN
1230      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
1235      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
1240      CFM=CFM*CI
      GO TO 50
      55 CFM=CFM+CINC
      GO TO 50
      54 CFM=CFM-CINC
      GO TO 50
1245      59 CONTINUE
      GO TO 400
      62 CONTINUE
      GO TO 400
1250      57 CFMPF=RCFMPF*1000000.
      C
      C      CALCULATION OF THE NUMBER OF FANS IN THE FAN SYSTEM
      C
      NOF=TOTCFM/CFMPF

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1255      IF (CFMPF.LT.FANDAH(I,6).OR.CFMPF.GT.FANDAH(I,7)) GO TO 400
      C
      C      CALCULATION OF HORSEPOWER REQUIREMENTS OF EACH FAN
      C
      HPPF=FANDAH(I,1)*FANDAH(I,2)*RCFMPF*FANDAH(I,3)*RCFMPF**2*FANDAH(I
1260      *,4)*RCFMPF**3*FANDAH(I,5)*RCFMPF**4.
      HPPF=HPPF/.07465/SPVOL
      HPPF=HPPF/GREFF
      C
      C      CALCULATION OF THE NUMBER OF CIRCULAR TOWERS BASED ON AN
1265      ALLOWABLE FAN PACKING FACTOR
      C
      TOWN = (WIDTH * CDANG / (PI * FANDAH(I,8))) **2 / (NOF * PFACT)
      ITOWN = TOWN
      IF (ITOWN.LT. ITMIN) GOTO 400
      IF (ITOWN.GT. ITMAX) GOTO 400
      C
      C      CALCULATION OF THE DIAMETER OF THE TOWERS
      DTOW = WIDTH * CDANG / (PI * ITOWN)
      C
      C      FAN ELECTRICAL WIRING COSTS
      C
      VM=2300.
      IF (HPPF.LT. 250.) VM = 480.
      IF (HPPF.GT. 2000.) VM = 6900.
1270      DPTTWR = DISI
      DTTSG = DTOW / 4. * (ITOWN*(3./2.) + 1.)
      DSGTM = DTOW / 2. + DTTSG / 2.
      IF (HPPF.LT. 251.) TRMA = 225000./NOF + 7.89*HPPF + (.116. - .159
      * HPPF) * HPPF
1285      IF (HPPF.GE. 251.) TRMA = 225000./NOF + 7.89*HPPF +
      * 870./SQRT(HPPF) * HPPF
      VS = 7200.
      IF (HPPF.LT. 2000.) VS = 13800.
      VS = 7200.
1290      IF (HPPF.LT. 550.) VS = 13800.
      TRMB = (DPTTWR*DTTSG-1000.) * (37. + .47*HPPF*NOF / SQRT(VS)
      * .5 * NOF) / NOF
      TRMC = (100. + 1.1*HPPF) * (DSGTM-250.) / SQRT(VM)
      CSR = HPPF * 55. + HPPF** 1.5 * 1000.
1295      FANLEC = TRMA + TRMB + TRMC
      C
      C      FAN MOTOR COSTS
      C
      FMC = 26.62
      IF (HPPF.GT. 300.) FMC = 24.33
      BIGMC = 0.0
      IF (HPPF.GT. 300.) BIGMC = 8000.
      CMOT = HPPF * FMC + BIGMC
      C
      C      TOTAL HORSEPOWER REQUIREMENT OF THE FAN SYSTEM
1305      70 TOTHP=HPPF*NOF
      C
      C      CAPITAL COSTS OF THE FAN
      C
      IF (I.LT.88) FCST=FANDAH(I,9)*(22.4*FANDAH(I,9)-60.)+19.2*FANDAH(I,8)

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*)
IF (I.GE.88) FCST=FANDAP(I,9)*(51.2+FANDAP(I,8)-950.)*136.6+FANDAP(I
1315      *.8)-2700.
      EFCSF = 1.05
      FCST = FCST * EFCSF
      SAAFI = 1.15
      HFR = 13. / 28. * FAND
1320      C
      C      STACK COSTS WITH VELOCITY RECOVERY
      IF (VELREC.EQ.1.) CFROS= UCS * UWS * PI * (FAND+HFR*TAN9) * HFR
      S      * SQRT(1. + TAN9**2)
      S      * UCS * UWS * PI * (FAND+HB*TAN19) * HB
      S      * SQRT(1. + TAN19**2)
1325      C
      C      STACK COSTS WITH OUT VELOCITY RECOVERY
      IF (VELREC.EQ.0.) CFROS = CVM * WPV * PI * FAND**2 / 6.
      S      * UCS * UWS * PI * (FAND + HB * TAN19) * HB
      S      * SQRT(1. + TAN19**2)
1330      C
      C      INCREASING THE FAN COSTS TO TAKE INTO ACCOUNT FOR SHIPPING
      C      AND ASSEMBLY OF FAN SYSTEM COMPONENTS
      CFROS = CFROS * SAAFI * POHFAN
      FCST = POHFAN * SAAFI * FCST
1335      CSR = POHFAN * SAAFI * CSR
      CMOT = CMOT * POHFAN * SAAFI
      FANLEC = FANLEC * POHLEC
      C
      C      TOTAL CAPITAL COST OF THE FAN SYSTEM
      TCSTPF = FCST + CMOT + CSR + FANLEC + CFROS
      TCSTF = TCSTPF * NOF
      C
      C      ANNUAL COST OF THE FAN SYSTEM
      C
1345      ANFCOS=(TCSTF*TOTHP*.7457*PLANC)*FCR+EHR*FCOS/10*.8*TOTHP*
      $.7457*CAPP*8760.
      C
      C      COST OF PLENUM
      C
1350      CPL = CPM * WPL * (ITOWN * PI/4. * DTOW**2 - NOF * PI/4. * (FAND+3.5)
      S      **2)
      CPL=CPL * POHSTC
      C
      C      STRUCTURAL AND FOUNDATION COSTS OF THE CIRCULAR TOWER
      C
1355      STRJCC = .2456 * (PI*DTOW**2/4.) * ELENG * ITOWN
      S      * (.00685 * ROOFL + .726)
      STRJCC = STRJCC * POHSTC
      FNDC = .019 * (WHX+WATERW) + .82*(PI/4.)*DTOW**2*ITOWN
1360      FNDC = FNDC * POHSTC
      ANSFPC = (CPL + STRJCC + FNDC) * FCR
      C
      C      ANNUAL FAN, STRUCTURAL AND FOUNDATION COSTS
      C
1365      ANSFPP = ANSFPC + ANFCOS
      150 IF (ANSFPP.GT.4FC) GO TO 400
      C
      C      STORAGE OF DESIGN PARAMETERS FOR THE LEAST COST FAN SYSTEM TO

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1370      C      TO BE PRINTED OUT BY THE SUBROUTINE RPTFAN
      C
      AFC = ANSEPF
      AFCH = ANFCOS
      AC = TCSTF
      AHP = TOTHP
1375      ADIA = FANDAP(I,8)
      ABLN = FANDAP(I,9)
      BLDANG = FANDAP(I,10)
      XN = AN = VOF
      XTOWN = TOWN
1380      NUMTOW = ITOWN
      CTOWD = DTOW
      AVEL = VEL
      CFPERF = CFMPF
      HPPERF = HPPF
1385      TPC = TP
      TOTCF = TOTCFM
      FRCPF = FCST
      FMCPF = CMOT + CSR
      CPLEN = CPL
1390      CYLRNG = CFRDS
      HPAIR = TOTHP
      FPOW = TOTHP/1.341
      DPFEL = (VP/(.07495*SPVOL))*5.2022.
      DPHX = OPTINW * 5.20218 / 144.
1395      HURDIA = SQRT (ADIA**2 - 4.*A/3.14159)
      TCTPF = TCSTPF
      FDCPF = FCST
      FMTRC = CMOT
      ACCTTP = (OPTINW + VP/(.07495*SPVOL)) * 5.2018/144.
1400      CFANEL = FANLEC
      ADJTP = TP * 5.20218/144.
      ACTBPD = DPHX
      ADJBPD = DPHX * .07495*SPVOL
      ACTVH = DPFEL/144.
1405      ADJVH = VP * 5.20218 / 144.
      ACTPPF = HPPERF
      ADJPPF = HPPF * SPVOL * .07495
      THPAIR = HPAIR
      TCTF = AC
1410      AFSCST = AFC
      AFCST = AFCH
      CSRD = CSR
400      CONTINUE
1415      IF (CTMAX .EQ. 0.0) KTMAX = 0
      IF (ABS (CTMAX - XTOWN) .LT. .0001) LOOPER = .TRUE.
      CTMAX = AMAX1 (CTMAX, XTOWN)
      KTMAX = KTMAX + 1
      IF (KTMAX .GT. 10) LOOPER = .TRUE.
      IF (LOOPER) AFC = 5.E+8
1420      RETURN
      END

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SUBROUTINE HXPFR(OD, REAIR, DFIN, 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)
 DFIN - OUTSIDE DIAMETER OF FINS (INCHES)
 FINHT - FIN HEIGHT (INCHES)
 HQ - 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 = (DFIN-OD) / 2.
 ARAT = 1. + 2.*PF*FINHT * (1. + (FINHT + THFIN) / OD)
 HQ = 0.29*(CONAIR/OD) * PRNDTL**.333 * REAIR**.633 / ARAT**.17
 HQ = HQ * 12.
 RETURN
 END

SUBROUTINE FEPFR (HYDDIA, PL, GAIR, FAIR)
DATA VISAIR /0.046/

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 MEMBER BASED ON HYDRAULIC DIAMETER
(DIMENSIONLESS)
VISAIR - VISCOSITY OF AIR (LBM/FT HR)

REHYD = HYDDIA * GAIR / (VISAIR * 12.)
IF (PL/HYDDIA .GT. 4.) FAIR = .5 * (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)

```

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      (DIMENSIONLESS)
C      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      PD        - 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,-0.315,-0.927,0.515/
30      DATA H1,H2,H3,H4,H5/0.1340,0.631,0.3333,0.200,0.1134/
C
C      TUBE ARRANGEMENT VARIABLE: K
C      1 - EQUILATERAL CONFIGURATION
C      2 - ISOSCELES CONFIGURATION
35
C      FRICTION FACTOR
C
C      REAIR = OD*GAIR/(.0460*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 = .709
C      CONA = .01516
C      ENGT = (DFIN-OD)/2.
C      H0 = (12.*CONA/OD)*H1*(REAIR**H2)*(PR**H3)*((SF/ENGT)**H4)*(SF/TF
55      1)**H5
C      RETURN
C      END

```

SUBROUTINE FRICT(DIA,GT,VIS,ID,F)

```

C      SUBROUTINE FRICT FOR GIVEN VALUES OF INSIDE DIAMETER (IN),
C      MASS FLUX (LBM/SQ FT-SEC), AND VISCOSITY (LBM/FT-HR),
5      DETERMINES THE FRICTION FACTOR OF DRAWN TUBING (ID=1), STEEL
C      PIPE (ID=2), OR CAST IRON PIPE (ID=3) USING MOODY FRICTION
C      FACTOR CHART EQUATIONS
C      REFERENCE, KNUDSEN, J.G. AND KATZ, D.L. "FLUID DYNAMICS AND
C      HEAT TRANSFER", MCGRAW-HILL, NEW YORK, 1959, P. 176
10     C
C      DIMENSION EP(3)
C
C      INSIDE SURFACE PROTUBERANCES FOR COMMERCIAL TUBING AND PIPE
C
15     DATA EP/0.00006,0.0018,0.0102/
C
C      CALCULATE REYNOLDS NUMBER AND DETERMINE IF IN LAMINAR OR
C      TURBULENT REGION
C
20     RE = 360.*GT*DIA/VIS
C      IF(RE-2000.)100,101,101
C
C      CALCULATE LAMINAR FLOW FRICTION FACTOR
C
25     100 F=16./RE
C      F = 4.*F
C      RETURN
C
C      CALCULATE RECIPROCAL OF RELATIVE ROUGHNESS AND RECIPROCAL OF
30     SQUARE ROOT OF FRICTION FACTOR FOR FULLY TURBULENT FLOW
C
C      101 RF=DIA/EP(ID)
C      FF=4.*ALOG10(RF)+2.28
C
35     C
C      CHECK TO DETERMINE IF TURBULENT FLOW IS FULLY DEVELOPED
C
C      CF=RF*FF/RE
C      IF(CF-0.01)104,103,103
C
40     C
C      DETERMINE RECIPROCAL OF SQUARE ROOT OF FRICTION FACTOR FOR
C      TRANSITION FLOW INITIALLY ASSUMING IT TO BE THE SAME AS FOR
C      FULLY TURBULENT FLOW
C
C      103 TRF=FF
45     107 TRFC=FF-4.*ALOG10(1.+4.67*RF*TRF/RE)
C
C      IF CALCULATED AND ASSUMED VALUES OF RECIPROCAL OF SQUARE ROOT
C      OF TRANSITION FLOW FRICTION FACTOR DO NOT AGREE WITHIN
C      SPECIFIED LIMITS, ASSUME NEW VALUE EQUAL TO CALCULATED VALUE
50     C
C      AND REPEAT CALCULATION
C
C      IF((ABS(TRFC-TRF)/TRF)-0.001)105,105,105
C      106 TRF=TRFC
C      GO TO 107
55     C
C      CALCULATE FULLY DEVELOPED TURBULENT FLOW OR TRANSITION FLOW
C      FRICTION FACTOR

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SUBROUTINE FRIC

74/74 OPT=1

FTN 4.2+74351

12/13/66

50

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C
105 FF=TRF
104 F=1./FF**2
      F = 4.*F
C
      RETURN
      END
```

SUBROUTINE HEADER(DOTM,DOTBR,DESVEL,RHO,RED,J,NN,DIAJ,DIA,TCST,
\$RCST,UPCST,ELCOST,FLGCST,EJCST)

```

C
C      THIS SUBROUTINE DETERMINES DESIGN AND COST INFORMATION FOR
5      THE MAIN CIRCULATION PIPING AND THE QUADRANT PIPING.
C
C      DEFINITION OF VARIABLES
C
C      APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
10      DESVEL - DESIGN VELOCITY (FT/SEC)
C      DIA - PIPE COMPONENT DIAMETER (INCHES)
C      DOTBR - MASS FLOW RATE TO BRANCH, I.E., TO CIRCULAR TOWER
C              OR TO TUBE BUNDLE (LBM/HR)
C      DOTM - MASS FLOW RATE IN GIVEN HEADER SECTION (LBM/HR)
15      EJCST - EXPANSION JOINT COST ($1000)
C      ELCOST - 90 DEGREE ELBOW COST ($1000)
C      FLGCST - FLANGE COST ($1000)
C      NKOS - NUMBER OF POSITIONS IN UNIT COST ARRAYS
C      NN - IF=0 THEN MAIN CIRCULATION HEADER IS DESIGNED
20      IF=1 THEN QUADRANT HEADER IS DESIGNED
C      PIPCST - BELOW GROUND PIPE COST ($1000/FT)
C      RED - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
C              HEADER SECTIONS (INCHES). IF RED=0, THE PROGRAM
C              CALCULATES THE REDUCTION
25      REDCOST - REDUCER COST ($1000)
C      REDUCT - REDUCTION IN DIAMETER BETWEEN ADJACENT HEADER
C              SECTIONS (INCHES). ONLY USED WHEN RED=0
C      RHO - DENSITY (LBM/CUFT)
C      TEECST - TEE COST ($1000)
30      UPCST - UNIT PIPE COST ($1000/FT)
C      VACST - VALVE COST ($1000), VALVES ARE MOTOR OPERATED
C              BUTTERFLY VALVES
C
C      DIMENSION DIAM(24), FLGCST(24), EJCST(24), REDCOST(24), ELCOST(24)
35      $, VACST(24), TEECST(24), PIPCST(24), APIPCST(24)
C
C      DATA DIAM /
40      $ 6. , 12. , 18. , 24. , 30. , 36. ,
C      $ 42. , 48. , 54. , 60. , 66. , 72. ,
C      $ 78. , 84. , 90. , 96. , 102. , 108. ,
C      $ 114. , 120. , 126. , 132. , 138. , 144. /
C
C      DATA FLGCST/
45      $ .136, .520, 1.03 , 1.92 , 3.17 , 4.42 ,
C      $ 5.82 , 9.22 , 12.0 , 14.7 , 21.1 , 27.5 ,
C      $ 33.9 , 40.4 , 46.8 , 53.2 , 59.7 , 66.1 ,
C      $ 72.5 , 78.9 , 85.4 , 91.8 , 98.2 , 105. /
C
C      DATA TEECST/
50      $ .344, .935, 1.96 , 3.82 , 14.8 , 25.8 ,
C      $ 31.7 , 37.6 , 53.4 , 69.1 , 87.9 , 107. ,
C      $ 125. , 145. , 163. , 182. , 201. , 220. ,
C      $ 239. , 258. , 277. , 296. , 314. , 333. /
C
C      DATA PIPCST/
55      $ .06. , .113, .147, .219, .409, .599,
C      $ .720, .841, 1.08 , 1.31 , 1.57 , 1.84 ,

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12/18/76

G-73

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115      C      THE PROGRAM MAY HAVE A SPECIFIED VALUE OF RED WHICH FIXES THE
      C      REDUCTION IN PIPE DIAMETERS BETWEEN HEADER SECTIONS. RED
      C      MUST BE A MULTIPLE OF 6. IF RED=0 THE ROUTINE CALCULATES A
      C      REDUCTION. FOR EXAMPLE, HEADER SECTION J-1 HAS BEEN ASSIGNED
120      C      A DIAMETER OF 96 INCHES. IT IS DETERMINED THAT HEADER SECTION
      C      J SHOULD BE 84 INCHES. THE REQUIRED REDUCTION IS 12 INCHES.
      C      IF RED=0 THEN A 96 INCH REDUCER IS COSTED AND HEADER SECTION
      C      J WILL BE ASSIGNED A DIAMETER OF 78 INCHES. IF RED=6 INCHES
      C      A 96 INCH REDUCER IS COSTED BUT DIAMETER J WOULD BE ASSIGNED
125      C      A VALUE OF 90 INCHES. IF RED=12 INCHES THEN A 96 INCH RE-
      C      DUCER IS COSTED AND DIAMETER J IS ASSIGNED A VALUE OF 84
      C      INCHES. IF RED=18 INCHES OR MORE THEN NO REDUCER IS SPECI-
      C      FIED AND DIAMETER J IS ASSIGNED A VALUE OF 96 INCHES. LARGER
      C      VALUES OF RED RESULT IN PIPE SIZES LARGER THAN REQUIRED BUT
      C      FEWER REDUCERS ARE REQUIRED.

130      C      CALCULATION OF REDUCTION, RED NOT SPECIFIED.

      C      IF (RED.NE.0.) GO TO 13
      C      IF (DIA.EQ.DIAJ) GO TO 12
135      C      REDUCT=DIAJ-DIA
      C      M=REDUCT/6.+.01
      C      IJK=I
      C      GO TO 14

140      C      RED SPECIFIED, POSSIBLE REASSIGNMENT OF DIAMETER J.
      C
      C      13 IF (DIA.GT.DIAJ-RED) GO TO 15
      C      DIA=DIAJ-RED
      C      M=RED/6.+.01
145      C      IJK=(DIA-DIAM(I))/6.+.01
      C      14 K=0
      C      JJ=M
      C
      C      DETERMINE REDUCER COST. IT HAS BEEN ASSUMED FROM THE RE-
150      C      DUCER COST DATA THAT, FOR EXAMPLE, A 96 INCH REDUCER WILL
      C      COST THE SAME WHETHER THE REDUCTION IS TO 90, 84, OR 78
      C      INCHES. IF THE TOTAL REDUCTION BETWEEN ADJACENT HEADER
      C      SECTIONS EXCEEDS 18 INCHES THEN AN ADDITIONAL REDUCER MUST BE
155      C      COSTED. IN THE EXAMPLE, THIS WOULD BE A 78 INCH REDUCER. IF
      C      THE TOTAL REDUCTION EXCEEDS 36 INCHES, SAY 96 TO 54, THEN A
      C      96, 78, AND 60 INCH REDUCER WOULD BE COSTED, AND SO ON.
      C
      C      16 CONTINUE
      C      IF (IJK+JJ.GT.NKOS) STOP "IN HEADER IJK+JJ EXCEEDS NKOS"
160      C      RCST = RCST + REDCST(IJK+JJ)
      C      K=K+1
      C      JJ=4-3*K
      C      IF (JJ.LE.0) GO TO 12
      C      GO TO 16

165      C      15 DIA=DIAJ
      C      12 M=(DIA-DIAM(I))/6.+.01
      C      IF (I+M.GT. NKOS) STOP "IN HEADER I+M EXCEEDS NKOS"
      C
      C      IF THE LAST HEADER SECTION IS BEING DESIGNED USE AN ELBOW
170      C      RATHER THAN A TEE.
      C

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```

      IF (ABS(DOTM-DOTBR).LT..0001) ELCOST=ELCST(I+M)
C
C      TEE COSTS ARE ASSUMED TO BE .67 TIMES THE COST OF A TEE
175 C      OF THE "RUN" DIAMETER PLUS .33 TIMES THE COST OF A TEE OF THE
C      "BRANCH" DIAMETER. DETERMINE THE "RUN" PORTION OF THE TEE
C      COST HERE.
C
      IF (DOTM.GT.DOTBR) TCST=.67*TEECST(I+M)
180 C
C      MAIN CIRCULATION PIPING IS UNDERGROUND. QUADRANT PIPING IS
C      ABOVE GROUND. FITTINGS COSTS WERE NOT DEPENDENT ON ABOVE OR
C      BELOW GROUND SPECIFICATION.
C
185 C      IF (NN .EQ. 0) UPCST = APIPCST(I+M)
C      IF (NN .NE. 0) UPCST = PIPCST(I+M)
C      RETURN
C      END
```

```

1      SUBROUTINE HLAMMO(TIN,DOIMA,DIA,HLENGTH,DIV,TOUT,DELP)
      COMMON/PROP/CPW,THCONW,DENSIV,VISW,HFC,
1      CPV,THCONV,DENSIV,VISV,SIGMA,
1      CPA,THCONA,DENSIA,VISA
      C
      C      SUBROUTINE HLAMMO CALCULATES THE PRESSURE AND TEMPERATURE
      C      DROPS OF AMMONIA DUE TO THE FLUID FLOW OF ITS VAPOR
      C      INSIDE A LENGTH OF PIPE
      C
11     C      DEFINITION OF VARIABLES
      C
      C      DELP - PRESSURE DROP IN THE PIPE (LBF/SQ FT)
      C      DELTX - SEGMENT OF THE PIPE (FT)
      C      DENSIV - DENSITY OF THE AMMONIA VAPOR (LBM/CU FT)
15     C      DIA - DIAMETER OF PIPE (IN)
      C      DIV - NUMBER OF DIVISIONS OF AMMONIA IN THE LENGTH OF
      C           THE PIPE (DIMENSIONLESS)
      C      DOIMA - MASS FLOW RATE IN THE PIPE (LBM/HR)
      C      F - FRICTION FACTOR FOR THE VAPOR FLOW (DIMENSIONLESS)
21     C      G - MASS FLUX OF AMMONIA IN THE PIPE (LBM/SQ FT HR)
      C      HLENGTH - LENGTH OF THE PIPE (FT)
      C      P1 - PRESSURE OF THE AMMONIA AT THE FRONT OF THE PIPE
      C           (LBF/SQ IN)
      C      P2 - PRESSURE OF THE AMMONIA AT THE END OF THE PIPE
25     C           (LBF/SQ IN)
      C      TIN - TEMPERATURE AT THE BEGINNING OF THE PIPE
      C      TOUT - TEMPERATURE AT THE END OF THE PIPE
      C
      C      DELP = 0.0
30     C      J = 0
      C      GA = 32.16*3600.*3600.
      C
      C      NUMBER OF DIVISIONS IN THE PIPE
      C      I = DIV + .01
35     C
      C      INLET PRESSURE
      C      P1 = FLUID(10,1,TIN,FLEV,"CALC 1")
      C
      C      LENGTH OF PIPE SEGMENTS
40     C      DELTX = HLENGTH/DIV
      C
      C      MASS FLUX OF AMMONIA THROUGH THE PIPE
      C      G = DOIMA/(3.14159*DIA**2/(4.*144.))
45     C      IF J = J + 1
      C
      C      FRICTION FACTOR IN THE PIPE
      C      CALL FRIC1(DIA,G/3600.,VISV,2,F)
      C
      C      PRESSURE DROP IN THE SEGMENT OF PIPE PLUS THE SUM OF THE
50     C      PRECEDING PRESSURE DROPS CAUSED BY PRECEDING SEGMENTS.
      C      OF PIPE
      C      DELP = F*G**2*DELTX/(2.*GA*DENSIV*(DIA/12.)) + DELP
      C
      C      NEW PRESSURE AT THE END OF THE SEGMENT OF PIPE
55     C      P2 = P1 - DELP/144.
      C
      C      NEW TEMPERATURE OF AMMONIA AT THE END OF THE SEGMENT OF

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SUBROUTINE HLAMMO

74/74 OPT=1

FTN 4.2+74351

12/18/76

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C      PIPE
60      TI = FLUID(11,1,P2,ELEV,"CALC 1")
      DELTI = .001
20      FTI = -P2 + FLUID(10,1,TI,ELEV,"CALC 2")
      FTIDEL = -P2 + FLUID(10,1,TI+DELT, ELEV,"CALC 3")
      TIPI = TI + DELTI*FTI/(FTIDEL - FTI)
      IF (ABS(TIPI - TI).LT.,.0001) GO TO 30
65      TI = TIPI
      GO TO 20
30      TOUT = TI
C
C      NEW VAPOR DENSITY AND VISCOSITY OF THE VAPOR AT THE END
C      OF THE SEGMENT OF PIPE
70      DENSIV = FLUID(7,1,TOUT,ELEV,"CALC 4")
      VISV = FLUID(8,1,TOUT,ELEV,"CALC 5")
      IF (J.EQ.1) GO TO 40
      GO TO 10
75      40 CONTINUE
      RETURN
      END

```

SUBROUTINE HTCLO(DTI,DL,ANG,GT,XI,X2,PRL,DENL,DENV,VISL,VISV,TKL,
ICPL,HTL,HTC,HTB,HTN,HTK,RET)
DIMENSION ANG(3)

```

5      C      SUBROUTINE HTCLO CALCULATES THE TUBESIDE TWO-PHASE LIQUID
      C      FILM HEAT TRANSFER COEFFICIENT FOR THE CONDENSATION OF
      C      A FLUID ON THE WALLS OF A TUBE
      C
      C      DEFINITION OF VARIABLES
10     C
      C      ANG(1) - ANGLE THE TUBE MAKES FROM THE HORIZONTAL (RAD)
      C      ANG(2) - SINE OF THE ANGLE THE TUBE MAKES FROM THE
      C      HORIZONTAL (DIMENSIONLESS)
      C      DENL - DENSITY OF THE LIQUID (LBM/CU FT)
15     C      DENV - DENSITY OF THE VAPOR (LBM/CU FT)
      C      DL - LENGTH OF THE LIQUID AND VAPOR TUBE (IN)
      C      DR - RATIO OF THE DENSITIES (DIMENSIONLESS)
      C      DTI - INSIDE DIAMETER OF THE TUBE (IN)
      C      GT - MASS FLUX OF THE FLUID THROUGH THE TUBE (LBM/
20     C      HR-SQ FT)
      C      HTB - HEAT TRANSFER COEFFICIENT ACCORDING TO THE CORRELA-
      C      TION BY BOYKO AND KRUGHILIN (BTU/HR-SQ FT-DEG F)
      C      HTC - HEAT TRANSFER COEFFICIENT ACCORDING TO THE
      C      CORRELATION BY CHATO (BTU/HR-SQ FT-DEG F)
25     C      HTK - HEAT TRANSFER COEFFICIENT ACCORDING TO THE
      C      CORRELATION BY KIRKBRIDE AND BADGER (BTU/HR-SQ FT-
      C      DEG F)
      C      HTN - HEAT TRANSFER COEFFICIENT ACCORDING TO THE
      C      CORRELATION BASED ON THE NUSSELT TYPE ANALYSIS
30     C      (BTU/HR-SQ FT-DEG F)
      C      PRL - PRANDTL NUMBER OF THE LIQUID (DIMENSIONLESS)
      C      RET - REYNOLDS NUMBER (DIMENSIONLESS)
      C      TKL - THERMAL CONDUCTIVITY OF THE LIQUID (BTU/HR-FT-DEG F)
      C      VISL - VISCOSITY OF THE LIQUID (CENTIPOISE)
35     C      XD - CHANGE IN VAPOR QUALITY FROM THE INLET TO THE EXIT
      C      OF THE TUBE (DIMENSIONLESS)
      C      XI - INLET QUALITY (DIMENSIONLESS)
      C      XO - EXIT QUALITY (DIMENSIONLESS)
40     C
      C      DR = DENL/DENV
      C      RET = DTI*GT/(VISL*29.)
      C      XD = A*IN1(X2+.999)
      C
      C      GRAVITY CONTROLLED STRATIFIED CONDENSATION (CHATO)
45     C      ANGLE OF THE CONDENSATE = 120 DEGREES
      C      XD = A*MAX1(XI-XO,.001)
      C      HTC = .024*TKL*(DENL*(DENL-DENV)*DL*ANG(3)/
1     C      (VISL*DTI**2*GT*XD))**.33
      C
      C      PRESSURE GRADIENT CONTROLLED ANNULAR CONDENSATION (BOYKO-
      C      KRUGHILIN)
50     C
      C      FTP = (SQRT(1. + (DR - 1.)*XI) + SQRT(1. + (DR - 1.)*XO)).5
      C      HTB = .024*TKL*RET**.8*PRL**.43*FTP/DTI**12.
      C      KOOL = 0
55     C
      C      IF(ANG(1)-0.017) 30,30,50
      C      IF(HTC-HTB) 100,100,40
30     C      KOOL=1
40     C

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SUBROUTINE HTCL0

74/74 OPT=1

FTN 4.2+74351

12/18/76

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      GO TO 100
50 PPN = TKL*(4.1858*ANG(2)*DENL*(DENL-DENV)/(VISL*2.42)**2)**.33
60 C
   C GRAVITY CONTROLLED VERTICALLY LAMINAR CONDENSATION (NUSSELT)
   C HTN = 1.47*PPN/(RET*(1.-XO))**.33
   C
65 C
   C GRAVITY CONTROLLED VERTICALLY TURBULENT CONDENSATION
   C (KIRKBRIDE-BADGER)
   C HTK = .0077*(RET*(1.-XO))**.4*PPN
100 HTL = AMAX1(HTC,HTB,HTN,HTK)
   RETURN
   END
```

SUBROUTINE HYDLOS(DIA,VEL,VIS,RHO,ID,HOLS)

```

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
10     HEAT TRANSFER", MCGRAW-HILL, NEW YORK, 1958, P.175
C
C      DIMENSION EP(3)
C
C      INSIDE SURFACE PROTUBERANCES FOR COMMERCIAL TUBING AND PIPE
C
15     DATA EP/0.00006,0.0018,0.0102/
C
C      CALCULATE REYNOLDS NUMBER AND DETERMINE IF IN LAMINAR OR
C      TURBULENT REGION
C
20     RE=300.*RHO*VEL*DIA/VIS
C      IF(RE-2000.)100,101,101
C
C      CALCULATE LAMINAR FLOW FRICTION FACTOR
C
25     100 F=16./RE
C      GO TO 102
C
C      CALCULATE RECIPROCAL OF RELATIVE ROUGHNESS AND RECIPROCAL OF
C      SQUARE ROOT OF FRICTION FACTOR FOR FULLY TURBULENT FLOW
C
30     101 RF=DIA/EP(ID)
C      FF=4.*ALOG10(RF)+2.28
C
C      CHECK TO DETERMINE IF TURBULENT FLOW IS FULLY DEVELOPED
C
35     CF=RF+FF/RE
C      IF(CF-0.01)104,103,103
C
C      DETERMINE RECIPROCAL OF SQUARE ROOT OF FRICTION FACTOR
C      FOR TRANSITION FLOW INITIALLY ASSUMING IT TO BE THE SAME AS
C      FOR FULLY TURBULENT FLOW
C
40     103 TRF=FF
C      107 TRFC=FF-4.*ALOG10(1.+4.67*RF*TRF/RE)
C
45     IF(CALCULATED AND ASSUMED VALUES OF RECIPROCAL OF SQUARE ROOT
C      OF TRANSITION FLOW FRICTION FACTOR DO NOT AGREE WITHIN
C      SPECIFIED LIMITS, ASSUME NEW VALUE EQUAL TO CALCULATED VALUE
C      AND REPEAT CALCULATION
C
50     IF((ABS(TRFC-TRF)/TRF)-0.001)105,105,106
C      106 TRF=TRFC
C      GO TO 107
C
55     CALCULATE FULLY DEVELOPED TURBULENT FLOW OR TRANSITION FLOW
C      FRICTION FACTOR

```

SUBROUTINE HYDLOS 74/74 OPT=1

FTN 4.2+74351

12/18/76

```

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

SUBROUTINE INPSUM

C
C
C

THIS ROUTINE REPORTS INPUT SUMMARY AND CASE DESCRIPTION

```

5      LOGICAL FIRST, FXTMP
      COMMON
      $ AFTER, ALPHA, ANG(3)
      $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAPF
10     $ ,CBU, CTJ3, CDANG, CLUVR, CHAILS, CVM
      $ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
      $ ,EFF
      $ ,FOR, FIRST, FIXL, FCOS, FFHX, FXTMP
      $ ,GBEFF
15     $ ,HXNP, HPCST
      $ ,ITMAX, ITMIN
      $ ,JCONS
      $ ,KCONV, KALEXT
      $ ,MXEXT
      $ ,NTUCAL(2), NTA
20     COMMON
      $ ODR
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
25     $ ,RBP, REDUCE, REDUCV, ROOFLL
      $ ,QREU, QREDUCE, QREDUCV
      $ ,SIGMAS, GAAT
      $ ,TD, TPO(4), TEPF, TLIM, THFIN, TLPRA, TFIX
      $ ,TCD, TX
      $ ,UCS, UWS
30     $ ,WCV
      $ ,VAS(5)
      $ ,XDEPA, XW, XD
      LOGICAL LOOPER
      COMMON/FAN/ FANDAP(153,10), FANDAH(153,10), FMCPF, FRCPF, P2, R, S,
35     $ VELREC, AFC, ELEV, EHR, LOOPER, CTMAX
      COMMON /TIME2/ CCM
126  FORMAT(//79X,"COEFFICIENTS FOR POLYNOMIAL CURVE FIT")
127  FORMAT(70X,"A0",11X,"A1",11X,"A2",11X,"A3",11X,"A4")
128  FORMAT(" HEAT RATE FACTOR AS FUNCTION OF BACKPRESSURE (INCHES OF M
40     +ERCURY) ",195E13.5//)
129  FORMAT(T4,"TURBINE RATING BACKPRESSURE",F6.2," INCHES OF MERCURY")
130  FORMAT(T4,"SITE ELEVATION",F7.0," FEET ABOVE SEA LEVEL")
202  FORMAT(1H1,T30,"I N P U T   S U M M A R Y   A N D   C A S E
45     $ D E S C R I P T I O N //")
204  FORMAT(T2.3("-----"),T90.2("-----"),"-")
206  FORMAT(T2,"OPTIONS SELECTED FOR THIS RUN",T90,"STARTING CONDITIONS
50     $")
200  FORMAT(140)
210  FORMAT(T4,"EXCHANGER DEPTH UNCONSTRAINED")
207  FORMAT (T4,"FRICTION FACTOR AND HT TRFR COEFF BY ",A10)
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+,T52,"PLUS OR MINUS ",F5.3)
220  FORMAT(1H+,T80,"TURBINE OUTLET TEMPERATURE. T1",F10.3," F")
55  225  FORMAT(T4,"EXCHANGER LENGTH UNCONSTRAINED")
220  FORMAT(T4,"EXCHANGER LENGTH FIXED AT ",F5.0," FEET")
235  FORMAT(1H+,T74,"TERMINAL TEMPERATURE DIFFERENCE TTD1",F10.3)

```



```

240 FORMAT(T4,"RUN WITH VELOCITY RECOVERY")
245 FORMAT(T4,"RUN WITHOUT VELOCITY RECOVERY")
60 250 FORMAT(IH,T91,"FRONTAL AREA. AFROV",F11.0)
255 FORMAT(T4,"NTU CALCULATION IS BY ",Z410)
260 FORMAT(IH,T82,"WIDTH TO LENGTH RATIO, WLRAT",F10.3)
300 FORMAT(T4,T51,"UNIT COSTS AND COSTING FACTORS"/T51,30(" ")/)
305 FORMAT(T2,"FUEL ",F7.3," CENTS/MMBTU"
65 $,T30,"POWER PLANT CONSTRUCTION",F11.3," $/KW"
$,T104,"FIXED CHARGE RATE",F9.3)
310 FORMAT(T2,"LAND ",F7.3," $/SQ FT"
$,T30,"REPLACEMENT POWER",7X,F11.3," MILLS/KWH"
$,T106,"CAPACITY FACTOR",F9.3)
70 315 FORMAT(T2,"MOTORS",F7.3," $ / HP"
$,T30,"STEAM SUPPLY",T54,F11.3," $/KW TURBINE OUTPUT"
$,T99,"BASE THERMAL EFFICIENCY",F9.3)
320 FORMAT(T30,"CAPACITY CHARGE",T54,F11.3," $/MWH"
$,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)
80 WRITE(6,200)
WRITE(6,209) TLIM
WRITE(6,207) FFHX

C
LOGSYM = ".LE."
85 IF (DEEPL.GT.0.0) LOGSYM = ".SE."
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

90 C
WRITE(6,220) VAS(1)
C
IF (FIXL.EQ.0.0) WRITE(6,225)
IF (FIXL.NE.0.0) WRITE(6,230) FIXL

95 C
WRITE(6,235) VAS(3)
C
IF (VELREC.EQ.0.0) WRITE(6,245)
IF (VELREC.NE.0.0) WRITE(6,240)

100 C
WRITE(6,250) VAS(4)
C
WRITE(6,255) NTUCAL
WRITE(6,260) VAS(5)

105 C
C
C
WRITE(6,126)
WRITE(6,127)
WRITE(6,129) (TPO(I),I=1,4)
WRITE(6,129) RBP
WRITE(6,130) ELEV

C
WRITE(6,300)

```

SUBROUTINE INPSUM

74/74 OPT=1

FTN 4.2.74351

12/19/6

115

WRITE(6,305) FCOS,PLANC,FCR
WRITE(6,310) COSTL,PWCOS,CAPF
WRITE(6,315) HPCST,CSSPKW,TEFF
WRITE(6,320) CAPCHG,CCM
WRITE(6,325) PER
RETURN
END

120

SUBROUTINE NOVART(VCST,RANGE)
REAL X COST(8)

5 C SUBROUTINE NOVART DETERMINES THE PERFORMANCE OF A PLANT
C DESIGNED AT A SPECIFIC AMBIENT TEMPERATURE OVER A WHOLE
C YEAR THE ROUTINE ALSO DETERMINES THE INCREMENTAL COST OF
C OPERATING THE POWER PLANT OVER THE ENTIRE YEAR
C
10 C DEFINITION OF VARIABLES
C
C CAPCHG - CAPACITY CHARGE (\$/MEGAWATT)
C CAPCST - CAPITAL COST FOR AUXILIARY POWER (\$)
C CAPF - CAPACITY FACTOR (DIMENSIONLESS)
C CCOS - COST OF THE HEAT EXCHANGER (\$)
15 C CLAND - COST OF THE LAND(\$)
C CONBAS - COST OF THE CONDENSER/REBOILER (\$)
C COSM - MAINTAINENCE COST (MILLS/KWH)
C CPA - SPECIFIC HEAT OF THE AIR (BTU/LBM-DEG F)
C CRIP - COST OF THE PIPING (\$)
20 C CSTCL - AUXILIARY POWER COST (MILLS/KWH)
C DELFC - INCREASED FUEL COST FOR THE PLANT (MILLS/KWH)
C DELPS - PRESSURE DROP IN THE SUPPLY PIPING AT THE DESIGN
C CONDITIONS (LBF/SQ FT)
C DELPS2 - PRESSURE DROP IN THE SUPPLY PIPING AT THE OFF DE-
25 C SIGN CONDITIONS (LBF/SQ FT)
C DENSIV - DENSITY OF THE VAPOR LEAVING THE CONDENSER/REBOILER
C AT DESIGN CONDITIONS (LBM/CU FT)
C DENSIV2 - DENSITY OF THE VAPOR LEAVING THE CONDENSER/REBOILER
C AT OFF DESIGN CONDITIONS (LBM/CU FT)
30 C EFF - EFFECTIVENESS OF THE HEAT EXCHANGER (DIMENSIONLESS)
C FCOS - FUEL COST (\$/MM BTU)
C FCR - FIXED CHARGE RATE (DIMENSIONLESS)
C FPOW - FAN POWER (KWH)
C HFG2 - HEAT OF VAPORIZATION AT OFF DESIGN CONDITIONS
35 C (BTU/LBM)
C HRFAC1 - HEAT RATE FACTOR AT RATING CONDITION (DIMENSIONLESS)
C HRFAC2 - HEAT RATE FACTOR AT DESIGN CONDITIONS (DIMENSION-
C LESS)
C HRFAC4 - HEAT RATE FACTOR AT OFF DESIGN CONDITIONS
40 C (DIMENSIONLESS)
C NTA - NUMBER OF TEMPERATURE INCREMENTS IN THE TEMPERATURE
C RANGE OF THE SITE
C P - BACK PRESSURE OF THE TURBINE (IN HGA)
C PARCOS - INCREMENTAL POWER PRODUCTION COST AT THE AMBIENT
45 C TEMPERATURE (MILLS/KWH)
C PGEN - POWER GENERATING BY THE PLANT (MEGAWATTS)
C PPOW - PUMP POWER (KWH)
C PSIZE - PLANT SIZE (MEGAWATTS)
C PSIZ13 - TOTAL POWER OUTPUT OF PLANT AT DESIGN
50 C CONDITIONS (MEGAWATTS)
C PTOT - TOTAL POWER OUTPUT OF PLANT AT OFF DESIGN
C CONDITIONS (MEGAWATTS)
C PWCOS - REPLACEMENT POWER COST (MILLS/KWH)
C P12 - AMMONIA PRESSURE AT THE CONDENSER/REBOILER (LBF/
55 C SQ FT)
C P22 - AMMONIA PRESSURE AT THE HEAT EXCHANGER (LBF/SQ FT)
C QIN1 - HEAT INPUT INTO THE POWER PLANT (BTU/HR)

```

C      QREJCT1 - HEAT REJECTED AT THE DESIGN CONDITIONS OF THE PLANT
C              (BTU/HR)
60  C      QREJCT2 - HEAT REJECTED AT THE OFF DESIGN CONDITIONS OF THE
C              PLANT (BTU/HR)
C      RANGE - TEMPERATURE RANGE OF THE AIR AT DESIGN CONDITIONS
C              (DEG F)
C      RANGE2 - TEMPERATURE RANGE OF THE AIR AT THE OFF DESIGN
65  C      CONDITIONS (DEG F)
C      SPCD - DIFFERENTIAL COST OF PLANT EXCLUDING THE COOLING
C              SYSTEM ($)
C      TA - AMBIENT TEMPERATURE (DEG F)
C      TFFF - BASE THERMAL EFFICIENCY OF THE PLANT (DIMENSIONLESS)
70  C      TFFF1 - RATED THERMAL EFFICIENCY OF THE PLANT
C              (DIMENSIONLESS)
C      TFFF3 - DESIGN THERMAL EFFICIENCY OF THE PLANT
C              (DIMENSIONLESS)
C      TFFF4 - OFF DESIGN THERMAL EFFICIENCY OF THE PLANT
75  C      (DIMENSIONLESS)
C      TI - TEMPERATURE OF THE AMMONIA AT THE INLET TO THE
C              HEAT EXCHANGER (DEG F)
C      TPER - FRACTION OF THE YEAR THAT THE CORRESPONDING
C              AMBIENT TEMPERATURE EXISTS (DIMENSIONLESS)
80  C      TTD1 - TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
C              STEAM AND AMMONIA IN THE CONDENSER/REBOILER
C              AT DESIGN CONDITIONS (DEG F)
C      TTD12 - TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
C              STEAM AND AMMONIA IN THE CONDENSER/REBOILER
85  C      AT OFF DESIGN CONDITIONS (DEG F)
C      TTD2 - TEMPERATURE DROP OF THE AMMONIA IN THE SUPPLY
C              PIPING (DEG F)
C      TI - SATURATED STEAM TEMPERATURE IN THE CONDENSER/
C              REBOILER (DEG F)
90  C      VCST - INCREMENTAL INCREASE IN COST OF THE POWER PRODUCED
C              BY THE OPTIMUM POWER PLANT DUE TO THE COOLING
C              SYSTEM (MILLS/KWH)
C      W3 - MASS FLOW RATE OF AMMONIA AT DESIGN CONDITIONS (LBM
C              /HR)
95  C      W32 - MASS FLOW RATE OF AMMONIA AT OFF DESIGN CONDITIONS
C              (LBM/HR)
C      WA - MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER
C              AT DESIGN CONDITIONS (LBM/HR)
C      YFP - PLANT SCALING FACTOR FOR FAN AND PUMP POWER LOSS
100 C      (DIMENSIONLESS)

```

```
COMMON /VARVAR/ VTPER(16), VTA(16)
```

```
COMMON /PROP/ CPW, THCONW, DENS1W, VISW, HFG,
*             CPV, THCONV, DENS1V, VISV, SIGMA,
*             CPA, THCONA, DENS1A, VISA
```

```
* LOGICAL FIRST, FXTMP
```

```
COMMON
```

```
S AFTR, ALPHA, ANG(3)
```

```
S ,CAPE, CSSPKW, CONF, CONVL, COSTL, CAPCHG, CONMAT, CONMA2, CAF
```

```
110 S ,CBJ, CTURB, CDANG, CLUVR, CHA1LS, CVM
```

```
S ,DANGLE, OFIN, DEEPL, DESVEL, DESVELV
```

```
S ,EFFF
```

```
S ,FCR, FIRST, FIXL, FQOS, FFHX, FXTMP
```

```
S ,GREFE
```

```

115      $ ,HXNP, HPCST
      $ ,ITMAX, ITMIN
      $ ,JCONS
      $ ,KCONV, KALEXT
      $ ,MXEXT
120      $ ,NTUCAL(2), NTA
      COMMON
      $ ODR
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, PCMDPL
      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCC
125      $ ,RBP, REDUCE, REDUCV, ROOFLL
      $ ,QREJ, QREDUCE, QREDUCV
      $ ,SIGMAG, SAAF
      $ ,TD, TPO(4), TEFF, TLIM, THFW, TLPRA, TFIX
      $ ,TCO, TW
130      $ ,UCS, UWS
      $ ,WFW
      $ ,VAS(5)
      $ ,XDEPA, XW, XD
135      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
      $ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
      $ FPOW, DELFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
      $ REWAT, NW, NT, NP, PLANC2, PSIZ12, SP9P, SW4, SW3,
      $ SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
      $ RP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
140      $ , TLAX, UCON, PMCST, FMCST, FBACC, EFFC, CH, CA, CS
      $ , CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLDGST
      $ , CAPST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTTUB, ADIA, ABLN
      $ , WTHR, WTERM, STRUCC, CPERF, HPERF, TOTCF, TPC, EFFIN, ANTU
145      $ , AIREF, WATER, XNMOD, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP
      $ , ACTHDD, ADJBDP, ACTVH, ADJVV, ADJPPF, THPAIR, TCTF, AFCST
      $ , CSRD, WATERW, WSTRCT, CFQND, HJSDIA, TOWLEN, NUMTOW, CTOWD
      $ , SQRJ, SQRUS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR
      $ , CSTHC, CYLRNG, CFANEL, PSTACS, PUFITC, PMCST, RPTPL, SEPCST
150      COMMON /SCALER/ HRFAC1, ATUR, CPRA, SSCD, PLANC1, CASSS1,
      $ GAIR, FAIR, HPAIR, HPWAT, HLRT, PLANC1
      COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2GE, LINOR, XNP, XQUALY
      DIMENSION VLIST(9)
      DATA NTRIP/0/
155      DATA VLIST /"CCOS","SPCD","CLAND","CPIP","CONBAS","COSM"
      $ , "TRPD","PARCOS","VCST"/

C
C      DESIGN THERMAL EFFECTIVENESS OF THE POWER PLANT
      TEFFB=TEFF/HRFAC2

C
C      RATED THERMAL EFFECTIVENESS OF THE POWER PLANT
      TEFF1 = TEFF/HRFAC1

C
C      HEAT INPUT INTO THE POWER PLANT
      QIN1 = 3413.E+3*PSIZ13/TEFF1
165      VCST = 0.0

C
C      LOOP TO FIND THE INCREMENTAL COST OF THE COOLING SYSTEM
      DO 500 I = 1,NTA

C
C      AMBIENT TEMPERATURE

```

```

      TA = VTA(I)
      C
      C      PERCENT OF THE YEAR AT THE ABOVE AMBIENT TEMPERATURE
      TPERI = VTPER(I)
      C
      C      INITIAL GUESS AT THE SATURATION TEMPERATURE FOR THE ABOVE
      C      AMBIENT TEMPERATURE
      T1 = TA + RANGE/EFF + TTD1 + TTD2
      C
      C      BACK PRESSURE AT THE SATURATION TEMPERATURE
      S P = EXP(17.168-9240./(T1+460.))
      C
      C      HEAT RATE FACTOR AT THE ABOVE BACK PRESSURE
      HRFAC4 = TPO(1) + TPO(2)*P + TPO(3)*P**2 + TPO(4)*P**3
      C
      C      THERMAL EFFECTIVENESS OF THE PLANT AT THE ABOVE BACK
      C      PRESSURE
      TEFF4 = TEFF/HRFAC4
      C
      C      HEAT REJECTED AT THE ABOVE THERMAL EFFECTIVENESS OF THE
      C      POWER PLANT
      QREJCT2 = QIN1*(1. - TEFF4)
      C
      C      HEAT REJECTED AT THE DESIGN THERMAL EFFECTIVENESS OF
      C      THE POWER PLANT
      QREJCT1 = QIN1*(1. - TEFF3)
      SQRUS = QREJCT1
      C
      C      TEMPERATURE DIFFERENCE BETWEEN THE SATURATED STEAM AND
      C      THE AMMONIA IN THE CONDENSER/REBOILER
      TTD12 = (QREJCT2/QREJCT1)*TTD1
      C
      C      PRESSURE OF THE AMMONIA LEAVING THE CONDENSER/REBOILER
      P12 = FLUID(10,1,T1-TTD12,ELEV,"CALC 22")
      HFG2 = FLUID(9,1,T1-TTD12,ELEV,"CALC 20")
      DENSIV2 = FLUID(7,1,T1-TTD12,ELEV,"CALC 21")
      C
      C      MASS FLOW RATE OF AMMONIA THROUGH THE COOLING SYSTEM
      W32 = QREJCT2/HFG2
      C
      C      PRESSURE DROP OF AMMONIA THROUGH THE SUPPLY PIPING
      DELPS2 = DELPS*(W32**2*DENSIV/(DENSIV2*W3**2))
      C
      C      PRESSURE AT THE END OF THE SUPPLY PIPING
      P22 = P12 - DELPS2/144.
      T1 = T1 - TTD1 - TTD2
      DELTI = .001
      C
      C      LOOP TO DETERMINE THE TEMPERATURE OF THE AMMONIA AT THE
      C      END OF THE SUPPLY PIPING
      10 FTI = -P22 + FLUID(10,1,T1,ELEV,"CALC 23")
      FTIDEL = -P22 + FLUID(10,1,T1+DELT1,ELEV,"CALC 24")
      TIP1 = T1 - DELTI*FTI/(FTIDEL - FTI)
      IF(ABS(TIP1 - T1).LT..0001) GO TO 20
      T1 = TIP1
      GO TO 10
      C

```

```

230      C      TEMPERATURE DROP IN THE AMMONIA FROM THE BEGINNING TO THE
      C      END OF THE SUPPLY PIPING
      C      20 TTD22 = T1 - TTD12 - T1
      C
      C      TEMPERATURE RANGE OF THE AIR
      C      RANG2 = QREUCT2 / (W4 * (1.+YFP) * CPA)
235      C
      C      SATURATION TEMPERATURE OF THE STEAM IN THE CONDENSER/
      C      REBOILER
      C      T11 = RANG2/EFF + TA + TTD12 + TTD22
      C
240      C      CONVERGENCE CRITERIA FOR THE SATURATION TEMPERATURE OF
      C      THE STEAM IN THE CONDENSER/REBOILER
      C      IF( .NOT. EXTEMP .AND. (T11-T1)**2 .LE. .001) GOTO 40
      C      IF( EXTEMP .AND. ABS((T11-T1)/T11) .LT. 0.0001) GOTO 40
      C      T1 = T11
245      C      GO TO 5
      C
      C      POWER OUTPUT OF THE LOW-PRESSURE TURBINE AT THE SPECIFIC
      C      AMBIENT TEMPERATURE
      C      40 PTOT = QIN1 * TEFF4/3413.E+3
250      C
      C      POWER OUTPUT OF THE PLANT AT THE SPECIFIC AMBIENT TEM-
      C      PERATURE
      C      PGEN=PTOT-PPQW/1000.-FPQW/1000.-
      C      TEFFD=TEFF4
255      C      IF(PGEN.GE.PSIZE) GO TO 50
      C
      C      COST OF THE AUXILIARY POWER REQUIRED TO MAKE UP FOR LOST
      C      CAPACITY ON HOT DAYS
      C      CSTCL=(PSIZE-PGEN)/PSIZE*PWCOS
260      C      TEFFD=TEFF3
      C      GO TO 40
      C      50 CSTCL = 0.0
      C
      C      INCREASED FUEL COST OF THE PLANT DUE TO OFF DESIGN
      C      CONDITIONS
265      C      60 DELFC = FCOS*3413.E-5 * ((1.+YFP)/TEFFD-1./TEFF)
      C      IF(Z.N=.1) GO TO 100
      C      CAPCST = 0.0
      C
270      C      FOR TEMPERATURES ABOVE 180 DEGREES THE VALUE OF VCOST
      C      IS FORCED TO A VERY HIGH NUMBER SO THAT THIS WILL BE
      C      BE CONSIDERED AS A TOO EXPENSIVE CASE THIS IS REQUIRED
      C      BECAUSE THE CURVE FIT FOR THE HEAT RATE FACTOR IS
      C      UNACCEPTABLE ABOVE 180 DEGREES (15 IN H3A)
275      C
      C      IF(T11.GT. TLIM) VCST = 1. E+ 38
      C      IF (T11.GT. TLIM) RETURN
      C      IF(PSIZE.LE.PGEN) GO TO 100
      C
280      C      CAPITAL CHARGE FOR THE AUXILIARY POWER
      C      CAPCST=CAPCHG*(PSIZE-PGEN)
285      C      100 CONTINUE
      C
      C      INCREASE IN COST OF OPERATING THE PLANT AT THIS AMBIENT
      C      TEMPERATURE DUE TO THE USE OF THE COOLING SYSTEM

```

```

      PARCOS = (CCOS + SPCD + CLAND + CPIP + CONBAS + CAPCST) * FCR/
& (PSIZE * CAPF * 8750.) + COSM + DELFC + CSTCL
C
C      FRACTION OF THE YEAR THAT THIS AMBIENT TEMPERATURE EXISTS
290 C      TIMES THE INCREMENTAL COST OF THE COOLING SYSTEM AT
C      THIS AMBIENT TEMPERATURE
      XCOST(I) = TPER * PARCOS
&00 CONTINUE
C
&95 C      SUMMING THE PRODUCTS TO OBTAIN THE TOTAL INCREMENTAL COST
C      OF THE COOLING SYSTEM
      DO &20 I=1,NTA
      VCST = VCST + XCOST(I)
&20 CONTINUE
300 C
      NDRUG = 0
      IF (NDRUG.EQ.0) RETURN
      NTRIP = NTRIP + 1
      WRITE(4,902) NTRIP
305 WRITE(4,900) CCOS,SPCD,CLAND,CPIP,CONBAS,COSM,TPER,PARCOS,VCST
      WRITE(4,901) VLIST
&00 FORMAT(1H,9G14.6)
&01 FORMAT(1H,9(4X,A6,4X))
&02 FORMAT("0NOVART CALL NO.",I10)
310 RETURN
      END

```



```
      SUBROUTINE OUT2(RBP,HRFAC1,SSCD,CASSSI,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,T97,"IN. HG",  
   $ T113,"HRFAC1=",F11.6)
```

```
10
```

```
2  FORMAT(T17,"STEAM SUPPLY COST DIFFERENTIAL $",F12.0  
   $ ,T31,"TURBINE COST DIFFERENTIAL",F11.0,T129,"$/KW")
```

```
3  FORMAT(T2,"PLANT COST INCLUDING STEAM SUPPLY AND TURBINE $",F12.0  
   $ ,T56,"PLANT UNIT COST INCLUDING STEAM SUPPLY AND TURBINE",F11.0  
   $ ,T129,"$")
```

```
15
```

```
      WRITE(6,1) RBP,HRFAC1  
      WRITE(6,2) SSCD, TCO  
      WRITE(6,3) 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, ANG(3)

\$,CAFF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI

\$,CBU, CTURB, CDANG, CLUVR, CHAILS, CVM

\$,DANGLE, DFIN, DEEPL, DESVEL, DESVELV

\$,EFFP

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

\$,GREFF

\$,HXNP, HPCST

\$,ITMAX, ITMIN

\$,JCONS

\$,KCONV, KALEXT

\$,MXEXT

\$,NTUCAL(2), NTA

COMMON

\$ ODR

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

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

\$,RBP, REDUCE, REDUCV, ROOFLL

\$,QREJ, QREDUCE, QREDUCV

\$,SIGMAG, SAAF

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

\$,TCD, TW

\$,UCS, UWS

\$,WCV

\$,VAS(5)

\$,XDEPA, XW, XD

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

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

\$ FPOW, DELEC, WIDTH, ELENG, VAIR, VBAT, HI, HO, T4,

\$ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,

\$ SPCPTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,

\$ BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX

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

\$, CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELFIP, AST, OLDGST

\$,CAPCST, XNFAN, BLDANG, CPLEN, DPFL, WHX, WTTUB, ADIA, ABLN

\$, WTHR, WTRM, STRJCC, CEPREF, HPPREF, TOTCF, TPC, EFFIN, ANTU

\$, AIREF, WATFF, XNMO, TCTPF, FOCPE, FMTRC, ACCTTP, ADJTP

\$, ACTBD, ADJBD, ACTVH, ADJVH, ADJPPF, THAIR, TCTF, AFCST

\$, CSRD, WATERW, WSTRCT, CFOUND, HUBDIA, TOLLEN, NUMTOW, CTOWD

\$, SPU, SPUJ, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR

\$, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST

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

\$ QIN1, CLAN1, REAIR1, Z1,HRFA2S, W41, U1, DEPW1, PPOW1,

\$ FPOW1, DEFC1, WIDTH1, ELENG1, VAIR1, VBAT1, HI1, HO1, T41,

\$ REWAT1, NW1, NT1, NP1, PLNC2, ZSIZ12, ZSPBP, SW41, SW31,

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

```

60      $ BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONSA1, XNTS1, VELD1
      $ , TLAL, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CHI, CAL, CSI
      $ , CLTC1, CFC1, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLDCS1
      $ , CAPCS1, XNFAN1, RLOAN1, CRLEN1, OPFEL1, WH1, WTTU1, ADI1, ABL1
      $ , WTHD1, WTRF1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1
      $ , AIRFF1, WATFF1, XNMO1, TCIPF1, FDCPF1, FHTRC1, ACTTP1, ADUTP1
65      $ , ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1
      $ , CSR1, WATER1, WSTRC1, CFOUN1, HUBO1, TOWLE1, NUMTO1, CTOWD1
      $ , SQRJ1, SQPUS1, ATUBC1, CBA1, ITD11, ITD21, DELPS1, CSTLV1
      $ , CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPCS1, PPTPL1, SEPC1
      $ , COMMON /SCALER/HRFAC1, ATUB, CPERA, SSCD, PLANC1, CASSS1,
70      $ GAIR, FAIR, HPAIR, HPWAT, WLRTF, PLANCT1
      COMMON /DJB/ DI, XDG, 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, " MW")
75  911  FORMAT(1X, T88, "PLANC2=", G15.7, " $/KW")
916  FORMAT(1X, T88, " SPBP=", G15.9, " $")
917  FORMAT(1X, T81, "BACK PRESSURE=", G15.7, " IV, H3")
918  FORMAT(1X, T79, "SAT TEMPERATURE=", G15.9, " DEG F")
921  FORMAT(1X, T12, "AMMONIA FLOW RATE", G15.9, " LB MASS / HR")
80  923  FORMAT(1X, T14, " HEAT REJECTED ", G15.9, " BTU/HR")
926  FORMAT(1X, T14, "AIR FLOW RATE ", G15.9, " LB MASS / HR")
931  FORMAT(1X, T14, " PUMP POWER ", G15.9, " KILOWATTS")
936  FORMAT(1X, T14, " FAN POWER ", G15.9, " KILOWATTS")
941  FORMAT(1X, T14, "HX SURFACE AREA ", G15.9, " SQ FT")
85  946  FORMAT(1X, T14, " FRONTAL AREA ", G15.9, " SQ FT")
951  FORMAT(1X, T11, "WIDTH/LENGTH RATIO ", G15.9)
956  FORMAT(1X, T15, " WIDTH ", I11, T45, " TUBES")
961  FORMAT(1X, T15, " WIDTH ", G15.9, " FEET")
962  FORMAT(1X, T9, "NO. CONDENSER TUBES ", G15.9)
90  963  FORMAT(1X, T8, "CONDENSER TURE LENGTH ", G15.9, " FT.")
964  FORMAT(1X, T13, "AMMONIA VELOCITY ", G15.9, " FT/SEC")
965  FORMAT(1X, T7, "CONDENSER HT TRFR AREA ", G15.9, " SQ FT TOTAL")
1001 FORMAT(1X, "SCALING FOR FAN AND PUMP POWER REQUIREMENTS",
      * T88, "SCALING FACTOR ", G15.9)
95  1005 FORMAT(1X, T88, " Psize ", G15.9, " MW")
1006 FORMAT(1X, T88, "PSIZ13 ", G15.9, " MW")
1011 FORMAT(1X, T88, "PTOTAL ", G15.9, " MW")
1016 FORMAT(1X, T88, "PLANC3 ", G15.9, " $/KW")
1021 FORMAT(1X, T88, " SPC ", G15.9, " $")
100  1026 FORMAT(1X, T88, " SSCD ", G15.9, " $")
9888 FORMAT(140, 12(" ** ** ** ")//)
      WRITE(6, 2000)
      WLRTF = WIDT1/ELEN1
105  IF(KWHICH.NE.1) GOTO 2000
      WRITE(6, 901) HRFAC2
      WRITE(6, 906) ZSIZ12
      WRITE(6, 911) ZPLNC2
      WRITE(6, 916) ZSPBP
      WRITE(6, 917) BP2MIN
110  WRITE(6, 919) VAR(1)
      WRITE(6, 921) W31
      WRITE(6, 923) SQRJ1
      WRITE(6, 926) W41
      WRITE(6, 931) (PPOW1/(1.*YFPMIN))

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115      WRITE(6,936) (FPDW1/(1.+YFPMIN))
        WRITE(6,941) (AAIR1/(1.+YFPMIN))
        WRITE(6,946) (AFRO1/(1.+YFPMIN))
        WRITE(6,951) WLRT1/(1.+YFPMIN)
        WRITE(6,956) NW2MIN
120      WRITE(6,961) WT2MIN
        WRITE(6,965) AST1
        WRITE(6,962) XNTS1
        WRITE(6,963) TLAL
        WRITE(6,964) VELD1
125      RETURN
2000 CONTINUE
        WRITE(6,1001) (1.+YFPMIN)
        WRITE(6,1005) PSIZE
        WRITE(6,1006) SPS13
130      WRITE(6,1011) PTOT1
        WRITE(6,1016) PLVC31
        WRITE(6,1021) SPC1
        WRITE(6,1026) SPCD1
        WRITE(6,921) SW31
135      WRITE(6,923) SQRJS1
        WRITE(6,925) SW41
        WRITE(6,931) PPOW1
        WRITE(6,936) FPOW1
        WRITE(6,941) AAIR1
140      WRITE(6,946) AFRO1
        WRITE(6,951) WLRT1
        WRITE(6,956) NW1
        WRITE(6,961) WIDT1
        WRITE(6,965) AST1 * (1. + YFPMIN)
145      WRITE(6,962) XNTS1 * (1. + YFPMIN)
        WRITE(6,963) TLAL
        WRITE(6,964) VELD1
        RETURN
END

```

SUBROUTINE PIPCLR(CTOW,TOWDIA,DOTMA,DIST,DESVELL,BUNWIDT,REDUCR,
S QREDUCR, DELL, PIPCSTL, COANG, POHCIR)

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5      C      THIS SUBROUTINE DESIGNS AND COSTS THE RETURN PIPING SYSTEM
      C      WHICH TRANSPORTS THE LIQUID AMMONIA. THIS INCLUDES ALL THE
      C      PIPE, VALVES, AND FITTINGS BETWEEN THE HEAT EXCHANGER AND
      C      THE CONDENSER/REBOILER. PIPE DIAMETER IS DETERMINED FROM THE
      C      AMMONIA FLOW RATE AND THE LIQUID DESIGN VELOCITY. VALVE AND
10     C      FITTING SIZES CORRESPOND TO THE PIPE SIZES WITH THE SAME
      C      FLOW RATE.
      C
      C      DEFINITION OF VARIABLES
      C
15     C      APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
      C      BRCHDIA - DIAMETER OF DISTRIBUTION PIPING OR BUNDLE FITTINGS:
      C                  (INCHES). IS USED TO GET "BRANCH" PORTION OF THE
      C                  TEE COSTS
      C      BRCCST - COST OF "BRANCH" PORTION OF TEE COST ($1000)
      C      BUNWIDT - WIDTH OF TUBE BUNDLE (FT)
20     C      CHANG - ANGLE OF DELTA HEAT EXCHANGER (DEGREES)
      C      CPW - SPECIFIC HEAT OF AMMONIA LIQUID (BTU/LBM DEG F)
      C      CTOW - NUMBER OF CIRCULAR TOWERS
      C      DELL - PRESSURE DROP IN RETURN CIRCULATION PIPING FOR
      C                  LIQUID AMMONIA (PSF)
25     C      DELPBR - PRESSURE DROP IN BUNDLE FITTINGS (PSF)
      C      DELPD,T - PRESSURE DROP IN DISTRIBUTION PIPING, TOWER PIPING
      C                  (T), (PSF)
      C      DELRH,Q - PRESSURE DROP IN MAIN CIRCULATION HEADER, QUADRANT
      C                  HEADER (Q), (PSF)
30     C      DENSILW - DENSITY OF AMMONIA LIQUID (LBM/CU FT)
      C      DESVELL - AMMONIA LIQUID DESIGN VELOCITY (FT/SEC)
      C      DIAR - DIAMETER OF MAIN CIRCULATION RETURN HEADER (INCHES)
      C      DIARD - DIAMETER OF DISTRIBUTION PIPING (INCHES)
      C      DIART - DIAMETER OF TOWER PIPING (INCHES)
35     C      DIST - DISTANCE FROM CONDENSER/REBOILER TO BOUNDARY OF
      C                  TOWERS (FT)
      C      DOTMA - TOTAL MASS FLOW RATE (LBM/HR)
      C      DOTMAB,Q,T - MASS FLOW RATE TO TUBE BUNDLE, QUADRANT (Q),
      C                  TOWER (T), (LBM/HR)
40     C      DOTREM - FLOW RATE REMAINING IN HEADER SECTION (LBM/HR)
      C      DYNHDL - DYNAMIC HEAD LOSS (FT OF AMMONIA)
      C      ELCST - 90 DEG ELBOW COST ($1000)
      C      EL45 - 45 DEG ELBOW COST ($1000)
      C      ERLN - EQUIVALENT LENGTH (FT)
45     C      FLGCST - FLANGE COST ($1000)
      C      HEAD - HEAD LOSS (FT OF AMMONIA/100 FT OF EQUIVALENT
      C                  LENGTH)
      C      HDR - LENGTH OF MAIN CIRCULATION HEADER SECTION (FT)
      C      IN - INDEX REFERS TO DISTRIBUTION PIPING
      C      IT - INDEX REFERS TO TOWER PIPING
50     C      J2 - IDENTIFIES MAIN CIRCULATION HEADER SECTION
      C      K2 - IDENTIFIES QUADRANT HEADER SECTION
      C      NUNPQD - NUMBER OF BUNDLES PER QUADRANT
      C      NFL - UPPER LIMIT TO NUMBER OF TUBE BUNDLES PER QUADRANT
      C      NFS - UPPER LIMIT TO NUMBER OF CIRCULAR TOWERS
55     C      PIPCST - BELOW GROUND PIPE COST ($1000/FT)
      C      PIPCSTL - TOTAL CIRCULATION RETURN PIPING COST ($1000)

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60      C      PCHCIR - INDIRECT COST FACTOR FOR CIRCULATION PIPING
        C      QHEDR - LENGTH OF QUADRANT HEADER SECTION (FT)
        C      QREDUCR - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
        C      QUADRANT HEADER SECTIONS (INCHES)
        C      QRLCST - COST OF 90 DEG ELBOW AT END OF QUADRANT HEADER
        C      ($1000)
65      C      RRF CST - COST OF RUNDLE FITTINGS ($1000)
        C      RCOST - COST OF MAIN CIRCULATION PIPING ($1000)
        C      RCST - REDUCER COST ($1000)
        C      REDUCER - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
        C      MAIN CIRCULATION HEADER SECTIONS (INCHES)
70      C      REJCST - COST OF EXPANSION JOINT AT CONDENSER/REBOILER
        C      INLET ($1000)
        C      RFLCST - COST OF 90 DEG ELBOW AT END OF MAIN CIRCULATION
        C      HEADER ($1000)
        C      RFLGCST - TOTAL COST OF APPROPRIATE FLANGES AT CONDENSER/RE-
        C      BOILER INLET ($1000)
75      C      RHO - DENSITY OF AMMONIA LIQUID (LBM/CUFT)
        C      RPCST - COST OF PIPE FOR MAIN CIRCULATION HEADER ($1000)
        C      RQCST - COST OF QUADRANT PIPING ($1000)
        C      RQDIA - COMPONENT DIAMETER OF QUADRANT HEADER SECTION
        C      (INCHES)
80      C      RQPCST - COST OF PIPE FOR QUADRANT HEADER ($1000)
        C      RQRCST - COST OF REDUCER FOR QUADRANT HEADER ($1000)
        C      RRCST - COST OF REDUCER IN MAIN CIRCULATION HEADER ($1000)
        C      RTCST - COST OF TEE IN MAIN CIRCULATION HEADER ($1000)
        C      RTDCST - COST OF DISTRIBUTION AND TOWER PIPING ($1000)
85      C      T CST - TEE COST ($1000)
        C      TQWDIA - DIAMETER OF CIRCULAR TOWER (FT)
        C      TRQCST - TOTAL RETURN QUADRANT PIPING COSTS ($1000)
        C      TRTDCST - TOTAL RETURN DISTRIBUTION AND TOWER PIPING COSTS
        C      ($1000)
90      C      UPCST - UNIT PIPE COST ($1000/FT)
        C      VACST - VALVE COST ($1000); VALVES ARE MOTOR OPERATED
        C      BUTTERFLY VALVES
        C      VELO - FLUID VELOCITY BASED ON FLOW RATE AND NOMINAL PIPE
        C      DIAMETER (FT/SEC)
95      C      VISW - VISCOSITY OF LIQUID AMMONIA (LBM/FT HR)
        C
        COMMON/PROP/CPW,THCONW,DENSIN,VISW,HFG,
        $      CPV,THCONV,DENSIV,VISV,SIGMA,
        $      CPA,THCONA,DENSIA,VISA
100     COMMON /RPTRET/
        $      SDELL, SDESVE, DIARD, DIART, SDOOMA, DYNHOLI
        $      HEDR(200)
        $      JR
        $      KR
105     $      SPIPCS
        $      QHEDR(200), QRLCST
        $      RQDIA(200), RPCST(200), RRCST(200), RTCST(200), RRF CST, RCOST
        $      RQDIA(200), RQPCST(200), RQRCST(200), RQTCST(200), REJCST, RELCST
        $      RFLGCST, RQCST, RTDCST
110     $      STOWDI, TRQCST, TRTDCST
        C
        COMMON /PCDIM/ NFS,NFL
        COMMON /PME/ PMELEC
        DIMENSION UPIPCST(200)

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115 DIMENSION DIAM(24), TEECST(24), PIPCST(24), ELCST(24), EL45(24)
 \$ VACST(24), FLGCST(24), APIPCST(24)

C

DATA DIAM /

120

\$ 5. , 12. , 18. , 24. , 30. , 36. ,
 \$ 42. , 48. , 54. , 60. , 66. , 72. ,
 \$ 78. , 84. , 90. , 96. , 102. , 108. ,
 \$ 114. , 120. , 126. , 132. , 138. , 144. /

C

DATA FLGCST/

125

\$.136, .520, 1.03 , 1.92 , 3.17 , 4.42 ,
 \$ 5.82 , 9.22 , 12.0 , 14.7 , 21.1 , 27.5 ,
 \$ 33.9 , 40.4 , 46.8 , 53.2 , 59.7 , 66.1 ,
 \$ 72.5 , 78.9 , 85.4 , 91.8 , 98.2 , 105. /

C

DATA TEECST/

130

\$.344, .935, 1.96 , 3.82 , 14.8 , 25.8 ,
 \$ 31.7 , 37.6 , 53.4 , 69.1 , 87.9 , 107. ,
 \$ 126. , 145. , 163. , 182. , 201. , 220. ,
 \$ 239. , 258. , 277. , 296. , 314. , 333. /

135

C

DATA PIPCST/

\$.06, .113, .147, .219, .409, .599,
 \$.720, .841, 1.08 , 1.31 , 1.57 , 1.84 ,
 \$ 2.10 , 2.36 , 2.62 , 2.88 , 3.15 , 3.41 ,
 \$ 3.67 , 3.93 , 4.19 , 4.46 , 4.72 , 4.98 /

140

C

DATA VACST/

145

\$ 2.87 , 7.09 , 16.9 , 26.7 , 52.2 , 77.8 ,
 \$ 109. , 141. , 164. , 187. , 213. , 240. ,
 \$ 266. , 293. , 319. , 346. , 372. , 399. ,
 \$ 425. , 452. , 478. , 505. , 531. , 558. /

C

DATA ELCST/

150

\$.275, .715, 1.35 , 2.94 , 9.54 , 16.1 ,
 \$ 27.4 , 38.8 , 51.9 , 65.1 , 87.6 , 110. ,
 \$ 133. , 155. , 179. , 200. , 222. , 245. ,
 \$ 269. , 290. , 312. , 335. , 357. , 380. /

C

DATA EL45/

155

\$.230, .558, .947, 2.16 , 7.67 , 13.2 ,
 \$ 20.2 , 27.2 , 37.7 , 48.1 , 65.2 , 84.3 ,
 \$ 102. , 120. , 138. , 157. , 175. , 193. ,
 \$ 211. , 229. , 247. , 265. , 283. , 301. /

160

C

DATA APIPCST/

\$.034 , .073 , .096 , .155 , .332 , .510 ,
 \$.614 , .719 , .939 , 1.16 , 1.41 , 1.67 ,
 \$ 1.91 , 2.15 , 2.41 , 2.66 , 2.99 , 3.16 ,
 \$ 3.41 , 3.66 , 3.91 , 4.16 , 4.42 , 4.67 /

165

C

DATA NFS,NFL /200,200/

NBUNPQD = 3.1416 * TDWDIA / (4.*BUNWIDT.CDANG) + 7.

DOTMAT=DOTMA/CTOW

DOTMAQ=DOTMAT/4.

DOTMAB=DOTMAQ/NBUNPQD

CONST1=4./(3.1416*3600.)

170

```

      RRCOST=L.
      RQCOST=J.
      DO 1 I=1,NFS
175      1 RRCOST(I)=0.
      DO 2 I=1,NFL
      2 RQCOST(I)=0.
      DELPH=0.
      DELPO=0.
180      RELCOST=J.
      RELGOST=0.
      REJCOST=0.
      DO 40 I=1,NFS
      40 RRCOST(I)=0.
185      C
      C      THE DENSITY AND VISCOSITY OF THE AMMONIA LIQUID ARE ASSUMED
      C      CONSTANT IN THE RETURN PIPING AND ARE EVALUATED AT THE HEAT
      C      EXCHANGER OUTLET CONDITIONS.
190      C
      RHO=DENSIW
      VIS=VISH
      CONST2=4.*144./(3.1416*3600.)
      JP=1
      DOTREM=DOTMA
195      C
      C      IN THE STATEMENTS THROUGH 47 + 1 THE MAIN CIRCULATION PIPING
      C      IS DESIGNED AND COSTED. THE PRESSURE DROP IS DETERMINED FOR
      C      PUMPING REQUIREMENTS.
200      C
      C      CALL HEADER TO DESIGN AND COST THE COMPONENTS OF HEADER
      C      SECTION JP. ALL HEADER SECTION COMPONENTS ARE DETERMINED
      C      BETWEEN STATEMENTS 43 AND 42 - 1.
      C
205      43 CALL HEADER(DOTREM,DOTMAT,BESVELL,RHO,REDUCR,JP,1,DIAJ,
      *DIAR,ICST,RCST,UPCST,RELCST,RELGOST,REJCST)
      C
      C      THE DIAMETER OF HEADER SECTION JP (DIAR) IS REPLACED BY DIAJ
      C      IN ORDER TO COMPARE THE DIAMETER OF SECTION JP WITH SECTION
      C      JP + 1 TO DETERMINE REDUCER REQUIREMENTS. RDIA IS THE STORED
210      C      VALUE OF THE DIAMETER OF HEADER SECTION JP.
      C
      DIAJ=DIAR
      RDIA(JP)=DIAR
      RICST(JP) = ICST
215      C
      C      ASSIGN THE COST OF A REDUCER TO THE PRECEDING HEADER SECTION.
      C      THE COST OF A REDUCER IS BASED ON THE LARGEST DIAMETER OF
      C      THE REDUCER.
220      C
      IF(JP.GT.1) RRCOST(JP-1)=RRCOST
      UPIPCST(JP)=UPCST
      C
      C      DETERMINE LENGTH OF HEADER SECTION. THE FIRST HEADER SECTION
      C      IS DESIGNATED HEADER SECTION 1. ALL EVEN NUMBERED HEADER
225      C      SECTIONS ARE EFFECTIVELY ZERO LENGTH BECAUSE THE CIRCULAR
      C      TOWERS ARE PAIRED ON OPPOSITE SIDES OF THE MAIN CIRCULATION
      C      HEADER. THERE IS ONE HEADER SECTION DESIGNATED FOR EACH
      C      CIRCULAR TOWER.

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230      C
          IF(JR.EQ.1) GO TO 10
          IF(MOD(JR,2).EQ.0) HEDR(JR)=0.
          IF(MOD(JR,2).NE.0) HEDR(JR)=1.5*TOWDIA
          GO TO 11
235      10 HEDR(JR)=DIST+.5*TOWDIA
          11 CONTINUE
          C
          C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN HEADER SECTION
          C      JR. THE EQUIVALENT LENGTH INCLUDES AN L/D OF 20 FOR THE TEE
          C      "RUN".
240      C
          EOLEN=HEDR(JR)+20.*DIAP/12.
          VELO=DOTREM*CONST2/(RHO*DIAR*DIAR)
          CALL HYDLOS(DIAR,VELO,VIS,RHO,2,HEAD)
          DELPH=DELPH+HEAD*RHO*EOLEN/100.
245      C
          C      SUBTRACT OUT THE FLOW TO ONE CIRCULAR TOWER TO GET THE FLOW
          C      IN HEADER SECTION JR + 1.
          C
          DOTREM=DOTREM-DOTMAT
250      C
          C      IF THE REMAINING FLOW IS ZERO THEN THE LAST HEADER SECTION
          C      HAS BEEN DESIGNED.
          C
          IF(DOTREM.LE.0.) GO TO 42
          JR=JR+1
          IF( JR .GT. NFS) PIPCSL = 1.E+40
          IF( JR .GT. NFS) RETURN
          GO TO 43
255      C
          C      DETERMINE THE DIAMETER OF THE DISTRIBUTION PIPING.
          C
          42 BRCHDIA=SQRT(DOTMAT*CONST1/(RHO*DESVELL))*12.
          IF(BRCHDIA.LT.DIAM(1)) BRCHDIA=DIAM(1)
          DO 44 I=1,23
260      C
          II=I
          IF(BRCHDIA-DIAM(II))45,45,44
265      C
          44 CONTINUE
          45 BRCHDIA=DIAM(II)
          C
          C      THE COST OF A TEE IS ASSUMED TO BE .67 TIMES THE COST OF A
          C      TEE OF THE "RUN" DIAMETER PLUS .33 TIMES THE COST OF A TEE
          C      OF THE "BRANCH" DIAMETER. THE "RUN" PORTION WAS DETERMINED
          C      IN SUBROUTINE "HEADER". THE "BRANCH" PORTION IS DETERMINED
          C      HERE.
270      C
          BRGST=.33*TEFGST(1)
          DO 46 I=1,JR
          PIGST(I)=PIGST(I)+BRGST
          46 RPGST(I)=UPIGST(I)*HEDR(I)
          PIGST(JR)=0.
          DO 47 I=1,JR
          IF(I.LT.JR)RCOST=RCOST+RPGST(I)+RPGST(I)+PIGST(I)
          IF(I.EQ.JR)RCOST=RCOST+RPGST(I)+RPGST(I)+PIGST(I)
          47 CONTINUE
          RCOST=RCOST+RELGST+REJOST
275      C

```

```

C
C      IN THE STATEMENTS THROUGH 51 + 4 THE DISTRIBUTION PIPING IS
C      DESIGNED. INDEXES FOR UNIT COST ARRAYS ARE DEFINED.
C      PRESSURE LOSS IS EVALUATED.
200 C
      DIARD=SQRT(DOTMAT*CONST1/(RHO*DESVELL))*12.
      IF(DIARD.LT.DIAM(1))DIARD=DIAM(1)
      DO 50 I=1,23
      IT=I
205 C      IF(DIARD-DIAM(IT))51,51,50
      50 CONTINUE
      51 DIARD=DIAM(IT)
C
C      THE EQUIVALENT LENGTH INCLUDES THE LENGTH OF PIPE CONNECTING
300 C      THE MAIN CIRCULATION HEADER TO THE TOWER DISTRIBUTION HEADER.
C      THIS LENGTH IS ASSUMED TO BE .2 TIMES THE TOWER DIAMETER.
C
      EOLEN=.2*TOWDIA+200.*DIARD/12.
      VELO=DOTMAT*CONST2/(RHO*DIARD*DIARD)
305 C      CALL HYDLOS(DIARD,VELO,VIS,RHO,2,HEAD)
      DELPD=HEAD*RHO*EOLEN/100.
C
C      IN THE STATEMENTS THROUGH 53 + 4 THE TOWER PIPING IS
C      DESIGNED. INDEXES FOR UNIT COST ARRAYS ARE DEFINED.
310 C      PRESSURE LOSS IS EVALUATED.
C
      DIART=SQRT(DOTMAQ*CONST1/(RHO*DESVELL))*12.
      IF(DIART.LT.DIAM(1))DIART=DIAM(1)
      DO 52 I=1,23
      IT=I
315 C      IF(DIART-DIAM(IT))53,53,52
      52 CONTINUE
      53 DIART=DIAM(IT)
      EOLEN=TOWDIA+60.*DIART/12.
320 C      VELO=DOTMAQ*CONST2/(RHO*DIART*DIART)
      CALL HYDLOS(DIART,VELO,VIS,RHO,2,HEAD)
      DELPT=HEAD*RHO*EOLEN/100.
      DELTD = DELPT + DELPD
C
325 C
C      SUM THE PRESSURE DROPS IN THE TOWER AND DISTRIBUTION PIPING.
C
C
330 C      COMPUTE THE COST OF THE DISTRIBUTION AND TOWER PIPING. PIPE
C      LENGTHS INCLUDE THE LENGTH OF PIPE CONNECTING THE MAIN CIR-
C      CULATION HEADER TO THE TOWER DISTRIBUTION HEADER (.2*TOWDIA)
C      AND THE TOTAL LENGTH OF PIPE CONNECTING THE TOWER
C      DISTRIBUTION HEADER TO THE FOUR QUADRANT HEADERS (3.25*
335 C      TOWDIA). THESE LENGTHS ARE GENERAL APPROXIMATIONS. THE
C      TOWER DISTRIBUTION HEADER IS ASSUMED TO APPROXIMATE THE
C      COST OF FOUR TEES. INDEX "10" REFERS TO THE DISTRIBUTION
C      PIPING, "IT" TO THE TOWER PIPING.
C
340 C      PTCOST=.2*TOWDIA*PIPCOST(IT)+4.*(1.67*TEECOST(10)+.33*TEECOST(IT))
      +3.25*TOWDIA*PIPCOST(IT)+10.*FLCOST(IT)+2.*EL45(IT)
      +4.*VACOST(IT)+8.*FLCOST(IT)

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      TRIDCST=RTDCST*GTOW
345      C
      C      IN THE STATEMENTS THROUGH 67 + 11 THE QUADRANT PIPING IS DE-
      C      SIGNED AND COSTED. THE PRESSURE LOSS IN THE QUADRANT HEADER
      C      AND BUNDLE FITTINGS IS DETERMINED.
      C
      DO 60 I=1,NFL
350      60 RQRCST(I)=0.
      KR=1
      DOUTPEM=DOUTMA0
      C
      C      IN STATEMENTS 63 TO 62 - 1 DESIGN AND COST INFORMATION FOR
355      C      EACH QUADRANT HEADER SECTION IS DETERMINED.
      C
      63 CALL HEADER(DOUTREM,DOUTMA0,DESVELL,RHO,QREDUCR,KR,0,DIAJ,
      C      *DIAR,TCST,RCST,UPOST,QRLOST,QELGOST,QEJOST)
360      C
      C      THE DIAMETER OF HEADER SECTION KR (DIAR) IS REPLACED BY DIAJ
      C      IN ORDER TO COMPARE THE DIAMETER OF SECTION KR WITH KR + 1
      C      TO DETERMINE REDUCER REQUIREMENTS. RQDIA IS THE STORED
      C      VALUE OF THE DIAMETER OF HEADER SECTION KR.
365      C
      DIAJ=DIAR
      RQDIA(KR)=DIAR
      RQTCST(KR)=TCST
      C
      C      ASSIGN THE COST OF A REDUCER TO THE PRECEDING HEADER SECTION.
370      C      THE COST OF A REDUCER IS BASED ON THE LARGEST DIAMETER OF THE
      C      REDUCER.
      C
      IF (KR.GT.1) RQRCST(KR-1)=RCST
      UPIPCST(KR)=UPOST
375      C
      C      THE FIRST QUADRANT HEADER IS ASSUMED TO HAVE
      C      ZERO LENGTH. THE PIPE LENGTH FOR THE REMAINING SECTIONS WILL
      C      BE SHORTER IF A DELTA HEAT EXCHANGER ARRANGEMENT IS USED.
      C      LENGTH OF THE TEE "RUN" IS ASSUMED TO BE 1.75 TIMES THE PIPE
380      C      DIAMETER AND THIS LENGTH IS SUBTRACTED.
      C
      IF (KR.EQ.1) QHEDR(KR)=0.
      IF (KR.GT.1) QHEDR(KR) = BUNWIRT * CDANG - 1.75*DIAR / 12.
385      C
      C      DETERMINE THE HEAD LOSS AND PRESSURE DROP IN THE QUADRANT
      C      HEADER SECTION.
      C
      EQLEN=QHEDR(KR)*20.*DIAR/12.
      VELO=DOUTREM*CONST1/(RHO*DIAR*DIAR)
390      CALL HYDLOS(DIAR,VELO,VIS,RHO,Z.HEAD)
      DELPQ=DELPG*HEAD*RHO*EQLEN/100.
      C
      C      SUBTRACT OUT THE FLOW TO ONE TUBE BUNDLE. IF THE FLOW
      C      REMAINING IS ZERO THEN THE LAST QUADRANT HEADER SECTION
395      C      HAS BEEN DESIGNED.
      C
      DOUTREM=DOUTREM-DOUTMAR
      IF (DOUTREM.LE.0.) GO TO 62
      KR=KR+1

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409      IF( KP .GT. NFS) PIPCSL = 1.E+40
      IF( KP .GT. NFS) RETURN
      GO TO 63

C
C      COMPUTE THE DIAMETER OF THE BUNDLE FITTINGS.
409      C
      62 BRCHDIA=SQRT(OUTBAR*CONST1/(PHO*DESVELL))*12.
      IF(BRCHDIA.LT.DIAM(1))BRCHDIA=DIAM(1)
      DO 64 I=1,23
      II=I
410      IF(BRCHDIA-DIAM(II))65,65,64
      64 CONTINUE
      65 BRCHDIA=DIAM(II)

C
C      THE PORTION OF THE TFF COST ATTRIBUTED TO THE "BRANCH". SEE
415      C      NOTE PRECEDING STATEMENT 45 + 1.
      C
      BRGST=.33*TFFCST(II)

C
C      EVALUATE THE COST OF THE QUADRANT HEADER.
424      C
      DO 66 I=1,KR
      RQTCST(I)=RQTCST(I)+BRGST
      66 RQPCST(I)=UPIPCST(I)*QHEUR(I)
      RQTCST(KR)=0.
425      DO 67 I=1,KP
      IF(I.LT.KR)RQCCST=RQCCST+RQPCST(I)+RQTCST(I)+RQRCST(I)
      IF(I.EQ.KR)RQCCST=RQCCST+RQPCST(I)+RQPCST(I)+RQRCST
      67 CONTINUE

C
C      DETERMINE THE COST OF THE BUNDLE FITTINGS, I.E., THE PIPE
439      C      CONNECTING THE QUADRANT HEADER TO THE TUBE BUNDLE HEADER.
      C
      BRBCST= (3. * APIPCST(II) + ELGST(II) +2. * FLGST(II))

C
435      C      TOTAL RETURN QUADRANT PIPING COSTS.
      C
      RQCCST=RQCCST+BRBCST*N9UNPQ9
      TRQCCST=RQCCST*CTOR*4.

C
440      C      DETERMINE HEAD LOSS AND PRESSURE DROP IN THE BUNDLE FITTINGS.
      C
      FOLEN = 150. * BRCHDIA/12.
      VELG=DOTMA2*CONST2/(PHO*BRCHDIA*BRCHDIA)
      CALL HYDLOS(BRCHDIA,VELG,VIS,PHO,2,HEAD)
445      DELPPR=HEAD*PHO*FOLEN/100.

C
C      DETERMINE TOTAL COST AND PRESSURE DROP IN RETURN PIPING
C      SYSTEM.
451      C
      PIPCSL=PCOST+TRBCST+TRQCCST
      PIPCSL = PIPCSL * PUNCI9
      DELL=DELPH+DELTID+DELRQ+DELPBR
      DYNHOL=DELL/PHO

C
455      C      STORE VALUES IN COMMON BLOCK /RPTRET/ FOR LATER USE IN
      C      OUTPUT.

```

SHIPPING PIPER 7/4/74 OPT=1

FTN 4.5+414

05/02/77

C

4.60

SDFSVE = DFSVELL
SDOTMA = DOTMA
SPIPCS = PIPCSL
STOWDI = TOWDIA
SDELL = DELL
RETURN
END

SUBROUTINE PIPCLS(CTOW,TOWDIA,DOTMA,TCONOUT,DIST,DESVELV,BUNWIDT,
S REDUCF, QREDUCS, TUBLEN, THXIV, DELV, PIPCSTV, CDANG, POHCIR)

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5      C      THIS SUBROUTINE DESIGNS AND COSTS THE SUPPLY PIPING SYSTEM
        C      WHICH TRANSPORTS THE VAPOR AMMONIA. THIS INCLUDES ALL THE
        C      PIPE, VALVES, AND FITTINGS BETWEEN THE HEAT EXCHANGER AND
        C      THE CONDENSER/REBOILER. PIPE DIAMETER IS DETERMINED FROM THE
        C      AMMONIA FLOW RATE AND THE VAPOR DESIGN VELOCITY. VALVE AND
10     C      FITTING SIZES CORRESPOND TO THE PIPE SIZES WITH THE SAME
        C      FLOW RATE.

        C      AMMONIA PROPERTIES ARE FIRST EVALUATED AT THE CONDENSER/
        C      REBOILER OUTLET TEMPERATURE. CONDITIONS ARE ASSUMED TO BE
        C      SATURATED. AFTER DESIGNING EACH HEADER OR PIPE SECTION THE
15     C      PRESSURE DROP IS DETERMINED IN THAT SECTION BY CALLING
        C      HLAAMO. THIS PROVIDES THE OUTLET TEMPERATURE OF THAT
        C      SECTION WHICH BECOMES THE INLET TEMPERATURE FOR THE NEXT
        C      SECTION.

20     C      DEFINITION OF VARIABLES

        C      APIPCST - ABOVE GROUND PIPE COST ($1000/FT)
        C      BRCHDIA - DIAMETER OF DISTRIBUTION PIPING OR BUNDLE FITTINGS
        C      (INCHES), IS USED TO GET "BRANCH" PORTION OF THE
25     C      TEE COSTS
        C      BRCCST - COST OF "BRANCH" PORTION OF TEE COST ($1000)
        C      BRDYNHD - DYNAMIC HEAD LOSS IN BUNDLE FITTINGS
        C      (FT OF AMMONIA)
        C      BUNWIDT - WIDTH OF TUBE BUNDLE (FT)
30     C      CDANG - ANGLE OF DELTA HEAT EXCHANGER (DEGREES)
        C      CPV - SPECIFIC HEAT OF AMMONIA VAPOR (BTU/LBM DEG F)
        C      CTOW - NUMBER OF CIRCULAR TOWERS
        C      DDYNHD - DYNAMIC HEAD LOSS IN DISTRIBUTION PIPING (FT OF
        C      AMMONIA)
35     C      DELP - PRESSURE DROP IN HEADER SECTION (PSF)
        C      DELPBS - PRESSURE DROP IN BUNDLE FITTINGS (PSF)
        C      DELPD,T - PRESSURE DROP IN DISTRIBUTION PIPING, TOWER PIPING
        C      (T), (PSF)
40     C      DELSH,Q - PRESSURE DROP IN MAIN CIRCULATION HEADER, QUADRANT
        C      HEADER (Q), (PSF)
        C      DELV - PRESSURE DROP IN SUPPLY CIRCULATION PIPING FOR
        C      VAPOR AMMONIA (PSF)
        C      DENS - DENSIV
45     C      DENSIV - DENSITY OF AMMONIA VAPOR (LBM/CU FT)
        C      DESVELV - AMMONIA VAPOR DESIGN VELOCITY (FT/SEC)
        C      DIAS - DIAMETER OF MAIN CIRCULATION SUPPLY HEADER (INCHES)
        C      DIASD - DIAMETER OF DISTRIBUTION PIPING (INCHES)
        C      DIAST - DIAMETER OF TOWER PIPING (INCHES)
50     C      DIST - DISTANCE FROM CONDENSER/REBOILER TO BOUNDARY OF
        C      TOWERS
        C      DOTMA - TOTAL MASS FLOW RATE (LBM/HR)
        C      DOTMA,B,Q,T - MASS FLOW RATE TO TUBE BUNDLE, QUADRANT (Q),
        C      TOWER (T), (LBM/HR)
        C      DOTREM - FLOW RATE REMAINING IN HEADER SECTION (LBM/HR)
55     C      DYNHDS - DYNAMIC HEAD LOSS IN MAIN CIRCULATION HEADER (FT OF
        C      AMMONIA)
        C      DYNHDV - DYNAMIC HEAD LOSS IN CIRCULATION VAPOR SUPPLY

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C      PIPING (FT OF AMMONIA)
C      ELCST - 90 DEG ELBOW COST ($1000)
60  C      EL45 - 45 DEG ELBOW COST ($1000)
C      EQLN - EQUIVALENT LENGTH (FT)
C      FLGCST - FLANGE COST ($1000)
C      HEDR - LENGTH OF MAIN CIRCULATION HEADER SECTION (FT)
C      ID - INDEX REFERS TO DISTRIBUTION PIPING
65  C      IT - INDEX REFERS TO TOWER PIPING
C      JS - IDENTIFIES MAIN CIRCULATION HEADER SECTION
C      KS - IDENTIFIES QUADRANT HEADER SECTION
C      NUNPQD - NUMBER OF BUNDLES PER QUADRANT
C      NFL - UPPER LIMIT TO NUMBER OF TUBE BUNDLES PER QUADRANT
70  C      NTS - UPPER LIMIT TO NUMBER OF CIRCULAR TOWERS
C      PIPGSTV - TOTAL CIRCULATION SUPPLY PIPING COST ($1000)
C      QDYNHDS - DYNAMIC HEAD LOSS IN QUADRANT HEADER (FT OF
C      AMMONIA)
C      PCHCIR - INDIRECT COST FACTOR FOR CIRCULATION PIPING
75  C      QHEDR - LENGTH OF QUADRANT HEADER SECTION (FT)
C      QREDUCS - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
C      QUADRANT HEADER SECTIONS (INCHES)
C      QSLCST - COST OF 90 DEG ELBOW AT END OF QUADRANT HEADER
C      ($1000)
80  C      SDFCST - COST OF BUNDLE FITTINGS ($1000)
C      SCST - COST OF MAIN CIRCULATION PIPING ($1000)
C      RCST - REDUCER COST ($1000)
C      REDUCS - ALLOWABLE REDUCTION IN DIAMETER BETWEEN ADJACENT
C      MAIN CIRCULATION HEADER SECTIONS (INCHES)
85  C      SEJCST - COST OF EXPANSION JOINT AT CONDENSER/REBOILER
C      OUTLET ($1000)
C      SELCST - COST OF 90 DEG ELBOW AT END OF MAIN CIRCULATION
C      HEADER ($1000)
C      SELGCST - TOTAL COST OF APPROPRIATE FLANGES AT CONDENSER/
90  C      REBOILER OUTLET ($1000)
C      SPCST - COST OF PIPE FOR MAIN CIRCULATION HEADER ($1000)
C      SQCST - COST OF QUADRANT PIPING ($1000)
C      SQDIA - COMPONENT DIAMETER OF QUADRANT HEADER SECTION
C      (INCHES)
95  C      SPCST - COST OF PIPE FOR QUADRANT HEADER ($1000)
C      SRCST - COST OF REDUCER FOR QUADRANT HEADER ($1000)
C      SPCST - COST OF REDUCER IN MAIN CIRCULATION HEADER ($1000)
C      STCST - COST OF TEE IN MAIN CIRCULATION HEADER ($1000)
C      STDOST - COST OF DISTRIBUTION AND TOWER PIPING ($1000)
100 C      TCONOUT - TEMPERATURE OF AMMONIA VAPOR AT CONDENSER/REBOILER
C      OUTLET (DEG F)
C      TOST - TEE COST ($1000)
C      TDYNHD - DYNAMIC HEAD LOSS IN TOWER PIPING (FT OF AMMONIA)
C      THXIN - TEMPERATURE OF AMMONIA VAPOR AT HEAT EXCHANGER
105 C      INLET (DEG F)
C      TIN, TOUT - TEMPERATURE OF AMMONIA VAPOR AT INLET AND OUTLET
C      TO EACH HEADER OR PIPE SECTION (DEG F)
C      TOWDIA - DIAMETER OF CIRCULAR TOWER (FT)
C      TSQCST - TOTAL SUPPLY QUADRANT PIPING COSTS ($1000)
110 C      TSTDOST - TOTAL SUPPLY DISTRIBUTION AND TOWER PIPING COSTS
C      ($1000)
C      TUBLEN - LENGTH OF HEAT EXCHANGER TUBE (FT), IT IS ASSUMED
C      THAT THE TOWER HEIGHT EQUALS TUBLEN
C      UPCST - UNIT PIPE COST ($1000/FT)

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115      C      VACST  - VALVE COST ($1000). VALVES ARE MOTOR OPERATED
      C      BUTTERFLY VALVES
      C
      COMMON/PROP/CPW,THCONW,DENSIW,VISW,HFG,
120      $      CPV,THCONV,DENSIV,VISV,SIGMA,
      $      CPA,THCONA,DENSA,VISA
      COMMON/RPTSUP/
      $      SDELV,DIASD,DIASD,SDOTMA,DYNHGV
      $      HEDR(200)
125      $      JS
      $      KS
      $      SPCSTV
      $      QSLCST,QHEDR(200)
      $      SBFCST,SCOST,SEJCST,SELCST,SFLGCST,SQCOST,STDCST
      $      SDIA(200),SPCST(200),SQDIA(200),SQPCST(200),SQRCST(200)
130      $      SATCST(200),SRCST(200),STCST(200)
      $      STCONO,STHXIN,STOWDI,TSQCST,TSTDCST
      COMMON/PCDIM/NFS,NFL
      DIMENSION DAPIPCST(200)
135      DIMENSION DIAM(24),TEECST(24),PIPCST(24),ELCST(24),EL45(24)
      $      VACST(24),FLGCST(24),APIPCST(24)
      C
      DATA DIAM /
140      $      5. , 12. , 18. , 24. , 30. , 36. ,
      $      42. , 48. , 54. , 60. , 66. , 72. ,
      $      78. , 84. , 90. , 96. , 102. , 108. ,
      $      114. , 120. , 126. , 132. , 138. , 144. /
      C
      DATA FLGCST/
145      $      .136, .520, 1.03 , 1.92 , 3.17 , 4.42 ,
      $      5.82 , 9.22 , 12.0 , 14.7 , 21.1 , 27.5 ,
      $      33.9 , 40.4 , 46.8 , 53.2 , 59.7 , 66.1 ,
      $      72.5 , 78.9 , 85.4 , 91.8 , 98.2 , 105. /
      C
      DATA TEECST/
150      $      .344, .935, 1.96 , 3.82 , 14.8 , 25.8 ,
      $      31.7 , 37.6 , 53.4 , 69.1 , 87.9 , 107. ,
      $      125. , 145. , 163. , 182. , 201. , 220. ,
      $      239. , 258. , 277. , 296. , 314. , 333. /
      C
      DATA PIPCST/
155      $      .26, .113, .147, .219, .409, .599,
      $      .720, .841, 1.08 , 1.31 , 1.57 , 1.84 ,
      $      2.10 , 2.35 , 2.62 , 2.88 , 3.15 , 3.41 ,
      $      3.67 , 3.93 , 4.19 , 4.46 , 4.72 , 4.98 /
160      C
      DATA VACST/
      $      2.87 , 7.09 , 16.9 , 26.7 , 52.2 , 77.8 ,
165      $      109. , 141. , 164. , 187. , 213. , 240. ,
      $      265. , 293. , 319. , 346. , 372. , 399. ,
      $      425. , 452. , 478. , 505. , 531. , 558. /
      C
      DATA ELCST/
170      $      .275, .715, 1.35 , 2.94 , 9.54 , 16.1 ,
      $      27.4 , 38.8 , 51.9 , 65.1 , 87.6 , 110. ,
      $      133. , 155. , 179. , 200. , 222. , 245. ,
      $      268. , 290. , 312. , 335. , 357. , 380. /

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C
175 DATA EL45/
      $ .230, .558, .947, 2.16, 7.67, 13.2,
      $ 20.2, 27.2, 37.7, 48.1, 65.2, 84.3,
      $ 102., 120., 138., 157., 175., 193.,
      $ 211., 229., 247., 265., 283., 301. /

C
180 DATA A0IPCST/
      $ .034, .073, .096, .155, .332, .510,
      $ .614, .719, .939, 1.16, 1.41, 1.67,
      $ 1.91, 2.15, 2.41, 2.66, 2.99, 3.16,
      $ 3.41, 3.65, 3.91, 4.16, 4.42, 4.67 /

C
185 100 FORMAT(8F10.2)
      NBUNPQD = 3.1416 * TOWDIA / (4.*9UNWIDT*CDANG) + 7.
      DOTMAT=DOTMA/CTOW
      DOTMAQ=DOTMAT/4.
      DOTMAB=DOTMAQ/NBUNPQD
190 TIN=TCNDOUT
      CONST1=4./((3.1416*3500.))
      DELSH=0.
      DYNIDS=0.
      SCOST=0.
      DO 1 I=1,NFS
195 1 SRCST(I)=0.
      DO 2 I=1,NFL
200 2 SRCST(I)=0.
      DELSQ=0.
      DDYNHD=0.
      SDCOST=0.
      SELCST=0.
      SFLGCST=0.
      SEJCST=0.
205 DOTREM=DOTMA
      JS=1

C
C      IN THE STATEMENTS THROUGH 17 + 1 THE MAIN CIRCULATION PIPING
C      IS DESIGNED AND COSTED. THE DYNAMIC HEAD LOSS AND PRESSURE
210 DROP ARE DETERMINED FOR PUMPING REQUIREMENTS.
C
C      CALL HEADER TO DESIGN AND COST THE COMPONENTS OF HEADER
C      SECTION JS. ALL HEADER SECTION COMPONENTS ARE DETERMINED
C      BETWEEN STATEMENTS 13 AND 12 + 1.
215 C
      13 CALLI HEADER(DOTREM,DOTMAT,DESVELV,DENSIV,REDUCS,JS,1,DIAJ,
        $DIAS,TCST,RCST,UPCST,SELCST,SFLGCST,SEJCST)

C
C      THE DIAMETER OF HEADER SECTION JS (DIAR) IS REPLACED BY DIAJ.
C      IN ORDER TO COMPARE THE DIAMETER OF SECTION JS WITH SECTION
220 JS + 1 TO DETERMINE REDUCER REQUIREMENTS. SDIA IS THE STORED
C      VALUE OF THE DIAMETER OF HEADER SECTION JS.
C
      DIAJ=DIAS
      SDIA(JS)=DIAS
225 STCST(JS)=TCST

C
C      ASSIGN THE COST OF A REDUCER TO THE PRECEDING HEADER SECTION.

```

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530      C      THE COST OF A REDUCER IS BASED ON THE LARGEST DIAMETER OF
      C      THE REDUCER.
      C
      IF(JS.GT.1)SRCST(JS=1)=RCST
      UPIPCST(JS)=UPCST

535      C      DETERMINE LENGTH OF HEADER SECTION. THE FIRST HEADER SECTION
      C      IS DESIGNATED HEADER SECTION 1. ALL EVEN NUMBERED HEADER
      C      SECTIONS ARE EFFECTIVELY ZERO LENGTH BECAUSE THE CIRCULAR
      C      TOWERS ARE PAIRED ON OPPOSITE SIDES OF THE MAIN CIRCULATION
      C      HEADER. THERE IS ONE HEADER SECTION DESIGNATED FOR EACH
540      C      CIRCULAR TOWER.
      C
      IF(JS.EQ.1)GO TO 10
      IF(MOD(JS,2).EQ.0)HEDR(JS)=0.
      IF(MOD(JS,2).NE.0)HEDR(JS)=1.5*TOWDIA
545      GO TO 11
10 HEDR(JS)=DIST+.5*TOWDIA

      C      DETERMINE THE OUTLET TEMPERATURE AND DYNAMIC HEAD LOSS FOR
      C      HEADER SECTION JS. THE EQUIVALENT LENGTH INCLUDES AN L/D OF
550      C      20 FOR THE TEE "RUN". THE OUTLET TEMPERATURE BECOMES THE
      C      INLET TEMPERATURE FOR THE NEXT HEADER SECTION. SAVE THE
      C      VAPOR DENSITY TO COMPUTE DYNAMIC HEAD LOSS. HLAHMO PROVIDES
      C      A NEW VAPOR DENSITY (THROUGH COMMON) FOR THE NEXT HEADER
      C      SECTION.
555      C
11 EQLEN=HEDR(JS)+20.*DIAS/12.

      C      SUBTRACT OUT THE FLOW TO ONE CIRCULAR TOWER TO GET THE FLOW
      C      IN HEADER SECTION JS + 1.
560      C
      DENS=DENSIV
      CALL HLAHMO(TIN,DOTREM,DIAS,EQLEN,1.,TOUT,DELP)
      DELSH=DELSH+DELP
      DYNHDS=DYNHDS+DELP/DENS
565      TIN=TOUT
      DOTREM=DOTREM-DOTMAT

      C      IF THE REMAINING FLOW IS ZERO THEN THE LAST HEADER SECTION
      C      HAS BEEN DESIGNED.
570      C
      IF(DOTREM.LE.0.)GO TO 12
      JS=JS+1
      IF(JS.GT.NFS)PIPCSTV=1.E+40
      IF(JS.GT.NFS)RETURN
575      GO TO 13

      C      DETERMINE THE DIAMETER OF THE DISTRIBUTION PIPING.
      C
12 BRCHDIA=SQRT(DOTMAT*CONST1/(DENSIV*DESVELV)).12.
580      IF(BRCHDIA.LT.DIAM(1))BRCHDIA=DIAM(1)
      DO 14 I=1,24
      II=I
      IF(BRCHDIA-DIAM(II))15,15,14
14 CONTINUE
585      15 BRCHDIA=DIAM(II)

```

```

C
C      THE COST OF A TEE IS ASSUMED TO BE .67 TIMES THE COST OF A
C      TEE OF THE "RUN" DIAMETER PLUS .33 TIMES THE COST OF A TEE
290 C      OF THE "BRANCH" DIAMETER. THE "RUN" PORTION WAS DETERMINED
C      IN SUBROUTINE "HEADER". THE "BRANCH" PORTION IS DETERMINED
C      HERE.
C
      BRCST=.33*TEECST(I1)
      DO 16 I=1,JS
295 C      STCST(I)=STCST(I)+BRCST
      16 SPCST(I)=HEDR(I)*UPIPCST(I)
      STCST(JS)=0.
      DO 17 I=1,JS
      IF(I.LT.JS) SCOST=SCOST+SPCST(I)*SRCST(I)+STCST(I)
300 C      IF(I.EQ.JS) SCOST=SCOST+SPCST(I)*SRCST(I)+SELCST
      17 CONTINUE
      SCOST=SCOST+SFLGCST+SEJCSCT
C
C      IN THE STATEMENTS THROUGH 21 + 4 THE DISTRIBUTION PIPING IS
305 C      DESIGNED. INDEXES FOR UNIT COST ARRAYS ARE DEFINED.
C      PRESSURE LOSS AND DYNAMIC HEAD LOSS ARE EVALUATED.
C
      DIASD=SQRT(DOTMAT*CONST1/(DENSIV*DESVELV))*12.
      DO 20 I=1,24
310 C      ID=I
      IF(DIASD-DIAM(ID))21,21,20
      20 CONTINUE
      21 DIASD=DIAM(ID)
      EQLEN=.2*TOWDIA+200.*DIASD/12.
315 C
C      THE EQUIVALENT LENGTH INCLUDES THE LENGTH OF PIPE CONNECTING
C      THE MAIN CIRCULATION HEADER TO THE TOWER DISTRIBUTION HEADER.
C      THIS LENGTH IS ASSUMED TO BE .2 TIMES THE TOWER DIAMETER.
C
320 C      DENS=DENSIV
      CALL HLAMMO(TIN,DOTMAT,DIASD,EQLEN,1.,TOUT,DELPO)
      DDYNHD=DELPO/DENS
C
C      THE TEMPERATURE OUT OF THE DISTRIBUTION PIPING IS THE
325 C      TEMPERATURE INTO THE TOWER PIPING.
C
      TIN=TOUT
C
C      IN THE STATEMENTS THROUGH 23 + 4 THE TOWER PIPING IS
330 C      DESIGNED. INDEXES FOR UNIT COST ARRAYS ARE DEFINED.
C      PRESSURE LOSS AND DYNAMIC HEAD LOSS ARE EVALUATED.
C
      DIAST=SQRT(DOTMAQ*CONST1/(DENSIV*DESVELV))*12.
      DO 22 I=1,24
335 C      IT=I
      IF(DIAST-DIAM(IT))23,23,22
      22 CONTINUE
      23 DIAST=DIAM(IT)
      EQLEN=TOWDIA+TUSLEN+.80.*DIAST/12.
340 C      DENS=DENSIV
      CALL HLAMMO(TIN,DOTMAQ,DIAST,EQLEN,1.,TOUT,DELPT)
      DDYNHD=DELPT/DENS

```

```

C
C      THE TEMPERATURE OUT OF THE TOWER PIPING IS THE TEMPERATURE
345 C      INTO THE QUADRANT PIPING.
C
C      TIN=TOUT
C
C      COMPUTE THE COST OF THE DISTRIBUTION AND TOWER PIPING. PIPE
350 C      LENGTHS INCLUDE THE LENGTH OF PIPE CONNECTING THE MAIN CIRC-
C      ULATION HEADER TO THE TOWER DISTRIBUTION HEADER (.2*TOWDIA)
C      AND THE TOTAL LENGTH OF PIPE CONNECTING THE TOWER
C      DISTRIBUTION HEADER TO THE FOUR QUADRANT HEADERS (3.25*
C      TOWDIA). THESE LENGTHS ARE GENERAL APPROXIMATIONS. THE
355 C      TOWER DISTRIBUTION HEADER IS ASSUMED TO APPROXIMATE THE
C      COST OF FOUR TEES. INDEX "ID" REFERS TO THE DISTRIBUTION
C      PIPING, "IT" TO THE TOWER PIPING.
C
C      STDCST=.2*TOWDIA*PIPCST(ID)+4.*(1.67*TEECST(ID)+.33*TEECST(IT))
360 C      $+(3.25*TOWDIA)*PIPCST(IT)+14.*ELCST(IT)+2.*EL45(IT)
C      ,+4.*VACST(I) + 8.*FLGCST(IT) + TUBLEN*APIPCST(IT)
C      TSTDCST=STDCST*CTOW
C
C      IN THE STATEMENTS THROUGH 35 + 11 THE QUADRANT PIPING IS DE-
365 C      SIGNED AND COSTED. THE DYNAMIC HEAD LOSS AND PRESSURE DROP
C      IN THE QUADRANT HEADER AND BUNDLE FITTINGS ARE DETERMINED.
C
C      DOTREM=DOTMAQ
C      KS=1
370 C
C      IN STATEMENTS 31 TO 30 - 1 DESIGN AND COST INFORMATION FOR
C      EACH QUADRANT HEADER SECTION IS DETERMINED.
C
375 C      31 CALLI HEADER(DOTREM,DOTMA3,DESVELV,DENSIV,QREDUC,KS,0,DIAJ,
C      $DIAS,TCST,RCST,UPCST,QLCST,SFLGCST,SEJCST)
C
C      THE DIAMETER OF HEADER SECTION KS (DIAS) IS REPLACED BY DIAJ.
C      IN ORDER TO COMPARE THE DIAMETER OF SECTION KS WITH KS + 1
C      TO DETERMINE REDUCER REQUIREMENTS. SQDIA IS THE STORED
380 C      VALUE OF THE DIAMETER OF HEADER SECTION KS.
C
C      DIAJ=DIAS
C      SQDIA(KS)=DIAS
C      SQTCTST(KS)=TCST
385 C
C      ASSIGN THE COST OF A REDUCER TO THE PRECEDING HEADER SECTION.
C      THE COST OF A REDUCER IS BASED ON THE LARGEST DIAMETER OF THE
C      REDUCER.
C
390 C      IF(KS.GT.1)SQRCT(KS-1)=RCST
C      UPIPCST(KS)=UPCST
C
C      THE FIRST QUADRANT HEADER IS ASSUMED TO HAVE
C      ZERO LENGTH. THE PIPE LENGTH FOR THE REMAINING SECTIONS WILL
395 C      BE SHORTER IF A DELTA HEAT EXCHANGER ARRANGEMENT IS USED.
C      LENGTH OF THE TEE "RUN" IS ASSUMED TO BE 1.75 TIMES THE PIPE
C      DIAMETER AND THIS LENGTH IS SUBTRACTED.
C
C      IF(KS.EQ.1)QHEDR(KS)=0.

```

```

400      IF(KS.GT.1) QHEDR(KS) = SUNWIDT * CDANG = 1.75 * DIAS / 12.
      C
      C      DETERMINE THE DYNAMIC HEAD LOSS AND PRESSURE DROP IN THE
      C      QUADRANT HEADER SECTION. SAVE THE VAPOR DENSITY BECAUSE IT
405      C      MUST BE USED IN COMPUTING DYNAMIC HEAD LOSS BUT IS REDEFINED
      C      IN HLAHMO. THE NEW VALUE OF DENSITY FROM HLAHMO, LIKE
      C      THE TEMPERATURE, TOUT, APPLIES TO THE NEXT HEADER SECTION.
      C
      DENS=DENSIV
      EQLEN=QHEDR(KS)+20.*DIAS/12.
410      CALL HLAHMO(TIN,DOTREM,DIAS,EQLEN,1.,TOUT,DELP)
      DELSQ=DELSQ+DELP
      QDYNHDS=QDYNHDS+DELP/DENS
      TIN=TOUT
      C
415      C      SUBTRACT OUT THE FLOW TO ONE TUBE BUNDLE. IF THE FLOW
      C      REMAINING IS ZERO THEN THE LAST HEADER SECTION HAS BEEN
      C      DESIGNED.
      C
      DOTREM=DOTREM-DOTMAB
420      IF(DOTREM.LE.0.)GO TO 30
      KS=KS+1
      IF( KS .GT. NFL) PIPCSTV = 1.E+40
      IF( KS .GT. NFL) RETURN
      GO TO 31
425      C
      C      COMPUTE THE DIAMETER OF THE BUNDLE FITTINGS.
      C
      30 BRCHDIA=SQRT(DOTMAB*CONST1/(DESVELV*DENSIV))*12.
      IF(BRCHDIA.LT.DIAM(1))BRCHDIA=DIAM(1)
430      DO 32 I=1,24
      II=I
      IF(BRCHDIA-DIAM(II))33,33,32
      32 CONTINUE
      33 BRCHDIA=DIAM(II)
435      C
      C      THE PORTION OF THE TEE COST ATTRIBUTED TO THE "BRANCH". SEE
      C      NOTE PRECEDING STATEMENT 15 + 1.
      C
      BR CST=.33*TEECST(II)
440      C
      C      SUBTOTAL QUADRANT COMPONENT COSTS. DETERMINE COST OF BUNDLE
      C      FITTINGS.
      C
      DO 34 I=1,KS
      SQT CST(I)=SQT CST(I)+BR CST
445      34 SQT CST(I)=QHEDR(I)*UPIPCST(I)
      SQT CST(KS)=0.
      SBFCST = 2. * APIPCST(II) + 2.*FLGCST(II)
450      C
      C      COMPUTE DYNAMIC HEAD LOSS IN BUNDLE FITTINGS.
      C
      DENS=DENSIV
      EQLEN = 120. * BRCHDIA/12.
455      CALL HLAHMO(TIN,DOTMAB,BRCHDIA,EQLEN,1.,TOUT,DELPBS)
      BSDYNHDS=DELPBS/DENS
      C

```

```

      C      EVALUATE THE COST OF THE QUADRANT HEADER.
      C
      DO 35 I=1,KS
460      IF(I.LT.KS) SQCOST=SQCOST+SQPCST(I)+SQRCST(I)+SQTCST(I)+SBFCST
      IF(I.EQ.KS) SQCOST=SQCOST+SQPCST(I)+SQRCST(I)+QSLCST+SBFCST
      35 CONTINUE
      C
      C      TOTAL SUPPLY QUADRANT PIPING COSTS.
465      C
      TSQCOST=SQCOST*CTOW*4.
      C
      C      THE VAPOR TEMPERATURE AT THE HEAT EXCHANGER INLET HAS BEEN
      C      DETERMINED ON THE BASIS OF THE ACCUMULATIVE PRESSURE DROPS
470      C      IN THE SUPPLY PIPING.
      C
      THXIN = TOUT
      C
      C      DETERMINE TOTAL COST, PRESSURE DROP, AND DYNAMIC HEAD LOSS
475      C      IN THE SUPPLY PIPING SYSTEM.
      C
      PIPCSTV=SQCOST+TSTD CST+TSQCOST
      PIPCSTV = PIPCSTV * POHCIR
      DELV=DELFSH+DELPD+DELP7+DELSQ+DELPgS
480      DYNHGV=DYNHOS+DDYNHD+TDYNHD+QDYNHOS+BSDYNHD
      C
      C      STORE VALUES IN COMMON BLOCK /RPTRET/ FOR LATER USE IN
      C      OUTPUT.
      C
485      SDELV = DELV
      SDO7MA = DO7MA
      SPCSTV = PIPCSTV
      STHXIN = THXIN
      STCONO = TCONOUT
      STHXIN = THXIN
      STOWDI = TOWDIA
490      RETURN
      END

```

SUBROUTINE PRPERT(TWATAV,TAIRAV,ALTITD)

SUBROUTINE PRPERT DETERMINES THE THERMODYNAMIC AND PHYSICAL
PROPERTIES OF AIR AND SATURATED AMMONIA

DEFINITION OF VARIABLES

CPA - HEAT CAPACITY OF AIR (BTU/LBM-DEG F)
CPU - HEAT CAPACITY OF AMMONIA VAPOR (BTU/LBM-DEG F)
CPW - HEAT CAPACITY OF AMMONIA LIQUID (BTU/LBM-DEG F)
DENSIA - DENSITY OF AIR (LBM/CU FT)
DENSIW - DENSITY OF AMMONIA VAPOR (LBM/CU FT)
DENSIW - DENSITY OF AMMONIA LIQUID (LBM/CU FT)
HFG - HEAT OF VAPORIZATION OF AMMONIA (BTU/LBM)
SIGMA - SURFACE TENSION OF AMMONIA (LBF/FT)
TAIRAV - AVERAGE AIR TEMPERATURE (DEG F)
THCONA - THERMAL CONDUCTIVITY OF AIR (BTU/HR-FT-DEG F)
THCONV - THERMAL CONDUCTIVITY OF AMMONIA VAPOR (BTU/HR-FT-DEG F)
THCONW - THERMAL CONDUCTIVITY OF AMMONIA LIQUID (BTU/HR-FT-DEG F)
TWATAV - AMMONIA TEMPERATURE (DEG F)
VISA - VISCOSITY OF THE AIR (LBM/HR-FT)
VISV - VISCOSITY OF THE AMMONIA VAPOR (LBM/FT-HR)
VISW - VISCOSITY OF THE AMMONIA LIQUID (LBM/FT-HR)

COMMON / PROP/ CPW, THCONW, DENSIW, VISW, HFG,
* CPV, THCONV, DENSIW, VISV, SIGMA,
* CPA, THCONA, DENSIA, VISA

AMMONIA PROPERTIES

CPW = FLUID(1,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 1")
THCONW = FLUID(2,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 2")
DENSIW = FLUID(3,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 3")
VISW = FLUID(4,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 4")
CPV = FLUID(5,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 5")
THCONV = FLUID(6,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 6")
DENSIW = FLUID(7,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 7")
VISV = FLUID(8,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 8")
HFG = FLUID(9,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 8.5")
SIGMA = FLUID(12,1,TWATAV,ALTITD,"SUBROUTINE PRPERT 8.7")

AIR PROPERTIES

CPA = FLUID(5,2,TAIRAV,ALTITD,"SUBROUTINE PRPERT 9")
THCONA = FLUID(6,2,TAIRAV,ALTITD,"SUBROUTINE PRPERT 10")
DENSIA = FLUID(7,2,TAIRAV,ALTITD,"SUBROUTINE PRPERT 11")
VISA = FLUID(8,2,TAIRAV,ALTITD,"SUBROUTINE PRPERT 12")

RETURN
END

SUBROUTINE PUMPCST(W3, DELPS, DELPR, DELPWT, DELPWC, X, DESVEL,
\$ PUMPCST, PUFITC)

SUBROUTINE PUMPCST DETERMINES THE COST OF THE PUMPS AND
THE FITTINGS FOR THE AMMONIA LOOP

DEFINITION OF VARIABLES

CPA - HEAT CAPACITY OF AIR (BTU/LBM-DEG F)
CPV - HEAT CAPACITY OF AMMONIA VAPOR (BTU/LBM-DEG F)
CPA - HEAT CAPACITY OF AMMONIA LIQUID (BTU/LBM-DEG F)
DELPR - PRESSURE DROP IN THE RETURN PIPING (LBF/SQ FT)
DELPS - PRESSURE DROP IN THE SUPPLY PIPING (LBF/SQ FT)
DELPWC - PRESSURE DROP IN THE CONDENSER/REBOILER
(LBF/SQ FT)
DELPWT - PRESSURE DROP IN THE HEAT EXCHANGER (LBF/SQ FT)
DENSIW - DENSITY OF AMMONIA LIQUID (LBM/CU FT)
DESVEL - DESIGN LIQUID VELOCITY (FT/SEC)
DIA - DIAMETER OF THE VALVES AND FLANGES (IN)
GPM1 - GALLONS PER MINUTE OF AMMONIA IN THE RETURN
PIPING (GPM)
GPM2 - GALLONS PER MINUTE OF AMMONIA ENTERING THE CON-
DENSER/REBOILER (GPM)
PIPCSP1 - FLANGE AND VALVE COST FOR PUMPING IN THE RETURN
PIPING (K\$)
PIPCSP2 - FLANGE AND VALVE COST FOR PUMPING IN THE LOOP TO
THE CONDENSER/REBOILER (K\$)
PUMPCST - TOTAL COST OF PUMPING SYSTEM (K\$)
PUMPCS2 - COST OF PUMP FOR LOOP TO THE CONDENSER/
REBOILER (K\$)
THH1 - DYNAMIC HEAD TO BE MADE UP BY THE RETURN PUMP (FT)
THH2 - DYNAMIC HEAD TO BE MADE UP BY THE PUMP IN THE
CONDENSER/REBOILER LOOP (FT)
W3 - MASS FLOW OF AMMONIA (LBM/HR)
X - EXIT QUALITY OF FLUID EXITING THE CONDENSER/
REBOILER (DIMENSIONLESS)

DIMENSION DIAM(24), FLGCST(24), VACST(24)
COMMON/PROP/CPW,THCONW,DENSIW,VISW,HFG,
1 CPV,THCONV,DENSIV,VISV,SIGMA,
2 CPA,THCONA,DENSA,VISA

DATA DIAM /

\$ 5.	12.	18.	24.	30.	36.
\$ 42.	48.	54.	60.	66.	72.
\$ 78.	84.	90.	96.	102.	108.
\$ 114.	120.	126.	132.	138.	144.

DATA VACST /

\$ 2.87	7.09	16.9	26.7	52.2	77.8
\$ 109.	141.	164.	187.	213.	240.
\$ 265.	293.	319.	346.	372.	399.
\$ 425.	452.	478.	505.	531.	558.

DATA FLGCST /

\$.136	.520	1.03	1.92	3.17	4.42
\$ 6.82	9.22	12.0	14.7	21.1	27.5
\$ 33.9	40.4	46.8	53.2	59.7	66.1
\$ 72.5	78.9	85.4	91.8	98.2	105.


```

      DATA NKOS/24/
60      C
      C      CONST1 IS 4 / (PI*3600 )
      DATA CONST1 / 3.536777 E-04 /
      C
      C      DIAMETER OF PIPE RETURNING FROM THE HEAT EXCHANGER
85      DIA = SQRT(W3*CONST1/(DENSIW*DESVEL))*12.
      DO 10 II = 1, NKOS
      I = II
      IF(DIA - DIAM(I)) 11,11,10
10      CONTINUE
      C
      C      DIAMETER OF PIPE ENTERING THE CONDENSER/REBOILER
70      C
      C      11 DIA = SQRT(W3*CONST1/(DENSIW*DESVEL*X))*12.
      DO 12 JJ = 1,NKOS
      J = JJ
      IF(DIA - DIAM(J)) 13,13,12
75      C
      C      12 CONTINUE
      C
      C      FLANGE AND VALVE COSTS FOR BOTH PUMPS
      C
      C      13 PIPCSP1 = 2.*FLGCST(I) + 2. * VACST(I)
      PIPCSP2 = 2.*FLGCST(J) + 2.*VACST(J)
      PUFITC = PIPCSP1 + PIPCSP2
80      C
      C      PUMP COSTS
      C
      C      GPM1 = W3*7.481/(DENSIW*60.)
      GPM2 = W3*7.481/(DENSIW*X*60.)
85      TDH1 = (DELPS + DELPR + DELPWT)/DENSIW
      TDH2 = DELPWC/DENSIW
      PUMPCS1 = (0.032*TDH1 + 1.54)*GPM1
      PUMPCS2 = (0.032*TDH2 + 1.54)*GPM2
      PUMPCS1 = PUMPCS1 / 1000.
90      PUMPCS2 = PUMPCS2 / 1000.
      C
      C      TOTAL COST OF PUMPING SYSTEM
      C
      C      PMPCT = PUMPCS1 + PUMPCS2 + PIPCSP1 + PIPCSP2
      RETJRN
95      END

```

```

      SUBROUTINE PUMLEC(POHLEC, HPWAT, DIST, EFFP, RPTPL)
      DATA NPMP /2/
      DATA DSGTM /100./
C
5      C.... COMPUTE PUMP MOTOR ELECTRICAL COSTS
C
C      NPMP, SET BY DATA STATEMENT.  THE NUMBER OF PUMPS
C
      HPPMP = HPWAT/(NPMP*EFFP)
10      IF(HPPMP .LT. 251.) TRMA = 112500./NPMP + 7.88 * HPPMP
          + (115.-.159*HPPMP)*HPPMP
      IF(HPPMP .GE. 251. .AND. HPPMP .LE. 4000.) TRMA = 112500./NPMP
          + 7.88*HPPMP + 870./SQRT(HPPMP)*HPPMP
      IF(HPPMP .GT. 2000.) TRMA = 112500./NPMP + 7.88 * HPPMP
15      VS = 7200.
      IF (HPPMP .LT. 2000.) VS = 13800.
      VM = 6000.
      IF(HPPMP .LT. 2000.) VM = 2300.
      IF (HPPMP .LT. 251.) VM = 480.
20      TRMB = (DIST/2. - 1000.)*(37. + .47*HPPMP*NPMP/SQRT(VS)
          + .5 * NPMP) / NPMP
      TRMC = (100. + 1.1 * HPPMP) * (DSGTM -250.) / SQRT(VM)
      PMELEC = (TRMA + TRMB + TRMC) * POHLEC
      RPTPL = PMELEC/1000. * NPMP
25      RETURN
      END

```

```

      SUBROUTINE RPRT2 (EFFF, TUBEM, TUBEM2)
      C
      C   THIS ROUTINE REPORTS CONDENSER DESIGN AND COSTS
      C
      COMMON /KPRT2/ UCON, HOCON, HICON, HWCON, HFC, VELO, VELDO, TTD, TS, XNP,
      1   IDLPWC, ARPS, TLA, XNTS, XNG
      COMMON /KPRT3/ TUBCST, SHLCST, FETCST, CHX
      5   6090 FORMAT(141)
      6100 FORMAT(
      10  C T40,20(" ")/T41,"C O N D E N S E R"/T40,20(" "))
      6105 FORMAT(
      L T03,"--- DESIGN CONDITIONS ---"
      R,T72,"--- DESIGN OPERATING CONDITIONS ---"//)
      15  6110 FORMAT(
      L T15,"STEAM TEMPERATURE",F6.1," F"
      R,T60,"OVERALL HEAT TRANSFER COEFFICIENT ",F8.2," BTU/HR SQ FT DEG
      20  6115 FORMAT(
      L T14,"AMMONIA TEMPERATURE",F5.1," F"
      R,T62,"STEAM HEAT TRANSFER COEFFICIENT",F8.2,"BTU/HR SQ FT DEG F")
      6120 FORMAT(
      L T11,"INLET AMMONIA VELOCITY",F3.2,"FT/SEC"
      R,T63,"AMMONIA HEAT TRANSFER COEFFICIENT",F8.2,"BTU/HR SQ FT DEG F"
      25  6125 FORMAT(
      L T10,"OUTLET AMMONIA VELOCITY",F3.2,"FT/SEC"
      R,T63,"WALL HEAT TRANSFER COEFFICIENT",F8.2,"BTU/HR SQ FT DEG F")
      6128 FORMAT(
      L T05,"PRESSURE DROP THRU CONDENSER",F8.1,"LB/SQ FT"
      30  R,T64,"FORCED CONVECTION COEFFICIENT",F8.2,"BTU/HR SQ FT DEG F")
      6130 FORMAT(
      L/T05,"--- CONDENSER DESCRIPTION ---"
      R,T73,"--- CONDENSER COSTS ---"//)
      35  6135 FORMAT(
      L T17,"NUMBER OF SHELLS",I6,
      R T75,"TUBING MATERIAL S",F14.2,X(" ",2A10," ")
      6140 FORMAT(
      L T03,"HEAT TRANSFER AREA PER SHELL",G11.5," SQ FT"
      R T85,"SHELLS S",F14.2)
      40  6145 FORMAT(
      L T07,"NUMBER OF PASSES PER SHELL",I6,
      R T77,"FIELD ERECTION S",F14.2)
      6150 FORMAT(
      L T22,"TUBE LENGTH",I6,T45,"FEET")
      45  6155 FORMAT(
      L T08,"NUMBER OF TUBES PER SHELL",I6
      R,T69,"TOTAL COST OF CONDENSER S",F14.0)
      C
      50  WRITE(6,6090)
      WRITE(6,6100)
      WRITE(6,6105)
      WRITE(6,6110) TS,UCON
      WRITE(6,6115) TS-TTD, HOCON
      WRITE(6,6120) VELO, HICON
      55  WRITE(6,6125) VELDO, HWCON
      WRITE(6,6128) IDLPWC, HFC
      WRITE(6,6130)

```

SUBROUTINE RPRT2

74/74 OPT=1

FTN 4.2+74351

12/13/76

60

```
WRITE(6,6135) (IFIX(XNS)),TUBCST,TUBEM,TUBEM2  
WRITE(6,6140) ARPS,SHLCST  
WRITE(6,6145) (IFIX(XNP)),FETCST  
WRITE(6,6150) (IFIX(TLA))  
WRITE(6,6155) (IFIX(XNTS)),(TUBCST+SHLCST+FETCST)  
RETURN  
END
```

SUBROUTINE RPTFAN

C
C
C

THIS ROUTINE REPORTS FAN DESCRIPTION AND COSTS

5

LOGICAL LOOPER

COMMON/FAN/ FANDAP(153.10),FANDAH(153.10),FMCPE,FBCPE,P2,R,S,

\$ VELREC, AFC, ELEV, EHR, LOOPER, CTMAX

LOGICAL FIRST, FXTMP

COMMON

10

\$ AFTR, ALPHA, ANG(3)

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

\$,CBJ, CTURB, CDANG, CLUVR, CHAHS, CVM

\$,DANGLE, DFIN, DEEPL, DESVEL, DESVELV

\$,EFFP

15

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

\$,GSEFF

\$,HXNP, HPCST

\$,ITMAX, ITMIN

\$,JCONS

20

\$,KCONV, KALEXT

\$,MXEXT

\$,NTUCAL(2), NTA

COMMON

\$ ODR

25

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

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

\$,RBP, REDUCE, REDUCV, ROOFL

\$,QREU, QREDUCE, QREDUCV

\$,SIGMAG, SAAF

30

\$,TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TPIX

\$,TCD, TW

\$,UCS, UWS

\$,WFO

\$,VAS(5)

35

\$,XDEP1, XW, XD

C

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

\$ RIN1, CLAN1, REA11, Z1, HFA2S, W41, U1, DEPW1, PPOW1,

40

\$ PPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, H11, H01, T41,

\$ REW1, NW1, VT1, NP1, ZPLV2, ZSI712, ZSPBP, SW41, SW31,

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

\$ BP2MIN, NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1,

\$, TL11, UCON1, PMCS1, FMC1, FBAC1, EFFC1, CHI, CAL, CS1

45

\$, CLTC1, CFC1, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLDOS1

\$,CAPCS1, XNFAN1, GLDAN1, CPLEN1, DPEL1, WH1, ATTU1, ADI1, ABL1

\$, WTH1, WTR1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1

\$, AIRF1, WATF1, XNMOD1, TCTP1, FOCPE1, FMTRC1, ACTTP1, ADJTP1

\$, ACTBP1, ADJBP1, ACTVH1, ADJH1, ADJPP1, THPA1, TCTF1, AFCST1

50

\$, CSR1, WATER1, WSTRC1, CFOUN1, HUBD1, TOWLE1, NUMT01, CTOWD1

\$, SCRJ1, SCRJS1, ATUBC1, CBA1, ITD1, ITD21, DELPS1, CSTLV1

\$, CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPCS1, RPTPL1, SEPCC1

REAL MOTOR(4,3), DRIVE(3,2), PITCH(3,2), RECVY(5,2)

C

55

DATA ((MOTOR(I,K), I=1,4), K=1,3)/

\$ "TOTALLY EN", "CLOSED SQU", "IRREL CAGE", " MOTOR "

\$ "EXPLOSION ", "PROOF SQUI", "IRREL CAGE ", "MOTOR "

\$ "TWO SPEED ", "SQUIRREL C", "AGE ", "

```

      DATA ((DRIVE(I,K),I=1,3),K=1,2)/
      * "SPIRAL BEV","VEL GEAR DR","IVE      ",
60  * "V-BELT DRI","VE      ","      "/
      DATA ((PITCH(I,K),I=1,3),K=1,2)/
      * "MANUAL PIT","CH BLADES ","      ",
      * "AUTO-VARIA","BLE PITCH ":"BLADES  "/
      DATA ((RECOVY(I,K), I=1,5),K=1,2)/
65  * "FANS NOT EQ","EQUIPPED WI","TH VELOCIT","Y RECOVERY",
      * "DIFFUSERS",
      * "FANS EQUIP","PED WITH V","VELOCITY RE","COVERY DIF",
      * "FUSERS      "/
C
70  1000 FORMAT(1H )
      1005 FORMAT(1H1)
      1010 FORMAT(T52,"F A N S")
      1020 FORMAT(T51,"-----")
      1030 FORMAT(T16,"--- DRIVE SYSTEM ---",T82,"--- FAN GEOMETRY ---")
75  1040 FORMAT(T84,"BLADE DIAMETER ",F6.2," FEET")
      1050 FORMAT(T87,"BLADE ANGLE ",F6.2," DEGREES")
      1060 FORMAT(T78,"NUMBER OF BLADES/FAN ",F6.2)
      1070 FORMAT(T84,"NUMBER OF FANS ",F6.0)
      1080 FORMAT(T17,"--- FAN COSTS ---",T78,"--- DESIGN CONDITIONS ---")
80  C
      1085 FORMAT (T100,"(ACTUAL)",T122,"(ADJUSTED),")
      1090 FORMAT(T73,"VOLUMETRIC FLOW RATE/FAN ",F12.0," CU FT/MIN")
      1100 FORMAT(T16,"BLADE AND HUB COST/FAN $",F10.0,T71,
      * "TOTAL VOLUMETRIC FLOW RATE ",F12.0," CU FT/MIN")
85  1120 FORMAT(T24,"MOTOR COST/FAN $",F10.0,T70,
      * "TOTAL AIR PRESSURE DROP OF H.X. ",F8.5," PSI",T120,F8.5)
      1130 FORMAT(T10,"SPEED REDUCER DRIVE COST/FAN $",F10.0,T69,
      * "PRESSURE DROP ACROSS H.X. BUNDLE ",F8.5," PSI",T120,F8.5)
      1140 FORMAT(T24,"STACK COST/FAN $",F10.0,T72,
90  * "NON-RECOVERABLE VELOCITY HEAD ",F8.5," PSI",T120,F8.5)
      1145 FORMAT(T19,"ELECTRICAL COST/FAN $",F10.0
      * $ ,T83,"HORSEPOWER/FAN",F13.0," HP",T116,F12.0)
      1150 FORMAT(T79,
      * "FAN POWER REQUIREMENTS ",F8.0," HP")
95  1190 FORMAT(T2,"*** ANNUAL OPERATIONAL COSTS $",F10.0)
      1200 FORMAT(T37,SA10)
      1210 FORMAT(
      * R T85,"HUB DIAMETER ",F6.2," FEET")
100  WRITE(6,1000)
      WRITE(6,1000)
      WRITE(6,1020)
      WRITE(6,1010)
      WRITE(6,1020)
      WRITE(6,1000)
105  IF (VELDEC.EQ.0) WRITE(6,1200) (RECOVY(I,1),I=1,5)
      IF (VELDEC.EQ.1) WRITE(6,1200) (RECOVY(I,2),I=1,5)
      WRITE(6,1000)
      WRITE(6,1030)
      WRITE(6,1000)
110  WRITE(6,1210) HUBDI1
      WRITE(6,1040) ADI1
      WRITE(6,1050) BLOAN1
      WRITE(6,1060) ABL1
      WRITE(6,1070) XNFAN1

```

```
115      WRITE(6,1000)
        WRITE(6,1000)
        WRITE(6,1080)
        WRITE(6,1000)
        WRITE(6,1085)
120      WRITE(6,1090) CFMPF1
        WRITE(6,1100) FDCPF1, TOTCF1
        WRITE(6,1120) FMTRC1, ACTTP1, ADUTP1
        WRITE(6,1130) CS21,ACTBP1, ADJBP1
        WRITE(6,1140) CYLRN1, ACTVH1, ADUVH1
125      WRITE(6,1145) CFANE1, HPPF1, ADJBP1
        WRITE(6,1150) THPA11
        WRITE(6,1190) AFCST1
        RETURN
      END
```

SUBROUTINE RPTHXC(AFRON)

C THIS ROUTINE REPORTS HEAT EXCHANGER DESIGN, OPERATING CONDITIONS
C AND COST

5 LOGICAL FIRST, EXTEMP

COMMON

\$ AFR, ALPHA, ANG(3)

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

10 \$ CBU, CTURB, CDANG, CLUVR, CHALS, CVM

\$ DANGLE, DFIN, DEEPL, DESVEL, DESVELV

\$ EFPF

\$ FOR, FIRST, FIXL, FCOS, FFHX, EXTEMP

\$ GBEFF

15 \$ HXNP, HPCST

\$ ITMAX, ITMIN

\$ JCONS

\$ KCONV, KALEXT

\$ MXEXT

20 \$ NTUCAL(2), NTA

COMMON

\$ ORR

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

25 \$ POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCU

\$ RRP, REDUCE, REDUCV, ROOFU

\$ QREU, QREDUCE, QREDUCV

\$ SIGMAG, SAAF

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

30 \$ TCD, TW

\$ UOS, UWS

\$ WFW

\$ VAS(5)

\$ XDEPA, XW, XD

COMMON /SINK/ VAR(5), CPLN1, CPI01, CCOS1, W31, COSM1, EFF1,

35 \$ QIN1, CLAN1, REA11, Z1, HRFAS2, W41, U1, DEPW1, PPW1,

\$ FROW1, DEFC1, WIDT1, ELEW1, VAIR1, VWAT1, HI1, HO1, T41,

\$ REW1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPBP, SW41, SW31,

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

40 \$ B2MIN, NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1

\$ TLA1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CA1, CS1

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

\$ CAPCS1, XNFA1, BLOAN1, CPLEN1, OFEL1, WH1, WTTU1, ADI1, ABL1

\$ ATHO1, WTER1, STRUC1, CFNPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1

45 \$ AIRFF1, WATFF1, XNMOD1, TCTP1, FDCPF1, FMTRC1, ACTTP1, ADJTP1

\$ ACTBP1, ADJBP1, ACTVH1, ADJUH1, ADJUP1, THPA1, TCTF1, AFCST1

\$ CSR1, WATER1, WSTRC1, CFJUN1, HJBD1, TOWLE1, NUMTOL, CTOWD1

\$ SRU1, SRUS1, ATUBC1, CSAL, TTD1, TTD21, DELPS1, CSTLV1

\$ CSTHS1, CYLRN1, CFANE1, PSTAC1, PUFIT1, PMPCS1, RPTPL1, SEPCCS1

50 COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2QE, LINOR, XNP, XQUALY

COMMON /HXD/ AT, ATOT

COMMON /ESCAL/ BSECF

COMMON /KPTSUP/ DUM(2017), THXINI, DUM2(3)

6390 FORMAT(

55 R T9, "AT OF AMMONIA ", F14.0, " LB")

6400 FORMAT(

L T9, "AFTR", G14.8


```

      R,T71,"WT OF TUBES ",F14.0," LB")
6410 FORMAT(
60      L T8,"ALPHA", G14.8
      R,T71,"WT OF FRAME ",F14.0," LB")
6420 FORMAT(
      L T8,"SIGMA", G14.8
65      R,T71,"WT OF HEADER",F14.0," LB")
6422 FORMAT(
      R T71,"WT OF STRUCT",F14.0," LB")
6424 FORMAT(
      L T71," ROOF LOAD",F14.0," LB"
      R,T105,"(",F8.2," LB/SQ FT)")
70 6430 FORMAT(
      L T3,"FITCD/ATOT", G14.8
      S)
6440 FORMAT (I40,2A10,T15,"NTU EFFECTIVENESS CORRELATION USED")
6500 FORMAT(I40)
75 6505 FORMAT(T35,30(" "))
6510 FORMAT(T36,"H E A T   E X C H A N G E R")
6512 FORMAT(I4+,T90,F6.1," FANS",T110,F4.1," PASS")
6515 FORMAT(
      L T2," AMMONIA FLOW RATE",I11," LBM/HR"
80      R,T71," COOLING SURFACE $",F10.0)
6520 FORMAT(
      L T2," AIR FLOW RATE",I11," LBM/HR"
      R,T71," HEADER AND NOZZEL $",F10.0)
6525 FORMAT(
85      L T2," TUBES IN DEPTH",F11.2," TUBES  (",F7.1," FT DEEP)"
      R,T71,"BUNDLE ASSEMBLE AND FRAME $",F10.0)
6530 FORMAT(
      L T2,"TUBES ACROSS FRONT",I11," TUBES  (",F7.1," FT WIDE)"
      R,T71," PLENUM $",F10.0)
90 6532 FORMAT(1X
      R, T71," LOUVERS $",F10.0)
6533 FORMAT (1X
      R, T71," HAIL SCREENS $",F10.0)
6535 FORMAT(
95      L T2," LENGTH",F11.0," FEET"
      R,T71," STRUCTURE $",F10.0)
6537 FORMAT(
      R T71," FOUNDATION $",F10.0)
6540 FORMAT(
100      L T2," FRONTAL AREA",I11," SQ FEET"
      R ,T71," HEAT XCHR SHIP AND ERECT $",F10.0)
6550 FORMAT(T40,2("FOR",F5.0," DEGREE F AMBIENT  "))
6541 FORMAT(T8,"SURFACE AREA",I11," SQ FT")
6555 FORMAT(T70,11(" "),2X,11(" "))
105 6560 FORMAT(T73,"AIR",T85,"AMMONIA")
6565 FORMAT(T70,25(" "))
6570 FORMAT(T50,"REYNOLDS NUMBER"
      S ,2(1P13.5,E14.5,3X))
6575 FORMAT(T49,"VELOCITY (FT/SEC)"
110      S ,2(1P13.5,E14.5,3X))
6580 FORMAT(T34,"PRESSURE DROP (LBS FORCE/SQ IN)"
      S ,2(1P13.5,E14.5,3X))
6581 FORMAT(T44,"INLET TEMPERATURE (F)",1P13.5,E14.5)
6582 FORMAT(T45,"EXIT TEMPERATURE (F)",1P13.5,E14.5)

```

```

115      6583 FORMAT(T56,"RANGE (F)",1PE13.5,E14.5)
      6584 FORMAT(T61,"TTD1",7X,1PE13.5)
      6585 FORMAT(T29,"HEAT TRFR COEFF (BTU/HR SQ FT DEG F)"
      $ ,2(1PE13.5,E14.5,3X))
120      6586 FORMAT(T52,"NTU",7X,1PE13.5)
      6587 FORMAT(T50,"FRICTION FACTOR"
      $ ,2(1PE13.5,E14.5,3X))
      6590 FORMAT(T35,"HEAT TRFR SURFACE AREA (SQ FT)"
      $ ,1PE13.5,E14.5)
      6592 FORMAT(T35,"EXIT TEMPERATURE (F)"
      $ ,2(1PE13.5,E14.5,3X))
125      6595 FORMAT(T35,"OVERALL U (BTU/HR SQ FT DEG F)"
      $ ,7X,1PE13.5,E14.5)
      6600 FORMAT(T52,"EFFECTIVENESS"
      $ ,T75,F7.4)
130      6610 FORMAT(T51,"FIN EFFICIENCY"
      $ ,T76,F7.4)
      6620 FORMAT(T07,"LOG MEAN TEMPERATURE DIFFERENCE"
      $ ,T46,F7.2,T76,F7.2)
C
135      WRITE(6,6500)
      WRITE(6,6505)
      WRITE(6,6510)
      WRITE(6,6512) XNFAN1, HXNP
      WRITE(6,6505)
140      WRITE(6,6500)
      WRITE(6,6505)
      WRITE(6,6550)
      WRITE(6,6555)
      WRITE(6,6570) REAI1, RENAI
145      WRITE(6,6575) VAIR1, VWAT1
      WRITE(6,6580) DEPA1/144., DPWT1/144.
      WRITE(6,6585) H01, H11
      WRITE(6,6587) AIRFF1, WATFF1
150      WRITE(6,6581) TD, THXIN1
      WRITE(6,6582) T41, THXIN1
      WRITE(6,6583) T41-TD
      WRITE(6,6584) VAR(3)
      WRITE(6,6586) ANTU1
      WRITE(6,6585) U1
155      WRITE(6,6600) EFF1
      WRITE(6,6610) EFFIN1
      WRITE(6,6500)
      WRITE(6,6390) WATER1
      WRITE(6,6400) AFTR, WTTU1
160      WRITE(6,6410) ALPHA, WTRF1
      WRITE(6,6420) SIGMAG,WTH01
      WRITE(6,6422) WSTRC1
      WRITE(6,6424) AFRON*ROOFL, ROOFL1
      WRITE(6,6430) FITCO1/ATOT
165      WRITE(6,6440) NTUCAL
      WRITE(6,6500)
C
      WRITE(6,6515) IFIX(SW31), CS1
      WRITE(6,6520) IFIX(SW41), CH1
170      WRITE(6,6525) Z1, Z1*XD/12., CA1
      WRITE(6,6530) NW1, WIDT1, CPLEN1

```

SUBROUTINE RPTHXC

74/74 OPT=1

FTN 4.2+74351

12/19/76

175

```
WRITE(6,6532) CSTLV1
WRITE(6,6533) CSTHS1
WRITE(6,6535) ELEN1, STRUC1
WRITE(6,6537) CFOUN1
WRITE(6,6540) IFIX(4FRON), (3SECFH1.)*(CA1 + CH1 + CSI)
WRITE(6,6541) IFIX(4AIR1)
RETURN
END
```

1

```

SUBROUTINE RPTRET(CTOWD1, PF, PSTAC1, PUFIT1, PUMPC1, RPTPL1,
$ SEPCSI)

```

C
C
C

THIS ROUTINE REPORTS RETURN PIPING DESIGN AND COSTS

5

```

COMMON /KPTRET/

```

```

$ DELL1, DESVE1, DIARD1, DIART1, DOTMA1, DYNHDI

```

```

$ HEDR1(200)

```

```

$ JRSAVE

```

10

```

$ KRSAVE

```

```

$ PIPCS1

```

```

$ QHEDR1(200), QRLCS1

```

```

$ RDIA1(200), RDCST1(200), RRCST1(200), RTCST1(200), RBFCST1, RCOST1

```

```

$ RQDIA1(200), RQPCST1(200), RQRCST1(200), RQTCST1(200), REUCST1

```

15

```

$ RELCS1, RELGCI, RQCOS1, RTDCST1

```

```

$ TOWD1, TRQCO1, TRTDC1

```

C

```

203 FORMAT(1H,14X,I2,1X,7F10.1)

```

20

```

204 FORMAT(///40X,"TOTAL COST OF CIRCULATION RETURN PIPING $",F5.0,
$ " *10**3"////)

```

```

205 FORMAT(/25X,"QUADRANT RETURN PIPING"

```

```

$ //42X,"COST IN 10**3 DOLLARS FOR"/40X

```

```

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

```

```

$ PIPE TEES REDUCERS"/21X,"(INCHES) (FEET)"//)

```

25

```

208 FORMAT(///42X,"TOTAL COST OF QUADRANT RETURN HEADERS $",F5.0,
$ " *10**3"////)

```

```

209 FORMAT(/25X,"TOWER RETURN PIPING"

```

```

$ //10X,"TOWER DIAMETER",23X,F5.0," FEET"/
$10X,"DIAMETER OF PIPE FROM CIRCULATION"

```

30

```

$"/10X,"HEADER TO TOWER DISTRIBUTION HEADER",F7.0," INCHES"/10X,"DI

```

```

$AMETER OF TOWER DISTRIBUTION PIPE",F7.0," INCHES"/10X,"COST OF DI

```

```

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

```

```

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

```

```

211 FORMAT(10X,"LIQUID DESIGN VELOCITY",F5.0," FPS"/

```

35

```

$ 10X,"MASS FLOW RATE",1PE10.3," LBM/HR"/

```

```

$ 10X,"RETURN PIPING PRESSURE DROP",10PF7.1," PSF"/

```

```

$ 10X,"RETURN PIPING DYNAMIC HEAD",F7.1," FEET"////)

```

```

$ 47X,"TOTAL RETURN PIPING SYSTEM COST $",F6.0," *10**3"////)

```

```

213 FORMAT(1H1)

```

40

```

214 FORMAT(1H,13X,I2,1X,7F10.1)

```

```

215 FORMAT(/10X,"COST OF RETURN HEADERS PER QUADRANT $",F5.1,
$ " *10**3")

```

```

216 FORMAT(30X,"-----"/30X,"RETURN PIPING"/30X,"-----"

```

45

```

$-----"/25X,"CIRCULATION PIPING"/52X,"COST IN 10**3"

```

```

$3 DOLLARS FOR"/40X,"-----"

```

```

$-----"/12X,"HEADER DIAMETER LENGTH PIPE TEES REDUCE

```

```

$RS EXPANSION FLANGES"/21X,"(INCHES) (FEET)",33X,"JOINT(1) (3

```

```

$)"/)

```

```

217 FORMAT(///10X,"FITTINGS COST PER BUNDLE $",F7.3," *10**3")

```

50

C

```

300 FORMAT(///T50,9("=")/T50,"P U M P S"/T50,9("=")///)

```

```

310 FORMAT(T10,"PUMP COST",T30,"$",F8.0,"*10**3"

```

```

$ /T10,"PUMP FITTINGS",T30,"$",F8.0,"*10**3"

```

```

$ /T10,"PUMP ELECTRICAL",T30,"$",F8.0,"*10**3")

```

55

```

320 FORMAT(///T50,"PUMP STATION",T80,"$",F8.0,"*10**3")

```

```

330 FORMAT(///T10,"SEPARATOR COST",T30,"$",F11.0,"*10**3")

```

C

```

        JR=JDSAVE
        KR=KDSAVE
50      WRITE(4,213)
        WRITE(4,216)
        DO 201 I=1,JR
        IF(I.GT.1) GO TO 202
        WRITE(4,203) I, RDIAL(I), HEDR1(I), RPCST1(I)*PF, RTCST1(I)*PF
65      $ ,RRCST1(I)*PF, REJCS1*PF, RFLGC1*PF
        GO TO 201
202    IF(I.EQ.JR) GO TO 210
        WRITE(4,203) I, RDIAL(I), HEDR1(I), RPCST1(I)*PF, RTCST1(I)*PF
        $ ,RRCST1(I)*PF
70      GO TO 201
210    WRITE(4,203) I, RDIAL(I), HEDR1(I), RPCST1(I)*PF, RELCS1*PF
        $ ,RRCST1(I)*PF
201    CONTINUE
        WRITE(4,204) RCOST1
75      WRITE(4,205)
        DO 206 I=1,KR
        IF(I.EQ.KR) GO TO 207
        WRITE(4,214) I, RQDIAL(I), QHEDR1(I), RQPCS1(I)*PF, RQTCST1(I)*PF
80      $ ,RQRCST1(I)*PF
        GO TO 206
207    WRITE(4,214) I, RQDIAL(I), QHEDR1(I), RQPCS1(I)*PF, QRLCST1*PF
        $ ,RQRCST1(I)*PF
206    CONTINUE
        WRITE(4,217) RBFCST1*PF
85      WRITE(4,215) RQCCST1*PF
        WRITE(4,208) TRQCCST1*PF
        WRITE(4,209) CTOWD1, DIARD1, DIART1, RTDCST1*PF, TRTDCST1*PF
        WRITE(4,211) DESVE1, DOTM41, DELL1, DYNWD1, PTPCST1
        WRITE(4,300)
90      WRITE(4,310) (PUMPC1-PUFIT1)*PF, PUFIT1*PF, RPTPL1
        WRITE(4,320) (PUMPC1*PF) + RPTPL1
        WRITE(4,330) SEPCST1
        RETURN
        END

```

```
SUBROUTINE RPTSUP(DESVELV, NUMTOW, CTOWD1)
```

```
THIS ROUTINE REPORTS RETURN PIPING DESIGN AND COSTS
```

C
C
C
C
C

```
COMMON /KPTSUP/
```

```
$ DELV1, DIASD1, DIAST1, DOTMA1, DYNHD1
```

```
$, HEDR1(200)
```

```
$, JSSAVE
```

```
$, KSSAVE
```

```
$, PIPCS1
```

```
$, QSLCS1, QHEDR1(200)
```

```
$, SFFCS1, SCOST1, SEJCS1, SELCST, SFLGC1, SQCOS1, STDCS1
```

```
$, SOTA1(200), SPCST1(200), SQOIAL(200), SQPCS1(200), SQRCS1(200)
```

```
$, SOTCS1(200), SRCST1(200), STCST1(200)
```

```
$, TCONO1, THXIN1, TOWD11, TSRCO1, TSTDC1
```

```
JS = JSSAVE
```

```
KS = KSSAVE
```

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

```
204 FORMAT(///40X,"TOTAL COST OF CIRCULATION SUPPLY PIPING $",F5.0,
```

```
$" *10**3"////)
```

```
205 FORMAT(/25X,"QUADRANT SUPPLY PIPING"
```

```
$ //42X,"COST IN 10**3 DOLLARS FOR"/40X
```

```
$,"-----"/12X,"HEADER DIAMETER LENGTH"
```

```
$ PIPE TEES REDUCERS"/21X,"(INCHES) (FEET)"/)
```

```
208 FORMAT(///42X,"TOTAL COST OF QUADRANT SUPPLY HEADERS $",F5.0,
```

```
$" *10**3"////)
```

```
209 FORMAT(/25X,"TOWER SUPPLY PIPING"
```

```
$ //10X,"NUMBER OF TOWERS",21X,15
```

```
$ /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
```

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

```
$F TOWER DISTRIBUTION PIPING $",F5.0," *10**3"////)
```

```
211 FORMAT(10X,"VAPOR DESIGN VELOCITY",F5.0," FPS"/
```

```
$ 10X,"MASS FLOW RATE",1P10.3," LB4/HR"/
```

```
$ 10X,"CONDENSER OUTLET TEMPERATURE",0P7.2," DEG. F"/
```

```
$ 10X,"HEAT EXCHANGER INLET TEMPERATURE",F7.2," DEG. F"/
```

```
$ 10X,"SUPPLY PIPING PRESSURE DROP",F7.1," PSF"/
```

```
$ 10X,"SUPPLY PIPING DYNAMIC HEAD",F7.1," FEET"////
```

```
$ 47X,"TOTAL SUPPLY PIPING SYSTEM COST $",F5.0," *10**3"////)
```

```
213 FORMAT(1H1)
```

```
214 FORMAT(1H,13X,12,1X,7F10.1)
```

```
215 FORMAT(/10X,"COST OF SUPPLY HEADERS PER QUADRANT $",F5.1,
```

```
$" *10**3")
```

```
216 FORMAT(30X,"-----"/30X,"SUPPLY PIPING"/30X,"-----"
```

```
$-----"/25X,"CIRCULATION PIPING"/52X,"COST IN 10**"
```

```
$3 DOLLARS FOR"/40X,"-----"
```

```
$-----"/12X,"HEADER DIAMETER LENGTH PIPE TEES REDUCE
```

```
$RS EXPANSION FLANGES"/21X,"(INCHES) (FEET)",33X,"JOINT(1) (3
```

```
$)"/)
```

```
217 FORMAT(///10X,"FITTINGS COST PER BUNDLE $",F5.3," *10**3")
```

```
WRITE(6,213)
```

```
        WRITE(4,216)
        DO 201 I=1,JS
60      IF(I.GT.1) GO TO 202
        WRITE(4,203) I, SDIA1(I), HEDR1(I), SPCST1(I), STCST1(I),
        $ SRCST1(I), SEJCS1, SFLGC1
        GO TO 201
65      202 IF(I.EQ.JS) GO TO 210
        WRITE(4,203) I, SDIA1(I), HEDR1(I), SPCST1(I), STCST1(I),
        $ SRCST1(I)
        GO TO 201
        210 WRITE(4,203) I, SDIA1(I), HEDR1(I), SPCST1(I), SEJCS1, SRCST1(I)
70      201 CONTINUE
        WRITE(4,204) SCOST1
        WRITE(4,205)
        DO 206 I=1,KS
        IF(I.EQ.KS) GO TO 207
75      WRITE(4,214) I, SQDIA1(I), QHEDR1(I), SQPCS1(I), SQTCS1(I),
        $ SORCS1(I)
        GO TO 206
        207 WRITE(4,214) I, SQDIA1(I), QHEDR1(I), SQPCS1(I), QSLCS1, SQRCS1(I)
        206 CONTINUE
80      WRITE(4,217) SRFCS1
        WRITE(4,215) SQCOS1
        WRITE(4,208) TSQC01
        WRITE(4,209) NUMTOW, CTOWD1, DIASD1, DIAST1, STDCS1, TSTDCT
        WRITE(4,211) DESVELV, DOTMA1, TCONO1, THXIN1, DELV1,DYNHD1, PIPCS1
85      RETURN
        END
```

SUBROUTINE RPTHXD

C
C
C

THIS ROUTINE REPORTS HEAT EXCHANGER DESCRIPTION AND UNIT COST DATA

```

5 LOGICAL FIRST, FXTMP
COMMON
$ AFTR, ALPHA, ANG(3)
$ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONWA2, CAP
10 $ ,CBU, CTUR, CDANG, CLUVR, CHAILE, CVM
$ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
$ ,EFFP
$ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
$ ,GREFF
15 $ ,HXNP, HPCST
$ ,ITMAX, ITMIN
$ ,JCONC
$ ,KCONV, KALEXT
$ ,MXEXT
$ ,NTUCAL(2), NTA
20 COMMON
$ OOR
$ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
$ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCLE
25 $ ,RBP, REDUCE, REDUCV, ROOFLE
$ ,REU, GREUCE, GREUCV
$ ,SIGNG, SAAP
$ ,TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
$ ,TCD, TW
30 $ ,UCS, UWS
$ ,WFM
$ ,VAG(2)
$ ,XDEPA, XW, XD
COMMON /HEADX/ CHH, CN, CHM, CMW, CRJ, CWJ, CST
35 $ , CMO, CSR, CSM, PITCHF, CPM, PRESS, HEDMAT, HEDTYP, NPASS:
$ ,
COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W3T, COSM1, EFF1,
$ QIN1, CLAN1, REA11, Z1, HRFAC2, W41, U1, DEPW1, PPOW1,
$ FPOW1, DEFC1, WIOT1, ELEN1, VAIR1, VWAT1, HI1, HO1, T41,
40 $ REWA1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPB0, SW41, SW31,
$ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
$ B2MIN, W2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
$ , TLAI, UCON1, PMOS1, FMOS1, FBAC1, EFFC1, CHI, CA1, CS1
$ , CLTCL, CFC1, CPCC1, FITCL, CSC1, CEPRE1, DEPI1, AST1, OLDCS1
45 $ , CAPCS1, XNFAN1, BLDAN1, CPLEN1, DPFE1, WH1, WTTU1, AD11, ASL1
$ , WTHD1, WTR1, STRUC1, CMPEF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1
$ , AIRFE1, WATFE1, XVMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
$ , ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1
$ , CSR1, WATER1, WSTR1, CFOJN1, HUGD1, TOWLE1, NUMTOL, CTOWD1
50 $ , SQRJ1, SQRJS1, ATUBC1, CBA1, ITD11, ITD21, DELPS1, CSTLV1
$ , CSTHG1, CYLRN1, CFANE1, PSTAC1, PUFIT1, PMPCS1, RPTPL1, SEPC1
COMMON /TINE/ XNS, TLA, XNTS, ARPS, ITD20E, LINOR, XNP, XQUALY
COMMON /SURFEX/ ODL, GAGLIN, NTUB, TUBMAT, FINTYP, FINMAT, CFB
$ , APLATE, COATC, ZINCC, CASTC, SS, EPREPC, XTUBMA, XHEDTY, XFINTY
COMMON /DJE/ DI, XDG, SF
55 COMMON /SUPPLY/ VAL(5), CPLV, CPIP2, CCOS, W3, COSM, EFF,
$ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
$ FPOW, DELFC, WIDTH, ELEN, VAIR, VWAT, HI, HO, T4,

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      S REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
      S SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
60  S BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
      S TLAX, UCON, PMOST, FMCST, FBACC, EFFC, CH, CA, CS
      S CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLDOST
      S CAPCST, XNFAN, BLDANG, CPLEN, DPPEL, WHX, HTTUB, ADIA, ABLN
65  S ATHR, WTERM, STRUCC, CPERF, HPERF, TOTCF, TPC, EFFIN, ANTU
      S AIRFF, WATFF, XNMOD, TCTPF, FOCPE, FMTRC, ACCTP, ADJTP
      S ACTRD, ADJBD, ACTVH, ADJUH, ADJPP, THRAIR, TCTF, AFCST
      S CSR, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S SQRJ, SQRUS, ATURC, CBA, TTD1, TTD2, DELPS, CSTLVR
      S CSTHC, CYLRNG, CFANEL, PSTACS, PJFITC, PMPCST, RPTPL, SEPCST
70  6600 FORMAT(1H1)
      6601 FORMAT(1H )
      6602 FORMAT(1H+,T10," NON - D E L I T A   H E A T   E X C H A N G E
      S R   D E S C R I P T I O N",T10,F5.1," DEG ")
      6603 FORMAT(
75  L T22,"SUPPORT SPACING ",F7.3,T47,"FEET"
      R,T60,"BOOT DIAMETER" ,F8.4,T82,"INCH")
      6605 FORMAT(
      L T8,"TUBE PITCH NORMAL TO AIR FLOW ",F7.3,T47,"INCH"
      R T63,"FIN THICKNESS",F8.4,T82,"INCH")
80  6610 FORMAT(
      L T2,"TUBE PITCH IN DIRECTION OF AIR FLOW ",F7.3,T47,"INCH"
      R ,T51,"FIN DIAMETER " ,F8.4,T82,"INCH")
      6615 FORMAT(
      L T18,"TUBE DIAGONAL PITCH ",F7.3,T47,"INCH"
85  R,T62,"FIN SPACING" ,F8.4,T82,"INCH")
      6620 FORMAT(
      L T23,"LINER MATERIAL ",Z410
      R,T61,"FIN MATERIAL ",Z410)
      6625 FORMAT(
90  L T11,"LINER THERMAL CONDUCTIVITY",F7.3
      R,T55,"FIN THERMAL COND. ",G11.4,T83,"BTU/(HR SQ FT DEG F)/FT")
      6630 FORMAT(
      L T8,"LINER TUBING OUTSIDE DIAMETER " ,F7.4,T47,"INCH"
      R,T62,"HEADER TYPE ",Z410)
95  6635 FORMAT(1H+
      L T38,"--- U N I T   C O S T S ---")
      6640 FORMAT(
      L T13,"FIN BONDING $",G10.4,"/SQ FT"
      R,T58,"HEADER MATERIAL (" ,Z410,") " $",F8.3,"/LB")
100  6645 FORMAT(
      L T6,"PROTECTIVE COATING $",G10.4,"/SQ FT"
      R,T58,"BOLTED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
      6650 FORMAT(
      L T8,"ZINC FOR SPACERS $",G10.4,"/LB"
105  R,T58,"WELDED JOINT, TUBE TO HEADER $",F8.3,"/TUBE")
      6655 FORMAT(
      L T10,"SPACER CASTING $",G10.4,"/EA"
      R,T58,"TUBE AND PLUG HOLE PREPARATION $",F8.3,"/HOLE")
      6660 FORMAT(
      L T9,"END PREPARATION $",G10.4,"/TUBE"
110  R,T65,"NOZZEL AND ATTACHING $",F8.3,"/HOLE")
      6662 FORMAT(
      R,T47,"BOLTED HEADER JOINT $", F8.3,"/FT")
      6665 FORMAT(

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115      RT58,"HEADER MACHINING AND WELDING  S",F8.3,"/FT")
      6670 FORMAT(
          LT09,"LINER TUBING      S",G11.5,"/FT",
          RT70,"STRUCTURAL STEEL  S",F8.3,"/L3")
120      6675 FORMAT(
          LT03,"PROTECTIVE COATING  S",G11.5,"/FT"
          R)
      6680 FORMAT(
          LT14,"FINNING      S",G11.5,"/FT"
          R)
125      6685 FORMAT(/
          LT29,"FINNED TUBE  S",G11.5,"/FT"
          R)
      6695 FORMAT(
          LT28,"TUBE SPACERS  S",G11.5,"/FT"
          R)
130      C
      6617 FORMAT(
          L T27,"LINER GAGE ",F5.1
          R ,T65,"FIN TYPE ",ZAL0)
135      6700 FORMAT(
          L T18,"TUBES THRU EACH FIN",F9.0,T47,"TUBES"
          R,T56,"AREA OF PLATE FIN ",F11.1," SQ IN.")
      6710 FORMAT(
          LT9,"LINER TUBING INSIDE DIAMETER ",F7.4,T47,"INCH"
          R,T60,"HEADER LENGTH",F11.3," FEET")
140      WRITE(6,6600)
      DO 20 I=1.3
      IF (DANGLE .LT. 1.E-30) WRITE(6,6602)
      IF (DANGLE .GT. 0.0) WRITE(6,6602) DANGLE*180. / 3.14159
145      20 CONTINUE
      WRITE(6,6601)
      WRITE(6,6603) SS      ,ODR
      WRITE(6,6605) XW      ,THFIN
      WRITE(6,6610) XD      ,DFIN
150      WRITE(6,6615) XDG    ,SF
      WRITE(6,6617) GAGLIN,FINTYP,XFINTY
      IF(FINTYP .EQ. "PLATE ") WRITE(6,6700) NTUB,APLATE
      WRITE(6,6620) TUBMAT,XTUBMA,FINMAT
      WRITE(6,6625) CONVL,CONF
155      WRITE(6,6630) ODL,HEDTYP,XHEDTY
      WRITE(6,6710) DI, WB
      WRITE(6,6601)
      WRITE(6,6601)
      C
160      DO 30 I=1.3
      30 WRITE(6,6635)
      WRITE(6,6601)
      WRITE(6,6640) CFB,HEDMAT,CHM
      WRITE(6,6645) COATC,CRJ
165      WRITE(6,6650) ZINCC,CWJ
      WRITE(6,6655) CASTC,CHH
      WRITE(6,6660) EPREPC,CN
      WRITE(6,6662) CRJ
      WRITE(6,6665) CMW
170      WRITE(6,6670) CLTCL, CST
      WRITE(6,6675) CPCC1

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SUBROUTINE RPTHXD 74/74 OPT=1

FTN 4,2,74351.

12/19/76

WRITE(4,6680) CFC1
WRITE(6,6685) FITCO1
WRITE(6,6695) CSC1

175

C

RETURN
END

SUBROUTINE SCALP(TI,RANGE,AFRON,WLRAT,TCHFCS,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

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

ADIA - FAN BLADE DIAMETER (FT)

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

ATUBC - HEAT EXCHANGER TUBE COST (\$)

BSECF - 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 (\$)

CFANEL - 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 (\$)

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

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

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

CONBAS - 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	CPM	- COST OF RENUM MATERIAL PER POUND (\$/LBM)
	C	CS	- 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	CMARA	- RATIO OF HEAT CAPACITY OF THE WATER TO THE AIR (DIMENSIONLESS)
	C	CYLRNG	- 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	FRACC	- 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/HW HR)
	C	FCB3	- FUEL COST FOR THE SCALED UP PLANT (MILLS /KW HR)
	C	FCOS	- COST OF FUEL FOR POWER PLANT (CENTS/BTU)
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 (\$/FAN)
85	C	FMCST	- TOTAL FAN MOTOR COST FOR THE FAN SYSTEM AFTER SCALE UP (\$)
	C	FDOW	- POWER REQUIREMENTS OF THE FAN SYSTEM (KW)
	C	HPAIR	- HORSEPOWER REQUIREMENTS OF THE FAN SYSTEM (HP)
	C	HPWAT	- HORSEPOWER REQUIREMENTS OF THE WATER PUMPING SYSTEM (HP)
90	C	HBFAC1	- HEAT RATE FACTOR AT POINT ONE (DIMENSIONLESS)
	C	HBFAC2	- HEAT RATE FACTOR AT POINT TWO (DIMENSIONLESS)
	C	HBFRT1	- RATIO OF HBFAC2 TO HBFAC1 USED FOR SCALING UP PLANT TO DESIGN CONDITIONS (DIMENSIONLESS)
95	C	HSLVA	- SURFACE AREA COVERED BY HAIL SCREENS OR LOUVERS (SQ FT)
	C	ITOWN	- NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
	C	KCONV	- INTERNAL VARIABLE FOR SPECIFYING THAT THE SET OF INPUT VARIABLES LEAD TO UNREASONABLE VALUES (DIMENSIONLESS)
100	C	KGA	- VARIABLE FOR SPECIFYING GAGE OF TUBES USED IN THE CONDENSER (DIMENSIONLESS)
	C	LD	- VARIABLE FOR SPECIFYING THE DIAMETER OF THE CONDENSER TUBING (DIMENSIONLESS)
105	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)
	C	NUMTOW	- NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
	C	NW	- NUMBER OF HEAT EXCHANGER TUBES IN WIDTH (DIMENSIONLESS)
110	C	PER	- PERCENTAGE OF TOTAL CAPITAL COSTS OF DRY COOLING TOWER ALLOWED FOR MAINTENANCE COST (PERCENT)
	C	PLANC	- BASE PLANT COSTS (\$/KW)
	C	PLANC1	- PLANT COSTS AT POINT ONE (\$/KW)
	C	PLANC2	- PLANT COST AT POINT TWO (\$/KW)

115	C	PLANC3	- PLANT COSTS AT POINT THREE
	C	PMELEC	- COST OF ELECTRICAL WIRING FOR WATER PUMPING SYSTEM
	C		(S)
	C	POHCND	- INDIRECT COSTS FOR SURFACE CONDENSER AS A PERCENT-
	C		AGE OF BASE COSTS (PERCENT)
120	C	POHSCU	- INDIRECT COSTS FOR AHIL SCREENS AND LOUVERS
	C		AS A PERCENTAGE OF BASE COSTS (PERCENT)
	C	POHSTC	- INDIRECT COSTS FOR THE STRUCTURES AND FOUNDATION
	C		FOR THE CIRCULAR TOWER AS A PERCENTAGE OF BASE
	C		COSTS (PERCENT)
125	C	PROW	- POWER REQUIREMENTS OF THE WATER PUMPING SYSTEM (KW)
	C	PSIZE	- SPECIFIED POWER OUTPUT OF THE PLANT AND MAKE UP
	C		SYSTEM TO THE POWER GRID (MW)
	C	PSIZ12	- POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK
	C		PRESSURE FOR A POWER OUTPUT OF THE TURBINE OF
130	C		PSIZE AT DESIGN CONDITIONS (MW)
	C	PSIZ13	- POWER OUTPUT OF TURBINE AT THE TURBINE RATED BACK
	C		PRESSURE FOR A POWER OUTPUT OF THE PLANT OF PIZSE
	C		AT DESIGN CONDITIONS (MW)
	C	PTOTAL	- TOTAL POWER OUTPUT OF THE TURBINE AT DESIGN
135	C		CONDITIONS (MW)
	C	RANGE	- TEMPERATURE DIFFERENCE OF THE WATER ENTERING
	C		AND LEAVING THE HEAT EXCHANGER (DEG F)
	C	ROOFL	- ROOF LOAD DESIGN CONDITIONS FOR STRUCTURAL COSTS OF
	C		CIRCULAR TOWERS (LBF/SQ FT)
140	C	SAPRON	- SCALED UP FRONTAL AREA OF THE HEAT EXCHANGER
	C		NORMAL TO AIR FLOW (SQ FT)
	C	SP9P	- INCREMENTAL PLANT COST BETWEEN PLANT DESIGNED AT
	C		RATED CONDITIONS (POINT 1) AND AT DESIGN CONDITIONS
	C		(POINT 2) (S)
145	C	SPC	- COST OF PLANT AT DESIGN CONDITIONS (POINT 3)
	C	SPCD	- INCREMENTAL COST OF PLANT USING DRY COOLING TOWERS
	C		AT DESIGN CONDITIONS (POINT 3) OVER PLANT AT RATED
	C		CONDITIONS (POINT 1) (S)
	C	STRUCC	- STRUCTURAL COST OF THE CIRCULAR TOWERS (S)
150	C	SWLRAT	- SCALED UP WIDTH TO LENGTH RATIO OF THE HEAT
	C		EXCHANGER (DIMENSIONLESS)
	C	SW3	- SCALED UP MASS FLOW RATE OF WATER THROUGH THE
	C		HEAT EXCHANGER (LBM/HR)
	C	SW4	- SCALED UP MASS FLOW RATE OF AIR THROUGH THE HEAT
155	C		EXCHANGER (LBM/HR)
	C	TOWFCS	- TOTAL COST OF THE PIPING SYSTEM (K\$)
	C	T _D	- DESIGN TEMPERATURE OF THE DRY COOLING TOWER (DEG F)
	C	T _{EFF}	- RATED BACK PRESSURE EFFICIENCY OF THE STEAM
	C		TURBINE (PERCENT)
160	C	T _{LA}	- LENGTH OF CONDENSER TUBING (FT)
	C	T _A	- EXIT TEMPERATURE OF THE AIR FROM THE HEAT EXCHANGER
	C		(DEG F)
	C	V _A	- SPECIFIC VOLUME OF THE AIR (CU FT/LBM)
	C	WATERW	- WEIGHT OF WATER IN THE HEAT EXCHANGER BUNDLES (LBM)
165	C	W _{WX}	- TOTAL WEIGHT OF THE HEAT EXCHANGER EXCLUDING
	C		WATER (LBM)
	C	WIDTH	- TOTAL HEAT EXCHANGER WIDTH (FT)
	C	WLRAT	- RATIO OF THE WIDTH TO THE LENGTH OF THE HEAT
	C		EXCHANGER (DIMENSIONLESS)
170	C	W _{PL}	- WEIGHT OF THE PLENUM PER UNIT AREA (LBF/SQ FT)
	C	WSTRUCT	- TOTAL WEIGHT OF THE COOLING TOWER STRUCTURES (LBF)

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C      WYFRM - TOTAL WEIGHT OF THE HEAT EXCHANGER FRAM (LBG)
C      WYHDR - TOTAL WEIGHT OF THE HEAT EXCHANGER HEADERS (LBF)
C      WYTUB - TOTAL WEIGHT OF THE HEAT EXCHANGER TUBES (LBF)
175  C      W3 - MASS FLOW RATE OF THE WATER THROUGH THE HEAT
C      W4 - MASS FLOW RATE OF THE AIR THROUGH THE HEAT
C          EXCHANGER (LBM/HR)
C      XNFAN - NUMBER OF FANS IN THE FAN SYSTEM (DIMENSIONLESS)
C      XNS - NUMBER OF SHELLS IN THE SURFACE CONDENSER
180  C          (DIMENSIONLESS)
C      XNTS - NUMBER OF CONDENSER TUBES PER SHELL (DIMENSIONLESS)
C      XW - TRANSVERS PITCH BETWEEN ADJACENT TUBES IN THE SAME
C          TUBE ROW OF THE HEAT EXCHANGER FROM CENTERLINE TO
C          CENTERLINE (IN)
185  C      YFPP1 - PLANT SCALING FACTOR TO TAKE INTO ACCOUNT FOR PUMP
C          AND FAN POWER
C
C      LOGICAL FXTLNG
C      LOGICAL NEGV
190  C      LOGICAL FIRST, FXTMP
C      COMMON
C      $ AFTR, ALPHA, ANG(3)
C      $ ,CAPF, CSGPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
195  C      $ ,CRU, CTURB, CDANG, CLUVR, CHAILE, CVM
C      $ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELY
C      $ ,EFFP
C      $ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
C      $ ,GREFF
C      $ ,HXNP, HPCST
200  C      $ ,ITMAX, ITMIN
C      $ ,JCONS
C      $ ,KCONV, KALEXT
C      $ ,MXEXT
C      $ ,NTUCAL(2), NTA
205  C      COMMON
C      $ ,ODR
C      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
C      $ ,POHRAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
C      $ ,RAP, REDUCE, REDUCV, ROOFLI
210  C      $ ,QREU, QREDUCE, QREDUCV
C      $ ,SIGMAG, SAAF
C      $ ,TD, TPO(4), TEFF, TLIM, THEIN, TLPRA, TFIX
C      $ ,TCD, TW
C      $ ,UCS, UWS
215  C      $ ,WCV
C      $ ,VAS(5)
C      $ ,XDEPA, XW, XD
C      COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
C      $ QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
220  C      $ FPOW, 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      $ BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
C      $ , TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
225  C      $ , CLTC, CFC, CPOC, FITC, CSC, CEPREP, DELPIP, AST, OLDGST
C      $ ,CAPCST, XNFAN, BLDANG, CLEN, DPEEL, WHX, WYTUB, ADIA, ABLN
C      $ , WYHDR, WYFRM, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU
C      $ , AIRFF, WATFF, XNMOD, TOTPF, FDCPF, FMTRC, ACCTTP, ADJTP

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230      S, ACTB=D, ADURPD, ACTVH, ADJUH, ADUPPF, THPAIR, TCTF, AFCST
      S, CSRD, WATERW, WSTRCT, CFOJND, HUBDIA, TOWLEN, NUMTOW, CTOWD
      S, SQRJ, SQRJS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR
      S, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
      COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOST, W31, COSM1, EFF1,
235      S, SIM1, CLAN1, REAIL, 71, HRFAC2, W41, H1, DEPW1, PPW1,
      S, FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, HT1, H01, T41,
      S, REWAL, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPRP, SW41, SW31,
      S, SPC1, PTOT1, PLNCB1, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
      S, BP2MIN, VW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
240      S, TL1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CAL, CS1
      S, CLTC1, CFC1, CPCC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLDCS1
      S, CAPCS1, XNFAN1, BLDAN1, CPLEN1, DPFE1, WH1, WTTU1, ADI1, ASL1
      S, WTHD1, WTR1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1
      S, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACTTP1, ADJTP1
245      S, ACTH1, ADURP1, ACTVH1, ADJUH1, ADUPP1, THPA1, TCTF1, AFCST1
      S, CSRD1, WATER1, WSTRC1, CFOJN1, HUBD1, TOWLE1, NUMTOW1, CTOWD1
      S, SQRJ1, SQRJS1, ATUBC1, CBA1, TTD1, TTD2, DELPS1, CSTLV1
      S, CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPC1, RPTPL1, SEPC1
      COMMON /SCALR/ HRFAC1, ATUB, CPRA, SSCD, PLANC1, CASSS1,
250      S, GAIR, FAIR, HPAIR, HPWAT, WLRT, PLANC1
      COMMON /LACALL/ SRN
      COMMON /ESCAL/ RSECF
      COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2QE, LINOR, XNP, XQUALY
      COMMON /TUBE/ KGA, LD, TID(7,6)
      COMMON /PLCOST/ WPL
255      COMMON /PME/ PMELEC
      COMMON /FLSW/ FXTLNG
      COMMON /HEADEX/ CHH, CN, CHM, CHW, CRJ, CWJ, CST, CMO, CSR, CSM, PITCHF, CPM,
      IPRESS, HEDMAT, HEDTYP, NPASS, WB
      LOGICAL LOOPER
260      COMMON /FAN/ FANDAP(153,10), FANDAH(153,10), FMCPF, FRCPF, P2, R, S,
      S, VELREC, AFC, ELEV, EHR, LOOPER, CTMAX
      DATA NEGVAL, FALSE, /
265      901 FORMAT(1X, A10, 'T1, RANGE, CWARA, AFROV, WLRAT', 5G14.4)
      NAMELIST /DBNL/ FLOSS, AFROV, VA, W4, THITE, TD, T4, CWARA, RANGE
      XTOW = ITOWN

      C
      C      SCALING FACTOR FROM POINT 1 TO POINT 2 TO ACCOUNT FOR CHANGE
      C      IN HEAT RATE FACTOR
      C
270      HRF21=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)
275      PSIZ12=PSIZE*HRF21

      C
      C      PLANT COSTS AT DESIGN CONDITIONS (POINT 2) WHICH INCLUDE
      C      STEAM SUPPLY AND BACK PRESSURE SCALING TO POINT 2
280      PLANC2=PLANC1 * HRF21

      C
      C      INCREMENTAL COST OF SCALING UP PLANT DUE TO INCREASED HEAT
      C      RATE FACTOR
285

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      SP3P=(PLANC2-PLANC)*PSIZE*1.E+3
      C
      C      SCALING FACTOR FOR SCALING PLANT SIZE TO MEET PUMP AND FAN
      C      POWER REQUIREMENTS
290      C
      IF(PSIZE*1000.-PPOW-FPOW.LE.0.0) KCONV=1
      IF(KCONV.EQ.1) RETURN
      YFP=(PSIZE*1.E+3)/(PSIZE*1.E+3-PPOW-FPOW)-1.0
      C
295      C      POWER OUTPUT OF THE TURBINE GENERATOR AT THE RATED
      C      BACK PRESSURE (POINT 1) WHICH MEETS THE POWER REQUIREMENTS OF
      C      THE FANS AND PUMPS (POINT 3) AND THE POWER OUTPUT OF THE
      C      PLANT AT THE DESIGN BACK PRESSURE (POINT 2)
      C
300      C      PSIZ13=(1.+YFP)*PSIZ12
      C
      C      TOTAL POWER OUTPUT OF THE PLANT AT POINT 3
      C
      PTOTAL = PSIZE * (1.+YFP)
305      C
      C      PLANT COST AT POINT 3 EXCLUDING THE DRY COOLING TOWER COST
      C
      PLANC3=PLANC2*(1.+YFP)
      SPC=PLANC3*PSIZE*1.E+3
310      C
      C      INCREMENTAL COST OF PLANT DUE TO DRY COOLING TOWERS
      C
      SPCD = (PLANC3-PLANC) * PSIZE * 1000.
      C
315      C      SCALING UP THE DRY COOLING TOWER DIMENSIONS AND THE COSTS
      C      ASSOCIATED WITH IT
      C
      C      INDEPENDENT PARAMETERS OF THE DRY COOLING TOWER
      C
320      C      YFPP1=YFP + 1.
      C      SW3=H3*YFPP1
      C      SW4=H4*YFPP1
      C      SAFFON=AFRON*YFPP1
      C      SWLRAT=WLRRAT * YFPP1
325      C
      C      SURFACE CONDENSER DIMENSIONS AND COSTS
      C
      ISUR = 1
      CALL SURCON(ISUR, KGA, LD, TLA, XNTS, ARPS, XNS, CONBAS, CONMAT
330      C      ,PONGMO)
      C      XNTS = XNTS*YFPP1
      C      CONBAS = CONBAS*YFPP1
      C
      C      SCALE THE NUMBER OF TUBES IN WIDTH AND THE WIDTH OF THE
      C      HEAT EXCHANGER
335      C
      IF(FXILNG) WIDTH=SAFRON/FIXL
      IF(.NOT.FXILNG) WIDTH=SQRT(SWLRAT*SAFRON)
      TOTLEN = WIDTH / (XTOW*2.)
      NW=WIDTH/XW*12.
340      C
      C      CHECK ON THE EXIT TEMPERATURE OF THE AIR LEAVING THE HEAT

```

```

      C      EXCHANGER
      C
345      T4 = RANGE + TD
      VA=53.35*(TD+460.)/(15.*144.)
      IF(FLOSS.LT.0.0) NEGV=.TRUE.
      IF(SAFCON.LT.0.0) NEGV=.TRUE.
      IF(VA.LT.0.0) NEGV=.TRUE.
350      IF(SW4.LT.0.0) NEGV=.TRUE.
      IF(THITE.LT.0.0) NEGV=.TRUE.
      IF(NEGV) WRITE(6,0BNL)
      IF(NEGV) STOP
      41 CONTINUE
365      UNSHFA=HFAIR
      UNSNFA=XNFAN
      C
      C      FAN AND PUMP POWER
      C
360      FPOW=FPOW * YFPP1
      PPOW=PPOW * YFPP1
      FPPOW = PPOW + FPOW
      HPWAT=HPWAT * YFPP1
      HPAIR= HPAIR * YFPP1
365      FPHP=HPWAT + HPAIR
      XNFAN=XNFAN*YFPP1
      C
      C      FAN BLADE COSTS
      C
370      FBACC=FBOPF*XNFAN
      FMCST=FBACC+FMOST
      C
      C      THE NUMBER OF FANS AND THE MOTOR, BLADE, AND ELECTRICAL
      C      WIRING COSTS OF THE FAN SYSTEM
375      C
      FMCST=XNFAN*FMOPF
      CFANEL = CFANEL * YFPP1
      C
      C      ELECTRICAL WIRING OF THE PIPING SYSTEM
380      C
      PMELEC = PMELEC * YFPP1
      C
      C      DIMENSIONS AND WEIGHT OF THE HEAT EXCHANGER
      C
385      ATUBC = (CA + CH + CS) * BSECF
      ATUBC = ATUBC*YFPP1
      AATR=AAIR * YFPP1
      WHX=WHX*YFPP1
      WTTUB=WTTUB*YFPP1
390      WTHOR=WTHOR*YFPP1
      WTERW=WTERW*YFPP1
      WATERW = WATERW * YFPP1
      C
      C      INCREASED FUEL COST OF THE PLANT
395      C
      C
      C      FUEL COST, FOR THE BASE PLANT WITH A CONVENTIONAL TURBINE
      C      OPERATING AT WATER BACK PRESSURE
      C

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```

400      FCR7= FCOS * 3413.1-5 / TEFF
      C
      C      INCREASED FUEL COST FOR THE SCALED UP PLANT
      C
410      FCOS = FCOS * 3413.1-5*(HPEAC2/TEFF) * (1.+YFP)
      C
415      DELFC= FCOS-FCR7
      C
      C      LAND AND PIPING COSTS
      C
      TEDIA=TEDIA * (1. + YFP)
      CLAND = COSTL*SAFROM
      SEPCST = (6.3971 * W3/60. - 140264.71) / 1000.
      SEPCST = SEPCST * FOMCIR
      TCWFCS = TCWFCS + SEPCST * RPIPL
      CPIP = TCWFCS * YFPP1 * 1000.
415      C
      C      TOWER DIAMETERS
      C
      CTOWD = CTOWD * YFPP1
      C
420      C      PLENUM SIZE AND COSTS
      C
      CPLFN = CPM * WPL * (ITOWN * 3.14159/4. * CTOWD**2
      & - XNFAN * 3.14159/4. * (ADIA+3.5)**2)
      CPLEN = CPLFN * POHSTC
425      C
      C      STRUCTURE AND FOUNDATION COSTS
      C
      CALL STRUCT(CTOWD, WHX, WATERPW, ROOFL, STRUCC, CFOUND, HSTRCT,
      & NUMTOW, ELENG, POHSTC)
430      CFOUND = POHSTC * CFOUND
      C
      C      LOUVER AND HAIL SCREEN COSTS
      C
      HSLVA = CTOWD * NUMTOW * 3.14159 * ELENG
      CSTLVR = CLUVR * HSLVA * POHSCL
      CSTHS = CHAILS * HSLVA * POHSCL
435      C
      C      TOTAL COST OF DRY COOLING TOWER
      C
440      C
      CCOS = FBACC + ATU3C + FMCST + CPLEN + STRUCC + CFOUND
      & + CSTLVR + CSTHS + CFANEL*XNFAN/YFPP1 + CYLNG*XNFAN
      C
      C      MAINTENANCE COST OF THE DRY COOLING TOWERS
      C
445      C
      COSM = PER * (CCOS + CPIP + CONBAS) / (PSIZE*CAPF*8760.)
      C
      C      INCREMENTAL COST OF DRY COOLING TOWER (NOT USED IN
      C      OPTIMIZATION)
      C
450      C
      OLDOST= (CCOS+SPCH+CLAND+CPIP+CONBAS)*FCO/(PSIZE*CAPF*8760.)
      & + COSM+ DELFC
      C
      RETURN
      C
      END

```

SUBROUTINE SERCH

THIS ROUTINE SEEKS MINIMUM BY SINGLE VARIABLE SEARCH METHOD

LOGICAL FXTLNG

COMMON /LACALL/ SRN

DIMENSION C(5)

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

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

\$ FPOW, DEFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,

\$ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,

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

\$ RP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX

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

\$, CLTC, CFC, CPOC, FITC, CSC, CEPREP, DELPIP, AST, OLDGST

\$, CAPCST, XNFAN, BLDANG, CLEN, DPFEI, WHX, WTTUB, ADIA, ABLV

\$, WTHDR, WTRFM, STRUCC, CFPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU

\$, AIRFF, WATFF, XNMOD, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP

\$, ACTBPD, ADJBPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST

\$, CSRD, WATERW, WSTRCT, CFOJND, HUBDIA, TOWLEN, NUMTOW, CTOWD

\$, SQRJ, SQRUS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR

\$, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMOST, RPTPL, SEPCST

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

\$ QIN1, CLAN1, REA11, Z1, HRFAC2S, W41, U1, DEPW1, PPOW1,

\$ FPOW1, DEFC1, WIDTH1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,

\$ REWAT1, NW1, NT1, NP1, PLANC2, PSIZ12, ZSPBP, SW41, SW31,

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

\$ BP2MIN, NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELO1

\$, TLAX1, UCON1, PMOS1, FMOS1, FBACC1, EFFC1, CH1, CA1, CS1

\$, CLTC1, CFC1, CPOC1, FITC1, CSC1, CEPRE1, DELPIP1, AST1, OLDGST1

\$, CAPCST1, XNFAN1, BLDANG1, CLEN1, DPFEI1, WH1, WTTU1, ADI1, ABL1

\$, WTHD1, WTRF1, STRUC1, CFMPF1, HSPF1, TOTCF1, TPI, EFFIN1, ANTU1

\$, AIRFF1, WATFF1, XNMOD1, TCTPF1, FDCPF1, FMTRC1, ACCTP1, ADJTP1

\$, ACTBPD1, ADJBPD1, ACTVH1, ADJVH1, ADJPP1, THPA11, TCTF1, AFCST1

\$, CSRD1, WATER1, WSTRC1, CFOJN1, HUBD11, TOWLE1, NUMT01, CTOWD1

\$, SQRJ1, SQRUS1, ATUBC1, CBA1, TTD11, TTD21, DELPS1, CSTLV1

\$, CSTHS1, CYLRN1, CFANEL1, PSTAC1, PUFIT1, PMOST1, RPTPL1, SEPCST1

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

\$ GAIR, FAIR, HPAIR, HPWAT, WLRTF, PLANC1

LOGICAL FIRST, FXTMP

COMMON

\$ AFTR, ALPHA, ANG(3)

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

\$, CBJ, CTURB, CDANG, CLUVR, CHAILE, CVM

\$, DANGLE, OFIN, DEEPL, DESVEL, DESVELV

\$, EFFP

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

\$, GREFF

\$, HXUP, HPCST

\$, ITMAX, ITMIN

\$, JCON

\$, KCONV, KALEXT

\$, MXEXT

\$, NTUCAL(2), NTA

COMMON

\$ ODR

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

```

      $ ,POHRAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLC
      $ , REP, REDUCE, REDUCV, ROOFLL
60      $ , QREJ, QREDUCE, QREDUCV
      $ , SIGMAG, SAAF
      $ , TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
      $ , TCD, TW
      $ , UCS, UWS
65      $ , WFW
      $ , VAS(5)
      $ , XDEPA, XW, XD
      COMMON /FLSW/ FXTLNG
      COMMON /TIVE/ XNS, TLA, XNTS, ARPS, TTD2QE, LINOR, XNP, XQUALY
70      DO 50 IVAL=1,5
50      VAL(IVAL)=VAR(IVAL)
      SRN="/SERCH-1/ "
      CALLI CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),1)
      CALLI STORE
75      C(1)=5.
      C(2)=1.
      C(3)=1.
      C(4)=CAF
      C(5)=50.
80      IB=1
      IF(FXTLNG) IB=2
      DO 8, I=IB,5
      M=6-I
      K=3
85      DO 9 IK=1,5
9      VAL(IK)=VAR(IK)
      KC=0
      J=0
      2 VAL(M)=VAR(M)+C(M)
90      IF(FXT=MP) VAL(1) = TFIX
      IF(M.GT.3) GO TO 10
      IF(VAL(1).GT.170.) GO TO 4
10      SRN="/SERCH-2/ "
      CALLI CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
95      IF(KCONV.EQ.1) GO TO 4
      IF(DELPA.LE.XDEPA) GO TO 3
      IF(TCOS.GE.TCOS1) GO TO 4
      J=1
      CALLI STORE
100      GO TO 2
      3 IF(K.EQ.1) KC=1
      4 IF(J.EQ.1) GO TO 7
      5 VAL(M)=VAR(M)-C(M)
105      IF(FXT=MP) VAL(1) = TFIX
      IF(VAL(M).LE.0.0) GO TO 7
      SRN="/SERCH-3/ "
      CALLI CALC(VAL(1),VAL(2),VAL(3),VAL(4),VAL(5),M)
      IF(KCONV.EQ.1) GO TO 7
      IF(DELPA.LE.XDEPA) GO TO 6
110      IF(TCOS.GE.TCOS1) GO TO 7
      CALLI STORE
      KC=0
      GO TO 5
      6 IF(K.EQ.1) KC=1

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SUBROUTINE SERCH

74/74 OPT=1

FTN 4.2+74351

12/18/66

```
115      7 IF(KC.EQ.1) CALL CHNGE(M)
          K=K-1
          IF(K.EQ.0) GO TO 9
          C(M)=C(M)/5.
          GO TO 1
120      8 CONTINUE
          RETURN
          END
```

SUBROUTINE SETUP(TSTAR,TEND)

THIS ROUTINE READS ALL INPUT DATA FOR THE RUN AND PRINTS EACH
VALUE READ

INPUT DESCRIPTION
FOR BNWL METAL FIN ROUND DCT AMMONIA
D E C E M B E R 1 0 1 9 7 6

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

CARD	TYPE	COLUMNS	FORMAT	NAME OF VARIABLE	DESCRIPTION AND (UNITS)
A1	1-80	(8A10)	DESCR(I) 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	1-80	BLANK IN ALL COLUMNS. ONE TYPE A2 CARD ONLY			
B1	1-10	(E10.0,	TSTAR	R	LOWEST DESIGN TEMPERATURE TO USE (DEGREES F)
	11-20	E10.0,	TEND	R	HIGHEST DESIGN TEMPERATURE TO USE (DEGREES F)
	21-30	E10.0,	VAS(1)	R	INITIAL VALUE FOR TURBINE OUTLET TEMPERATURE (DEGREES F)
	31-40	E10.0,	VAS(3)	R	INITIAL VALUE FOR TTD1, TERMINAL TEMPERATURE DIFFERENCE (DEGREES F)
	41-50	E10.0,	VAS(4)	R	INITIAL VALUE FOR AFRON, AIR SIDE FRONTAL AREA (SQ FT)
	51-60	E10.0,	VAS(5)	R	INITIAL VALUE FOR WLRAT, RATIO OF HEAT EXCHANGER WIDTH/LENGTH (DF)
	61-70	E10.0,	FIXL	R	LENGTH OF HEAT EXCHANGER (FT). IF THE ABSOLUTE VALUE OF FIXL=0. THEN THE PROGRAM WILL CALCULATE THE LENGTH.

```

60      C      71-75   F5.0,   DEEPL   R  LIMITING VALUE FOR NUMBER OF TUBES
      C      IN DEPTH FOR HEAT EXCHANGER.
      C      (NUMBER OF TUBES)
      C
      C      IF THE ABSOLUTE VALUE OF DEEPL = 0.0
      C      THEN THE PROGRAM WILL COMPUTE THE
      C      DEPTH WITH NO CONSTRAINTS
65
      C
      C      IF POMDPL IS BLANK OR ZERO THEN A
      C      POSITIVE VALUE FOR DEEPL IMPLIES A
      C      CONSTRAINT OF EQUAL TO OR GREATER
70      C      THAN DEEPL, WHILE A NEGATIVE VALUE
      C      FOR DEEPL IMPLIES A CONSTRAINT OF
      C      EQUAL TO OR LESS THAN DEEPL.
      C
      C      75-80   F5.0)   POMDPL   R  TOLERANCE ON DEEPL. NOTE THAT A ZERO
75      C      OR BLANK IS NOT INTERPRETED AS ZERO
      C      TOLERANCE. (SEE DEFINITION OF DEEPL)
      C
      C.....
      C.....
80      C
      C      C1      1-40   (BF5.0,   TA(I)   R  TEMPERATURES REPRESENTATIVE OF
      C      TPER(I) FRACTION OF YEAR (DEGREES F)
      C
      C      41-80   BF5.0)   TPER(I)   R  FRACTION OF YEAR OVER WHICH TEMPERA-
85      C      TURE TA(I) IS TYPICAL. (OF)
      C      C A U T I O N - HIGHEST TA
      C      MUST BE FIRST
      C
      C.....
90      C
      C      C2      1-40   (BF5.0,   TA(I)   R  CONTINUATION OF TA(I) FOR I= 9 TO 16
      C
      C      41-80   BF5.0)   TPER(I)   R  CONTINUATION OF TPER(I)
95      C
      C      NOTE - A TYPE C2 CARD IS REQUIRED EVEN IF BLANK.
      C
      C.....
      C.....
100     C      D1      4-10   (E10.0,   PSIZE   R  BASE PLANT SIZE (MEGAWATTS)
      C
      C      11-20   E10.0,   TEFF   R  BASE THERMAL EFFICIENCY (OF)
      C
      C      21-30   E10.0,   CAPF   R  CAPACITY FACTOR (OF)
      C
105     C      31-40   E10.0,   FCR   R  FIXED CHARGE RATE (OF)
      C
      C      41-50   E10.0,   PER   R  RATIO MAINTENANCE COST TO CAPITAL
      C      COST (OF)
      C
110     C      51-60   E10.0,   CCM   R  CONSTRUCTION COST MULTIPLIER (OF)
      C
      C      61-70   E10.0,   ELEV   R  SITE ELEVATION ABOVE SEA LEVEL (FT)
      C
      C      71-80   E10.0)   ROOFL   R  ROOF LOAD (LB/SQ FT)

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115      C
      C .....
      C .....
      C
120      C E1    1-10  (E10.0, FCOS   R FUEL COST (CENTS/MMBTU)
      C      11-20  E10.0, PWCOS   R REPLACEMENT POWER COST (MILLS/KWH)
      C      21-30  E10.0, PLANC   R POWER PLANT CONSTRUCTION COST ($/KW)
125      C      31-40  E10.0, COSTL  R COST OF LAND ($/SQ FT)
      C      41-50  E10.0, CSSPKW  R COST OF STEAM SUPPLY ($/KW)
      C      51-60  E10.0, CAPCHG  R CAPACITY CHARGE ($/MEGAWATT)
130      C      61-70  E10.0, HPCST  R COST OF ELECTRIC MOTORS ($/HP)
      C      71-80  E10.0, CTURB   R ADDITIONAL TURBINE COST BECAUSE OF
      C                               NUCLEAR POWER PLANT ($/KW)
135      C
      C .....
      C
140      C E2    1-10  (E10.0, POHBAF R INDIRECT COST FACTORS FOR -
      C                               BUNDLE ASSEMBLY AND FRAME
      C      11-20  E10.0, POHFAN  R FANS
      C      21-30  E10.0, POHLEC  R ELECTRICAL
145      C      31-40  E10.0, POHCIR R CIRCULATION PIPING
      C      41-50  E10.0, POHCND  R CONDENSER
150      C      51-60  E10.0, POHSTC R STRUCTURE
      C      61-70  E10.0, POHSCL  R SCREENS AND LOUVERS
      C
      C .....
155      C F1    1-10  (F10.0, RBP    R TURBINE RATING BACK PRESSURE (INCHES
      C                               OF MERCURY)
      C      11-70  4-15.8) TPU(1)  R COEFFICIENTS FOR THIRD ORDER POLY-
160      C                               NOMIAL FOR HEAT RATE AS A FUNCTION
      C                               OF TURBINE BACK PRESSURE.
      C .....
      C .....
165      C G1    1-10  E10.0  EFFP   R EFFICIENCY OF PUMPS (DF)
      C .....
      C .....
170      C H1    1-10  (E10.0, VELREC R CONTROL VARIABLE.

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74/74. OPT=1

FTN 4.2+74351

12/18/76

					=1 FOR VELOCITY RECOVERY	
					=0 FOR NO VELOCITY RECOVERY	
775		11-20	E10.0,	XDEPA	R	MINIMUM AIR SIDE PRESSURE DROP THRU HEAT EXCHANGER (LB FORCE/SQ FT)
		21-30	E10.0,	TLIM	R	MAXIMUM STEAM TEMPERATURE FOR THE TURBINE (DEGREES F). ASSUMED 180 IF FIELD IS BLANK OR 0.
780		31-40	E10.0,	TOWMIN	R	THE MINIMUM ALLOWABLE NUMBER OF TOWERS PER GROUP. ASSUMED 1 IF NOT SPECIFIED
785		41-50	E10.0,	PFACT	R	PACKING FACTOR, RATIO OF CIRCULAR TOWER ROOF AREA TO FAN SWEEP AREA (DF)
790		51-60	E10.0,	TFIX	R	FIXED TURBINE OUTLET TEMPERATURE (F) ENTRY IS IGNORED IF BLANK OR ZERO
795		61-70	E10.0)	TOWMAX	R	THE MAXIMUM ALLOWABLE NUMBER OF TOWERS PER GROUP. ASSUMED 9999 IF NOT SPECIFIED.
800	H2	1-10	E10.0	GBEFF	R	FAN GEARBOX EFFICIENCY
805	I1	1-10	(E10.0,	CPM	R	PLENUM COST (\$/LB)
		11-20	E10.0,	WPL	R	WEIGHT OF PLENUM MATERIAL (LB/SQ FT)
		21-30	E10.0,	CLUVR	R	COST OF LOUVERS (\$/SQ FT)
810		31-40	E10.0,	CHAILS	R	COST OF HAIL SCREENS (\$/SQ FT)
		41-50	E10.0,	UCS	R	UNIT COST OF STACK \$/LB
815		51-60	E10.0,	UWS	R	UNIT WT OF STACK LB/CU FT
		61-70	E10.0,	CVM	R	FAN RING MATERIAL UNIT COST \$/LB
		71-80	E10.0)	WVY	R	UNIT WT OF STRAIGHT CYLINDER LB/SQ FT
820						
825	J1	1-20	(2A10,	NTUCAL	I	CONTROL VARIABLE FOR SPECIFYING THE METHOD TO BE USED TO CALCULATE NTU. NTUCAL MUST BEGIN IN COLUMN 1. CROSS FLOW COUNTER FLOW

TABLE

230

CROSS FLOW OR COUNTER FLOW CAUSES
CALCULATION OF NTU BY EQUATIONS.
TABLE CAUSES TABLE LOOKUP OF NTU.

235

21-30 F10.0, HXNP R NUMBER OF PASSES THRU HEAT EXCHANGER

31-40 F10.0, WB R HEADER LENGTH (FEET)

41-50 F10.0, NTUB R NUMBER OF TUBES THRU PLATE FINS

240

51-60 F10.0, SS R SUPPORT SPACING (FT)

61-70 F10.0, ANGLE R HEAT EXCHANGER ANGLE (DEGREES)

245

C.....

J2 1-10 (F10.0, DESVEL R DESIGN VELOCITY (LIQUID) FOR PIPING
(FT/SEC)

250

11-20 F10.0, REDUCE R MINIMUM STEP CHANGE IN PIPE DIAMETER
FOR LIQUID PHASE TOWER PIPING (INCH-
ES)
MAY BE 6, 12, OR 18

255

21-30 F10.0, QREDUCE R MINIMUM STEP CHANGE IN PIPE DIAMETER
FOR LIQUID PHASE QUADRANT HEADERING
(INCHES)
MAY BE 6, 12, OR 18

260

31-40 F10.0, DIST R DISTANCE FROM TOWER TO CONDENSER
ROOM (FT)

C.....

265

J3 1-10 (F10.0, DESVELV R DESIGN VELOCITY (VAPOR) FOR PIPING.
(FT/SEC)

11-20 F10.0, REDUCEV R MINIMUM STEP CHANGE IN PIPE DIAMETER
FOR VAPOR PHASE TOWER PIPING
(INCHES)
MAY BE 6, 12, OR 18

270

21-30 F10.0, QREDUCV R MINIMUM STEP CHANGE IN PIPE DIAMETER
FOR VAPOR PHASE QUADRANT HEADERING
(INCHES)
MAY BE 6, 12, OR 18

275

C.....

280

C.....

K1 1-10 (E10.0, XW R TUBE TRANSVERSE PITCH (NORMAL TO AIR
FLOW) (INCHES)

285

11-20 E10.0, XD R TUBE PITCH IN DIRECTION OF AIR FLOW

74/74. OPT=1

FTN 4,2+74351

12/18/76

LINE NO.	ITEM NO.	DESCRIPTION	UNIT	REMARKS
	21-30	E10.0, XDG	R	TUBE DIAGONAL PITCH (INCHES)
290	31-40	E10.0, SF	R	FIN SPACING (INCHES)
	41-50	E10.0, DFIN	R	FIN DIAMETER (INCHES)
295	51-60	E10.0, THFIN	R	FIN THICKNESS (INCHES)
	61-70	E10.0, DANGLE	R	BASE ANGLE FOR DELTA HEAT EXCHANGER (DEGREES)
300	L1	1-10 (F10.0, ODL)	R	HX LINER OUTSIDE DIAMETER (INCHES)
	11-20	F10.0, DI	R	HX LINER INSIDE DIAMETER (INCHES)
305	21-30	F10.0, GAGLIN	R	GAGE OF HX LINER TUBE (MAY BE 22, 20, 19, 18, 17, 16, 15, 14.5, 14, 13, 12, 11, 10)
310	31-50	2A10, TUBMAT, XTUBMA	R	LINER MATERIAL. MUST BEGIN IN COL 3
315				MAY BE - ADMIRALTY, COPPER, CU-10 NI, CU-30 NI, ALUMINUM, STEEL WELDED, STEEL SEAMLESS, WELDED SST
320	51-60	F10.0, CONL	R	THERMAL CONDUCTIVITY OF LINER MATERIAL (BTU/(HR SQFT DEG F/ FT))
325	M1	1-20 (2A10, FINTYP, XFINTY)	R	TYPE OF FIN. MUST START IN COLUMN 1.
330				MAY BE - STRAIGHT FIN, SINGLE FOOT, DOUBLE FOOT, EMBEDDED, EXTRUDED, PLATE, NO LINER
335				IF NO LINER THEN FIN MATERIAL MUST BE ALUMINUM
340	21-30	A10, FINMAT	R	FIN MATERIAL. MUST START IN COL. 21

74/74 OPT=1

FTN 4,2074351

12/18/76

LINE NO.	ITEM NO.	QTY	UNIT	DESCRIPTION	REMARKS
345					MAY BE - ALUMINUM STEEL
350	31-40	F10.0)	CONF	R	THERMAL CONDUCTIVITY OF FIN MATERIAL (BTU/(HR SQFT DEG F/FT))
	N1	1-10	(E10.0,	CFB	R FIN BONDING COST (\$/SQ FT)
355		11-20	E10.0,	COATC	R FIN PROTECTIVE COATING COST (\$/SQFT)
		21-30	E10.0,	ZINCC	R ZINC COST FOR SPACERS (\$/LB)
360		31-40	E10.0,	CASC	R FIXED CASTING COST FOR SPACERS (\$/SPACER)
		41-50	E10.0)	EPREPC	R END PREPARATION COST (\$/TUBE)
365					
	P1	1-20	(2A10,	HEDTYP, XHEDTY	R HEADER TYPE. MUST START IN COLUMN 1.
370					MAY BE - WELD REMOVABLE WELD PLUG FORM REMOVABLE FORM PLUG
375		21-30	A10,	HEDMAT	R HEADER MATERIAL. MUST START IN COLUMN 21. MAY BE - ALUMINUM STEEL
380		31-40	F10.0)	TW	R THICKNESS OF HEADER MATERIAL (INCHES)
385					
	Q1	1-10	(E10.0,	CRJ	R COST OF ROLLED JOINT, TUBE TO HEADER (\$/TUBE)
390		11-20	E10.0,	CWJ	R COST OF WELDED JOINT, TUBE TO HEADER (\$/TUBE)
		21-30	E10.0,	CHH	R TUBE AND PLUG HOLE PREPARATION COST (\$/HOLE)
395		31-40	E10.0,	CN	R NOZZEL AND ATTACHING COST (\$/HOLE)
		41-50	E10.0,	CMW	R COST OF HEADER MACHINING AND WELDING (\$/FT)

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400      C      51-60  E10.0,  CST  R  STRUCTURAL STEEL COST ($/LB)
      C
      C      61-70  E10.0)  CBJ  R  COST OF BOLTED HEADER JOINT ($/FT)
      C
405      C.....
      C.....
      C  R1      1-10  (E10.0,  XNS  R  NUMBER OF CONDENSER SHELLS
      C
410      C      11-20  E10.0,  VELN  R  NOMINAL DESIGN VELOCITY THRU CONDENSER
      C      TUBES (FT/SEC)
      C
      C      21-30  E10.0,  ODC  R  CONDENSER TUBE O.D. (INCHES)
      C
415      C      31-40  E10.0,  GA  R  CONDENSER TUBE WALL GAGE. MAY BE
      C      12, 14, 16, 18, 20, 22, 24.
      C
      C      41-50  E10.0,  TKCT  R  THERMAL CONDUCTIVITY OF CONDENSER
      C      TUBING
420      C      (BTU/(HR SQFT DEG F/FT))
      C
      C      51-60  E10.0,  TTD2GE  R  TERMINAL TEMPERATURE DIFFERENCE
      C      ESTIMATE
425      C      (DEGREES F)
      C
      C      61-80  2A10)  CONMAT, R  CONDENSER TUBING MATERIAL. MUST START IN
      C      CONMA2  R  COLUMN 61. MAY BE
      C
      C      ADMIRALTY
      C      CU-10 NI
      C      304 S/S WELDED
430      C.....
      C
435      C  R2      1-10  (E10.0,  XNP  R  NUMBER OF PASSES THRU CONDENSER
      C
      C      11-2  E10.0,  TLA  R  CONDENSER TUBING LENGTH (FEET)
      C
440      C      21-3  E10.0)  XQUALY  R  AMMONIA VAPOR QUALITY OUT OF
      C      CONDENSER.
      C
      C.....
445      C  R3      1-5  (15)  LINOR  R  CONTROL VARIABLE
      C      =1 FOR LINDE TUBING
      C      =0 FOR BARE TUBES
      C
      C.....
450      C
      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      TABLE OF FANS. DEFAULT VALUES ARE
      C      LFB=1 AND LFE=153
455      C
      C      -----

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SUBROUTINE SETUP

74/74 OPT=1

FTN 4,2+74351

12/18/76

[illegible]

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COMMON /FNLOOP/ LFB, LFE
COMMON /PLCOST/ WPL
LOGICAL FXTLNG
DIMENSION DESCR(4)
LOGICAL FIRST, FXTMP
COMMON
515 $ AFTR, ALPHA, ANG(3)
$ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP
$ ,CBU, CTURB, CDANG, CLUYR, CHAILE, CVM
$ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
$ ,EFFP
525 $ ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
$ ,GREFF
$ ,HXNP, HPCST
$ ,ITMAX, ITMIN
$ ,JCONS
530 $ ,KCONV, KALEXT
$ ,MXEXT
$ ,NTUCAL(2), NTA
COMMON
$ ODR
535 $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
$ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSLI
$ ,RBP, REDUCE, REDUCV, ROOFLI
$ ,QREJ, QREDUCE, QREDUCV
$ ,SIGMAG, SAAF
540 $ ,TD, TPO(2), TEFF, TLIN, THEIN, TLPRA, TFIX
$ ,TCD, TW
$ ,UCS, UWS
$ ,WFM
$ ,VAS(5)
545 $ ,XDEP, XW, XD
COMMON /SUPPLY/ VAL(5), CPLV, CPIP, CCOS, W3, COSM, EFF,
$ QIN, CLAND, REAIR, Z, HRFACR, W4, U, DELPW, PPOW,
$ FPOW, DELFC, WIDTH, ELENG, VAIR, VBAT, HI, HO, T4,
$ FEWAT, NW, NT, NO, PLANC2, PSIZ12, SPBP, SW4, SW3,
550 $ SPC, PTOTAL, PLANC3, SAFROV, AAIR, YFP, SPCD, PSIZ13, WT2,
$ BP2, VW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELOX
$ , TLAX, UCON, PMCST, FMCST, FRACC, EFFC, CH, CA, CS
$ , CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPIP, AST, OLD CST
$ , CAPCST, XNFAN, BLDANG, CPLEN, DPFEI, WHX, WTTUB, ADIA, ABLN
555 $ , WTHOR, WTERM, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU
$ , AIRFF, WATFF, XNMOD, TOTPF, FDCPF, FMTRC, ACCITP, ADJTP
$ , ACTROD, ADJBPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
$ , CSRD, WATERW, WSTRCT, CROUND, HUBDIA, TOWLEN, NUMTOR, CTOWD
$ , SORU, SORUS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLYR
560 $ , CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
COMMON /VARVAR/ TPER(15), TA(15)
COMMON /FAN/ FANDAR(153,10), FANDAH(153,10), FMCPP, FBCPP, P2, R, S,
$ VELREC, AFC, ELEV, EHR
DATA BLANK/" "
565 C SURFACE CONDENSER TUBE OD AND TUBE GAGE ARRAYS
C
DATA TOD/0.525,0.750,0.975,1.000,1.125,1.250/
DATA TGA/12.,14.,16.,18.,20.,22.,24./
C
570 C CONDENSER TUBE ID AND GPM PER FPS VELOCITY THROUGH TUBE AS A.

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C FUNCTION OF TUBE GAGE AND TUBE OD.

C

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DATA TID/0.407,0.459,0.495,0.527,0.555,0.569,0.581,
575 $ 0.532,0.584,0.620,0.552,0.680,0.694,0.705,
$ 0.657,0.709,0.745,0.777,0.805,0.819,0.831,
$ 0.782,0.834,0.870,0.902,0.930,0.944,0.956,
$ 0.907,0.959,0.995,1.027,1.055,1.069,1.081,
$ 1.032,1.094,1.120,1.152,1.180,1.194,1.206/
89 FORMAT("0 INPUT ERROR. THE SUM OF THE TPER(I) SHOULD BE 1.0000")
580 6000 FORMAT(1H1//T10,"BNW1 DRY COOLING TOWER COST MODEL --")
$," AMMONIA CIRCULAR TOWER VERSION"
$ ,T90,"THIS RUN MADE ",A10,5X,A10)
5001 FORMAT(2A10)
6001 FORMAT(T21,8A10)
585 5002 FORMAT(8E10.0)
6002 FORMAT(/1X,4G15.8)
5003 FORMAT(16F5.0)
6003 FORMAT(/1X,8F8.1,8F8.4)
5004 FORMAT(F10.0,4F15.8)
590 6004 FORMAT(/1X,F10.2,4G15.8)
5005 FORMAT(2A10,6F10.0)
6005 FORMAT(/1X,2A10,1X,6G15.8)
5006 FORMAT(3F10.0,2A10,F10.0)
6006 FORMAT(/1X,3F10.5,1X,2A10,F10.5)
595 5007 FORMAT(3A10,5F10.0)
6007 FORMAT(/1X,2A10,1X,A10,5G15.8)
5008 FORMAT(8I5)
6008 FORMAT(/1X,8I6)
5009 FORMAT(6E10.0,2A10)
600 6009 FORMAT(/1X,6G15.8,5X,2A10)
5011 FORMAT(7E10.0,2F5.0)
6011 FORMAT(/1X,8G15.8,G10.4)
7060 FORMAT(T5,"TSTAR",T21,"TEND",T35,"VAS(1)",T51,"VAS(3)"
$ ,T56,"VAS(4)",T91,"VAS(5)",T96,"FIXL",T111,"DEEPL",T121,"POMDPL")
605 7090 FORMAT( 4X,"TA(1)",3X"TA(2)",3X"TA(3)",3X"TA(4)",3X"TA(5)"
$ ,3X"TA(6)",3X"TA(7)",3X"TA(8)",1X"TPER(1)",1X"TPER(2)",1X"TPER(3)"
$ ,1X"TPER(4)",1X"TPER(5)",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)")
610 7150 FORMAT(T5,"PSIZE",T23,"TEFF",T39,"CAPF",T54,"FCR",T69,"PER"
$ ,T94,"CCM",T96,"ELEV",T108,"ROOFL")
7180 FORMAT(T5,"FCOS",T23,"PWCOS",T39,"PLANC",T52,"COSTL",T57,"CSSPKW"
$ ,T32,"CAPCHG",T97,"HPCST",T112,"CTURB")
615 7185 FORMAT(T5,"POHSAF",T20,"POHFAV",T35,"POHLEC",T50,"POHCIR",
$ T65,"POHCND",T80,"POHSTC",T95,"POHSCL")
7210 FORMAT(T5,"RBP",T17,"TPO(1)",9X"TP(2)",9X"TP(3)",9X"TP(4)")
7240 FORMAT(T5,"EFP")
7270 FORMAT(T4,"VELREC",T20,"XDEPA",T35,"TLIM",T50,"TOWMIN",T65,"PFACT"
$ ,T90,"TFIX",T105,"TOWMAX")
620 7280 FORMAT(5X,"GFEFF")
7300 FORMAT(T5,"CPM",T20,"WPL",T35,"CLUVR",T50,"CHAILS",T65,"UCS",T80
$ ,T95,"CVM",T110,"WV")
7330 FORMAT(T5,"NTUCAL",T24,"HXNP",T44,"WB",T58,"NTUB",T75,"SS",T90,
625 1"ANGLE")
7335 FORMAT(T5,"DESVEL",T21,"REDUCE",T35,"QREDUCE",T50,"DIST")
7340 FORMAT(T5,"DESVELV",T21,"REDUCV",T35,"QREDUCV")

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7360 FORMAT(5X,"XW",13X,"XD",13X,"XDG",12X,"SF",13X,"DFIN",11X,
$ "THFIN",10X,"DANGLE")
630 7390 FORMAT(5X,"ODL",12X,"DI",03X"GAGL",9X"TUBMA",13X"CONL")
7420 FORMAT(3X"FINTYP",14X"FINMAT",4X"CONF")
7450 FORMAT(5X"CFB",12X"COATC",10X"ZINCC",10X"CASTC",10X,"EPREPC")
7480 FORMAT (T4,"HENTYP", T24,"HEDMAT",T36,"TW")
7510 FORMAT(5X,"CRJ",12X,"CWJ",12X,"CHH",12X,"CN",12X,"CMW",12X,"CST",
$ 12X,"CRJ")
635 7540 FORMAT(5X"XNS",12X"VELN",11X"ODC",12X"GA",10X"TKCT",10X,"TID2GE"
$ ,15X"CONMAT")
7550 FORMAT(5X,"XNP",10X,"TLA",10X,"XQUALY")
7555 FORMAT(3X,"LINCR")
640 7570 FORMAT(T4, "LFR", T11, "LFE", T15, "MXEXT")
7580 FORMAT(5X,"FFHX")
C
$XTLNG=.FALSE.
CALL DATE(DOY)
CALL TIME(HEURE)
645 WRITE(4,6000) DOY,HEURE
C
CARDS A1 - A2
30 READ(5,5001) DESCR
650 DO 35 I=1,8
IF(DESCR(I).NE,SLANK) GOTO 37
35 CONTINUE
GOTO 40
37 WRITE(4,5001) DESCR
655 GOTO 30
40 CONTINUE
C
CARD B1
660 READ(5,5011) TSTAR, TEND, VAS(1), VAS(3), VAS(4), VAS(5)
$ ,FIXL, DEEPL, POMDPL
WRITE(6,6011) TSTAR, TEND, VAS(1), VAS(3), VAS(4), VAS(5)
$ ,FIXL, DEEPL, POMDPL
WRITE(6,7050)
C
665 CARD C1
READ(5,5003) (TA(I),I=1,8) , (TPER(I),I=1,8)
WRITE(6,6003) (TA(I),I=1,8) , (TPER(I),I=1,8)
WRITE(6,7090)
C
670 CARD C2
READ(5,5003) (TA(I),I=9,16) , (TPER(I),I=9,16)
WRITE(6,6003) (TA(I),I=9,16) , (TPER(I),I=9,16)
WRITE(6,7120)
C
675 CARD D1
READ(5,5002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
WRITE(6,6002) PSIZE, TEFF, CAPF, FCR, PER, CCM, ELEV, ROOFL
WRITE(6,7150)
C
680 CARD E1
READ(5,5002) FCOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
$ , CTURP
WRITE(6,6002) FCOS, PWCOS, PLANC, COSTL, CSSPKW, CAPCHG, HPCST
$ , CTURP

```

```

685      WRITE(6,7180)
      C
      CARD E2
      READ(5,5002) POHBAF, POHFAN, POHLEG, POHCIR, POHCND, POHSTC
      & .POHSCL
690      WRITE(6,6002) POHBAF, POHFAN, POHLEG, POHCIR, POHCND, POHSTC
      & .POHSCL
      WRITE(6,7185)
      C
      CARD F1
695      READ(5,5004) R3P, (TPO(I),I=1,4)
      WRITE(6,6004) R3P, (TPO(I),I=1,4)
      WRITE(6,7210)
      C
      CARD G1
700      READ(5,5002) EFPF
      WRITE(6,6002) EFPF
      WRITE(6,7240)
      C
      CARD H1
705      READ(5,5002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX
      & .TOWMAX
      WRITE(6,6002) VELREC, XDEPA, TLIM, TOWMIN, PFACT, TFIX
      & .TOWMAX
      ITMIN = TOWMIN + 1.E-30
      IF (ITMIN .LT. 1) ITMIN = 1
      ITMAX = TOWMAX + 1.E-30
      IF (ITMAX .LT. 1) ITMAX = 9999
      IF (ITMAX .LT. ITMIN) STOP"TOWMAX IS LESS THAN TOWMIN"
710      WRITE(6,7270)
      EXTEMP = .FALSE.
715      IF (TFIX.GT.0.0) EXTEMP = .TRUE.
      C
      CARD H2
      READ(5,5002) GBEFF
720      WRITE(6,6002) GBEFF
      WRITE(6,7280)
      C
      CARD I1
      READ(5,5002) CPM, WPL, CLUVR, CHAILS, UCS, UWS, CVM, WVV
725      WRITE(6,6002) CPM, WPL, CLUVR, CHAILS, UCS, UWS, CVM, WVV
      WRITE(6,7300)
      C
      CARD J1
      READ(5,5005) NTUCAL, HXNP, WB, NTUB, SS, ANGLE
730      WRITE(6,6005) NTUCAL, HXNP, WB, NTUB, SS, ANGLE
      WRITE(6,7330)
      C
      CARD J2
      READ(5,5002) DESVEL, REDUCE, OREDUCE, DIST
735      WRITE(6,6002) DESVEL, REDUCE, OREDUCE, DIST
      WRITE(6,7335)
      READ(5,5002) DESVELV, REDUCV, OREDUCV
      WRITE(6,6002) DESVELV, REDUCV, OREDUCV
      WRITE(6,7340)
740      C
      CARD K1

```

```

      READ(5,5002) XW, XD, XDG, SF, OFIN, THFIN, DANGLE
      WRITE(6,5002) XW, XD, XDG, SF, OFIN, THFIN, DANGLE
      WRITE(6,7360)
745      C CONVERT DEGREES TO RADIANS
          DANGLE = DANGLE * 3.14159 / 180.
          COANG = COS (DANGLE)
      C
      CARD L1
750      READ(5,5006) OOL, DI, GAGLIN, TUBMAT, XTUBMA, CONL
          WRITE(6,5006) OOL, DI, GAGLIN, TUBMAT, XTUBMA, CONL
          WRITE(6,7390)
      C
      CARD M1
755      READ(5,5007) FINTYP, XFINTY, FINMAT, CONF
          WRITE(6,5007) FINTYP, XFINTY, FINMAT, CONF
          WRITE(6,7420)
          IF (FINTYP .EQ. "NO LINER " .AND. FINMAT .NE. "ALUMINUM ")
      760      & STOP "ILLEGAL FIN MATERIAL FOR UNLINED TUBING"
      C
      CARD N1
          READ(5,5002) CFB, COATC, ZINCC, CASTC, EPREPC
          WRITE(6,5002) CFB, COATC, ZINCC, CASTC, EPREPC
          WRITE(6,7450)
765      C
      CARD P1
          READ(5,5007) HEDTYP, XHEDTY, HEDMAT, IW
          WRITE(6,5007) HEDTYP, XHEDTY, HEDMAT, IW
          WRITE(6,7480)
770      C
      CARD Q1
          READ(5,5002) CRJ, CMJ, CHH, CM, CMW, CST, CBJ
          WRITE(6,5002) CRJ, CMJ, CHH, CM, CMW, CST, CBJ
          WRITE(6,7510)
775      C
      CARD R1
          READ(5,5009) XNS, VELN, ODC, GA, TKCT, ITD2QE, CONMAT, CONMA2
          WRITE(6,5009) XNS, VELN, ODC, GA, TKCT, ITD2QE, CONMAT, CONMA2
          WRITE(6,7540)
780      C
      CARD R2
          READ(5,5002) XNP, TLA, XQUALY
          WRITE(6,5002) XNP, TLA, XQUALY
          WRITE(6,7550)
785      C
      CARD P3
          READ(5,5008) LINOR
          WRITE(6,5008) LINOR
          WRITE(6,7555)
790      C
      CARD S1
          READ(5,5008) LFP, LFE, MXEXT
          WRITE(6,5008) LFP, LFE, MXEXT
          WRITE(6,7570)
795      IF (MXEXT .LT. 1) MXEXT = 1
          IF (LFP .LT. LFB) STOP "LFB EXCEEDS LFE ON INPUT CARD"
      C
      CARD T1

```

```

      READ(5,5005) FFHX
800  WRITE(6,6005) FFHX
      WRITE(6,7580)
      IF(FFHX.NE."PER" .AND. FFHX.NE."FRICHO")
5 STOP "*** ** UNRECOGNIZED FFHX ON CARD 11"
      C
805  FHR = 3414.43 / TEFF
      IF(FIXL.GT.0.0) FXTLNG=.TRUE.
      DO 45 J=1,16
      IF(TPER(J).LT.1.E-20) GOTO 46
      NTA=J
810  45 CONTINUE
      46 CONTINUE
      SMPER=0.0
      DO 20 I=1,16
815  20 SMPER=SMPER + TPER(I)
      IF(ABS(SMPER-1.0).LT.1.E-10) GOTO 22
      WRITE(6,89)
      STOP
      22 CONTINUE
      C
820  C
      C DETERMINE POSITION OF TUBE O.D. AND GAGE IN RESPECTIVE ARRAYS
      C
      DO 99 I=1,6
      LO = I
825  IF(ABS(ODG-TOD(LO)).LT..001) GOTO 1011
      99 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE OD"
      C
      1011 DO 98 I= 1,7
      KGA = I
830  IF(ABS(GA-TGA(KGA)).LT..001) GOTO 100
      98 CONTINUE
      STOP "ILLEGAL VALUE FOR CONDENSER TUBE GAGE"
      C
835  100 CONTINUE
      ANG(1) = ANGLE*3.141592654/180.
      ANG(2) = SIN(ANG(1))
      ANG(3) = COS(ANG(1))
      IF(ABS(ANG(3)).LT..0001) ANG(3) = 0.0
840  C
      C CALL COSTEX TO EVALUATE ODR
      C
      CALL COSTEX (DUMX1,DUMX2)
      C
845  RETURN
      END

```

SUBROUTINE SHOT(L)

C
C
C
CTHIS ROUTINE ESTABLISHES A STARTING PLACE FOR THE MINIMIZING PRO-
CEDURE BY SAMPLING POINTS AROUND THE STARTING VALUES PROVIDED.

5

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

10

\$ AFTR, ALPHA, ANG(3)
\$ CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
\$ CBU, CTURB, CDANG, CLUVR, CHAILE, CVM
\$ DANGLE, DFIN, DEEPL, DESVEL, DESVELV
\$ EFFF
\$ ECR, FIRST, FIXL, ECOS, EFHX, FXTMP
\$ GREFE
\$ HXNP, HPCST
\$ ITMAX, ITMIN
\$ JCONS
\$ KCONV, KALEXT
\$ MEXT
\$ NTUCAL(2), NTA
COMMON

15

20

25

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50

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\$ DDRI
\$ PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
\$ PCHBAF, PCHBAN, PCHLEC, PCHCIR, PCHCND, PCHSTC, PCHSCL
\$ RAP, REDUCE, REDUCV, ROOFLL
\$ GREJ, GREduce, GREduceV
\$ SIGMAG, SAAF
\$ TD, TPO(4), TEFF, TLIM, THFIN, TLRA, TFIX
\$ TCD, TW
\$ UCS, UWS
\$ WFFV
\$ VAS(5)
\$ XDEPA, XW, XD
COMMON /FLSW/ FXTLNG
COMMON /LACALL/ SRN
COMMON /SUPPLY/ VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
\$ OTN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
\$ FPOW, DEFC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
\$ REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
\$ SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
\$ BP2, NW2, TCOS, DELPA, DELPWT, DELPWC, CONBAS, XNTSX, VELDX
\$ TLAX, UCON, PMCST, FMCST, FBACC, EFFE, CH, CA, CS
\$ CLTC, CFC, CPCC, FITC, CSC, CEPREF, DELPIP, AST, OLOEST
\$ CAPCST, XNFAN, BLDANG, CPLEN, DPFEI, WHX, WTTUB, AOIA, ASLN
\$ NTHAR, WTERM, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU
\$ AIREF, WATER, XNMOD, TCTPF, FOCPE, FMTRC, ACCTTP, ADJTP
\$ ACTRPD, ADJRPD, ACTVH, ADJVVH, ADJPPF, THPAIR, TCTF, AFCST
\$ CSRP, WATERW, WSTPCT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD
\$ SPRJ, SQRJ, ATUBC, CBA, TT01, TT02, DELPS, CSTLVR
\$ CSTHG, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPST
COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
\$ QIN1, CLAN1, REA11, Z1, HRFAC2S, W41, U1, DEPW1, PPOW1,
\$ FPOW1, DEFC1, WIDTH1, ELENG1, VAIR1, VWAT1, HI1, HO1, T41,
\$ REW1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPBP, SW41, SW31,
\$ SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,

```

60      $ 992MIN,NW2MIN,TCOS1,DEPA1,DPWT1,DPWC1,CONBA1,XNTS1,VELD1
      $ ,TLA1,UCON1,PMCS1,FMCS1,FBA1,EFFC1,CHI,CAL,CS1
      $ ,CLTC1,CFC1,CPC1,FITC1,CS1,CEPRE1,DEPI1,AST1,OLDCS1
      $ ,CAPCS1,XNFAN1,BLDAN1,CLEN1,DPFEL1,WH1,WTU1,ADI1,ABL1
      $ ,WTH1,WTR1,STRUC1,CFMPF1,HPPE1,TOTCF1,TP1,EFFIN1,ANTU1
      $ ,AIRFF1,WATFF1,XNMOD1,TCTPF1,FDCPF1,FMTRC1,ACTTP1,ADJTP1
      $ ,ACTBP1,ADJRP1,ACTVH1,ADJVH1,ADJPP1,THPA1,TCTF1,AFCST1
65      $ ,CSR1,WATER1,WSTRC1,CFOUN1,HUBD1,TOWLE1,NUMTO1,CTOWD1
      $ ,SRJ1,SQRJ1,ATUB1,CBA1,ITD1,ITD21,DELPS1,CSTLV1
      $ ,CSTHS1,CYLRN1,CFANEL,PSTAC1,PUFIT1,PMPCS1,RPTPL1,SEPCS1
      $ ,FAIR,FAIR,HPAIR,HPWAT,HLRTP,PLANCT1
70      COMMON /TINE/ XNS,TLA,XNTS,ARPS,ITD2DE,LINOR,XNP,XQUALY
9500  FORMAT('0IN SHOT AT CHECKPOINT A. VAR(4)=",1PE12.4,6X,"VAM(4)=",
      $ E12.4,6X,"DAFRO=",E12.4)
9501  FORMAT('0IN SHOT AT CHECKPOINT B. I=",I1,6X,"DAFRO=",1PE12.4,6X,
      $ "VAR(4)=",E12.4,6X,"AFRO(I)=",E12.4)
75  9502  FORMAT('0IN SHOT AT CHECKPOINT C. I=",I1,6X,"VAR(4)=",1PE12.4,
      $ 6X,"FAF=",E12.4)
9503  FORMAT('0IN SHOT AFRO WILL BE BAD BECAUSE VAS(4)=",1PE12.4)
      IDR=0
      IF(L.EQ.2) GO TO 31
80      DO 1 IS=1,5
1      VAM(IS)=0.0
      TCOS1=0.
      TCOS2=0.
      DO 20 I=1,3
85      T(I)=VAS(1)+(I-2)*5.
      IF(FXT=MP) T(I)=TFIX
      IF (T(I).GT.180.) T(I)=180.
20      IF (T(I).LE.0.0) T(I)=10.0
      DO 21 I=1,4
90      CWAR(I)=VAS(3)+(I-2)*2.
21      IF(CWA=(I).LE.0.) CWAR(I)=.5
      DO 22 I=1,4
95      WLRA(I)=VAS(5)+(I-2)*10.
22      IF(WLRA(I).LE.0.) WLRA(I)=5.
      AFRO(1)=VAS(4)/2.
      AFRO(2)=VAS(4)
      AFRO(3)=VAS(4)*2.
      DT1=1.
      DCWAR=1.
100     DAFRO=1.
      DWLRA=1.
      LC=4
      LW=4
      GO TO 31
105     31 DT1=VAR(1)-VAM(1)
      DCWAR=VAR(3)-VAM(3)
      DAFRO=VAR(4)-VAM(4)
      IF(DAFRO.LE.0.0.AND.IDB.NE.0) WRITE(6,9500) VAR(4),VAM(4),DAFRO
      DWLRA=VAR(5)-VAM(5)
      IF(DT1.EQ.0.0.OR.DT1.EQ.VAR(1)) GO TO 33
110     DO 32 I=1,3
      T(I)=VAR(1)-(I-1)*DT1/2.
      IF(FXT=MP) T(I)=TFIX
32     CONTINUE

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115      GO TO 25
      33 DO 34 I=1,3
          T(I)=VAR(1)+(I-2)*2.
          IF(FXTEMP) T(I) = TFIX
120      34 IF(T(I).GE.170.) T(I)=170.
      35 IF(DCWAR.EQ.0.0.OR.DCWAR.EQ.VAR(3)) GO TO 37
          DO 36 I=1,4
              CWAR(I)=VAR(3) -(I-1)*DCWAR/3.
              IF(CWAR(I).LE.0.0) CWAR(I)=0.25
125      36 CONTINUE
          GO TO 39
      37 DO 38 I=1,3
          CWAR(I)=VAR(3) + (I-2)
          IF(CWAR(I).LE.0.0) CWAR(I)=0.25
130      38 CONTINUE
          LC=3
      39 IF(DAFRO.EQ.0.0.OR.DAFRO.EQ.VAR(4)) GO TO 41
          DO 40 I=1,3
135      40 AFR0(I)=VAR(4)-(I-1)*DAFRO/2.
          IF(IDB.EQ.0) GOTO 43
          DO 3940 I=1,3
              IF(AFR0(I).LE.0.0) WRITE(6,9501) I,DAFRO,VAR(4),AFR0(I)
140      8040 CONTINUE
          GO TO 43
      41 FAF=.5F5
          TC=ABS(FAF-VAR(4))
          IF(TC.LT.1.E+4) FAF=FAF*0.9
          DO 42 I=1,3
              AFR0(I)=VAR(4)+(I-2)*FAF
              IF(AFR0(I).LE.0.0) AFR0(I)=1000. * I
145      42 CONTINUE
          IF(IDB.EQ.0) GOTO 43
          DO 8042 I=1,3
              IF(AFR0(I).LE.0.0) WRITE(6,9502) I,VAR(4),FAF
150      8042 CONTINUE
      43 IF(DWLRA.EQ.0.0.OR.DWLRA.EQ.VAR(5)) GO TO 45
          DO 44 I=1,4
              WLRA(I)=VAR(5)-(I-1)*DWLRA/3.
              GO TO 51
155      44 DO 46 I=1,3
              WLRA(I)=VAR(5)+(I-2)*5.
              LW=3
          51 DO 15 IT=1,3
              DO 15 IC=1,LC
                  IF(CWAR(IC).EQ.0.0) WRITE(6,9504) IC
160      9504 FORMAT('0IN SHOT, DIVISION BY ZERO, CWAR(",I2,")=0.00')
              RANGL = T(IT) - CWAR(IC) - TT02QE - TD
              2 RAN3(1)=.9*RANGL
              RAN3(2)=.7*RANGL
              RAN3(3)=.5*RANGL
              DO 15 IR=1,3
              DO 15 IA=1,3
              DO 15 IW=1,LW
                  KCALC=1
                  IF(IR.GT.1.OR.IC.GT.1) KCALC=2
                  IF(IA.GT.1) KCALC=4
                  IF(IW.GT.1) KCALC=5

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SRN="/SHOT-1/ "
CALL CALC(T(IT),RANG(IR),CHAR(IC),AFRO(IA),WLRA(IW),KCALC)
175 IF(KCONV.EQ.1) GO TO 15
IF(DEL=4.LE.XDEPA) GO TO 16
IF(TCOS1.EQ.0.) GO TO 14
IF(TCOS.GE.TCOS1) GO TO 16
IF(TCOS2.EQ.0.) GO TO 18
IF(TCOS1.GE.TCOS2) GO TO 14
180 18 TCOS2=TCOS1
DO 19 II=1,5
19 VAM(II)=VAR(II)
14 TCOS1=TCOS
VAR(1)=T(IT)
185 VAR(2)=RANG(IR)
VAR(3)=CHAR(IC)
VAR(4)=AFRO(IA)
VAR(5)=WLRA(IW)
CAF=AFRO(1)*.1
190 GO TO 15
16 IF(L.EQ.2) GO TO 15
IF(TCOS2.EQ.0.) GO TO 17
IF(TCOS.GE.TCOS2) GO TO 15
17 TCOS2=TCOS
195 VAM(1)=T(IT)
VAM(3)=CHAR(IC)
VAM(4)=AFRO(IA)
VAM(5)=WLRA(IW)
15 CONTINUE
200 IF(IDB.EQ.0) RETURN
WRITE(A,553)TCOS1,VAR(1),VAR(2),VAR(3),VAR(4),VAR(5)
553 FORMAT(" TCOS1="E12.5," T11="F4.0," RANG1="F7.4," CHAR1="F7.3,
1" AFRO1="E10.3," WLRA1="F4.0)
RETURN
205 END

```

SUBROUTINE SPDES(ITS,TTD,XNS,XNP,CHLD,TLA,X,VELD,VELDO,ARPS,XNTS,
IDELP,LINOR,

SUBROUTINE SPODES DESIGNS A CONDENSER/REBOILER ON THE
 BASIS OF THE TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
 STEAM AND THE SATURATED AMMONIA, THE AMOUNT OF HEAT
 TO BE TRANSFERRED, THE TEMPERATURE OF THE STEAM, THE
 LENGTH OF THE TUBES, AND THE EXIT QUALITY OF THE AMMONIA
 LEAVING THE TUBES. THE CONDENSER/REBOILER CAN BE DESIGNED
 WITH TWO TYPES OF TUBES (1) BARE TUBES, AND (2) ENHANCED
 TUBES.
 FOR BARE TUBES THE OUTSIDE COEFFICIENT IS PROVIDED BY
 NUSSULT AND THE INSIDE COEFFICIENT BY ROHSENOW.
 FOR THE ENHANCED TUBES THE OUTSIDE AND INSIDE COEFFICIENTS
 ARE PROVIDED BY A REPORT FROM LINDE CORPORATION.

DEFINITION OF VARIABLES

APPS	- AREA PER CONDENSER/REBOILER SHELL (SQ FT)
ACT	- TOTAL AREA OF CONDENSER/REBOILER SHELLS (SQ FT)
BETA	- CONSTANT IN CORRELATION FOR HEAT TRANSFER ON THE OUTSIDE OF THE TUBE (BTU/HR-SQ FT-DEG F**3/4)
C	- SPACING BETWEEN CONDENSER/REBOILER TUBES (IN)
CHLD	- HEAT TRANSFERED IN THE CONDENSER/REBOILER (BTU/HR)
COW	- SPECIFIC HEAT OF LIQUID AMMONIA (BTU/LBM-DEG F)
DFLP	- PRESSURE DROP OF THE AMMONIA THROUGH THE CONDENSER/ REBOILER (LBF/SQ FT)
DELTA	- AMMONIA SIDE TEMPERATURE DROP (DEG F)
DELTK	- WALL TEMPERATURE DROP (DEG F)
DELTS	- AVERAGE STEAM SIDE TEMPERATURE DROP (DEG F)
DENSIV	- DENSITY OF AMMONIA VAPOR (LBM/CU FT)
DENSIW	- DENSITY OF AMMONIA LIQUID (LBM/CU FT)
DEPTHN	- NUMBER OF TUBES IN DEPTH OF A TUBE BANK IN THE CONDENSER/REBOILER (DIMENSIONLESS)
G	- ACCELERATION DUE TO GRAVITY (FT/SQ HR)
GT	- AVERAGE MASS FLUX OF AMMONIA THROUGH THE CONDENSER/ REBOILER TUBES (LBM/HR-SQ FT)
Ha	- FORCED CONVECTION COEFFICIENT ON THE INSIDE OF THE CONDENSER/REBOILER TUBES (BTU/HR-SQ FT-DEG F)
HFG	- HEAT OF VAPORIZATION FOR SATURATED AMMONIA (BTU/ LBM)
HICON	- HEAT TRANSFER COEFFICIENT ON THE INSIDE OF THE CONDENSER/REBOILER TUBES (BTU/HR-SQ FT-DEG F)
HOCON	- AVERAGE HEAT TRANSFER COEFFICIENT ON THE OUTSIDE OF THE CONDENSER/REBOILER TUBES (BTU/HR-SQ FT-DEG F)
HFGI	- HEAT OF VAPORIZATION FOR SATURATED STEAM (BTU/LBM)
HWCON	- EFFECTIVE HEAT TRANSFER COEFFICIENT FOR THE CONDENSER/REBOILER TUBE WALL (BTU/HR-SQ FT-DEG F)
KSF	- THERMAL CONDUCTIVITY OF SATURATED WATER (BTU/HR- FT-DEG F)
ODC	- OUTSIDE DIAMETER OF THE CONDENSER TUBING (IN)
PRW	- PRANDTL NUMBER OF SATURATED AMMONIA (DIMENSIONLESS)
QAO	- HEAT FLUX THROUGH THE INSIDE CONDENSER/REBOILER TUBE WALL (BTU/HR-SQ FT)
RAEF	- DENSITY OF SATURATED WATER (LBM/CU FT)
ROEG	- DENSITY OF SATURATED STEAM (LBM/CU FT)
SIGMA	- SURFACE TENSION OF LIQUID AMMONIA (LBF/FT)

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60      C      THCONW - THERMAL CONDUCTIVITY OF SATURATED AMMONIA (BTU/HR-
      C      FT-DEG F)
      C      TID      - INSIDE DIAMETER OF THE CONDENSER/REBOILER TUBES
      C      (IN)
      C      TKCT      - THERMAL CONDUCTIVITY OF THE CONDENSER/REBOILER
      C      TUBES (BTU/HR-FT-DEG F)
      C      TLA      - CONDENSER/REBOILER TUBE LENGTH (FT)
65      C      TLAA      - TOTAL FLOW PATH FOR THE AMMONIA (FT)
      C      TS      - TEMPERATURE OF THE SATURATED STEAM (DEG F)
      C      TTD      - TEMPERATURE DIFFERENCE BETWEEN THE STEAM AND
      C      AMMONIA (DEG F)
      C      UCON      - OVERALL HEAT TRANSFER COEFFICIENT IN THE CONDENSER/
      C      REBOILER (BTU/HR-SQ FT-DEG F)
70      C      VEL      - INLET VELOCITY OF THE AMMONIA TO THE CONDENSER/
      C      REBOILER TUBES (FT/SEC)
      C      VELD      - INLET VELOCITY OF THE AMMONIA TO THE CONDENSER/
      C      REBOILER TUBES (FT/SEC)
75      C      VELD0      - EXIT VELOCITY OF THE AMMONIA LEAVING THE CONDENSER/
      C      REBOILER TUBES (FT/SEC)
      C      VISS      - VISCOSITY OF SATURATED WATER (LBM/FT-HR)
      C      VISV      - VISCOSITY OF SATURATED AMMONIA VAPOR (LBM/FT-HR)
      C      VISW      - VISCOSITY OF SATURATED AMMONIA LIQUID (LBM/FT-HR)
80      C      VSG1      - SPECIFIC VOLUME OF SATURATED WATER (CU FT/LBM)
      C      VSG1      - SPECIFIC VOLUME OF SATURATED STEAM (CU FT/LBM)
      C      X      - EXIT QUALITY OF THE AMMONIA LEAVING THE CONDENSER/
      C      REBOILER TUBES (DIMENSIONLESS)
      C      XNP      - NUMBER OF PASSES OF THE AMMONIA THROUGH THE
85      C      CONDENSER (DIMENSIONLESS)
      C      XNS      - NUMBER OF SHELLS IN THE CONDENSER/REBOILER
      C      (DIMENSIONLESS)
      C      XNTS      - NUMBER OF TUBES PER SHELL (DIMENSIONLESS)
90      REAL KSF
      DIMENSION TSAT(64), VSG(64), VISW(64), HSG(64), ANG(3)
      COMMON/PROP/CPW,THCONW,DENSIW,VISW,HFG,
1      CPV,THCONV,DENSIW,VISV,SIGMA,
2      CPA,THCONA,DENSIW,VISA
95      COMMON/OHTC/VELN,ODC,TKCT
      COMMON/TUBE/KGA,LD,TID(7,6)
      COMMON/RPRT2/UCONN,HCON,HCON,HCON,HCON,HFC,VELD7,VELD07,TTD7,TS7,
1XNP7,DELPW7,ARPS7,TLAT,XNTS7,XNS7
      COMMON/SUPPLY/VAL(5), CPLN, CPIP, CCOS, W3, COSM, EFF,
100      QIN, CLAND, REAIR, Z,HRFAC2, W4, U, DELPW, PPOW,
      FPOW, DELFC, 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,
      BR2, NW2, TCOS, DELPA,DELPAT,DELPWC,CONBAS,XNTSX,VELDX
105      TLAX, UCON, PMCST, FMCST, FBACC, EFFC, CH, CA, CS
      CLTC, CFC, CPOC, FITC, CSC,CEPREP,DELP1P, AST,OLDGST
      CAPCST,XNFAN,BLDANG,CLEN,DPFEL, WHX, WTTUB, ADIA, ABLN
      WTHAR, WTERM,STRUCC,CPPERF,HPPERF,TOTCF, TPC, EFFIN, ANTU
      AIRFF, WATFF, XNMOD, TCTPF, FOCPE, FMTRC, ACCTP, ADJTP
110      ACTBPD, ADJBPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
      CSRO, WATERW, WSTRCT, CPOJND, HYBDA, TOWLEN, NUMTON, CTOWD
      SORJ, SORJ, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR
      CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST

```

C

115

C
C

PROPERTIES OF STEAM VERSUS TEMPERATURE

DATA TSAT/40.24,44.98,49.07,52.57,55.90,
 1 58.82,61.5,63.97,66.27,68.42,70.44,72.34,74.14,75.85,
 177.48,79.04,81.96,84.66,87.17,89.52,91.72,93.8,95.78,97.65,99.43,
 2101.14,102.77,104.34,105.85,107.3,108.7,110.06,111.36,112.63,113.8
 36.115,06.116,22.117,34.118,44.119,51.120,56.125,42.129,78.133,75,
 4137.4,140.77,143.91,146.85,149.62,152.24,154.72,157.08,159.33,
 5161.48,165.53,169.28,172.77,176.05,179.13,182.05,184.81,187.45,
 6189.96,192.37/

125

DATA VSF/.016019,.016020,.016022,.016025,.016028,
 1 .016032,.016035,.016039,.016043,.016047,.016051,.016055,
 1.016059,.016062,.016066,.016070,.016077,.016084,.016091,.016097,
 2.016104,.016110,.016116,.016122,.016128,.016134,.016139,.016145,
 3.016150,.016155,.016160,.016165,.016170,.016175,.016180,.016184,
 4.016189,.016194,.016198,.016202,.016207,.016227,.016245,.016264,
 5.016281,.016297,.016312,.016327,.016341,.016354,.016367,.016380,
 6.016392,.016403,.016426,.016447,.016467,.016486,.016505,.016522,
 7.016532,.016556,.016572,.016587/

130

DATA VSG/2423.96,2038.97,1761.71,1552.30,1388.42,
 1 1286.58,1148.17,1057.42,980.30,913.94,856.22,805.54,
 1760.68,720.69,684.80,652.41,596.25,549.23,509.27,474.87,444.95,
 2418.68,395.42,374.68,356.06,339.26,324.02,310.13,297.41,285.73,
 3274.95,264.99,255.74,247.13,239.11,231.6,224.56,217.95,211.74,
 4205.87,200.34,176.7,158.19,143.28,131.01,120.73,112.1,104.47,97.92,
 592.17,81.08,52.53,78.46,74.77,58.39,63.03,58.48,54.55,51.14,48.143
 6.45,486.43,116.40,989.39,067/

135

DATA HSG/1070.8,1068.1,1065.8,1063.8,1062.0,
 1 1060.3,1058.8,1057.4,1055.1,1054.9,1053.8,1052.7,1051.7,
 11050.7,1049.8,1048.9,1047.3,1045.8,1044.3,1043.1,1041.8,1040.6,
 21039.5,1038.4,1037.4,1036.4,1035.5,1034.6,1033.7,1032.9,1032.1,
 31031.3,1030.6,1029.9,1029.1,1028.5,1027.8,1027.1,1026.5,1025.9,
 41025.3,1022.5,1020.1,1017.7,1015.5,1013.6,1011.7,1010.1,1008.4,
 51005.8,1005.4,1004.1,1002.6,1001.3,999.9,996.7,994.6,992.5,990.7,
 6988.9,987.3,985.6,984.1,982.5/

140

150

C
C

SETTING OF CONSTANTS

ANG(1) = 0.0
 ANG(2) = 0.0
 ANG(3) = 1.0
 G = 32.16-3600.-3600.
 VELD = VELN
 C = .25

155

C
C

PHYSICAL PROPERTIES OF STEAM

HSFG1 = TLU(TS,TSAT,HSFG,59)
 VSF1 = TLU(TS,TSAT,VSF,59)
 VSG1 = TLU(TS,TSAT,VSG,59)
 PRW = CPW*VISH/THCONW
 ROEF1 = 1./VSF1
 ROEG1 = 1./VSG1
 KSF = -3.363968E-01 + 2.04203E-03*(TS+460.)-1.42164E-06*(TS+460.)
 1**2
 VISS = 5.93897E-02*10.**((446.04/((TS+460.)-252.))

160

165

C
C

TUBE BANK DEPTH (10 FT) IN NUMBER OF TUBES
 DEPTHN = 10.*12./(ODC + C)

170

```

C
C      SETTING OF CONSTANT FOR OUTSIDE HEAT TRANSFER COEFFICIENT
175  BETA = .728*((G*ROEF*(ROEF-ROEG)*KSF**3*HSFG1/((ODC/12.*VISS))
      1**25)/DEPTHN**1.6667
      IF(LINOR.EQ.1) BETA = 16700./DEPTHN**1.6667
C
C      SETTING OF CONSTANT FOR INSIDE HEAT TRANSFER COEFFICIENT
180  HB = ((CPW/(HFG*.015*(PRW)**1.7))**3)*VISW*HFG/(SIGMA/(DENSIV-
      1DENSIV))**.5
      IF(LINOR.EQ.1) HB = 592.628*HB
      JI = 0
C
C      BEGINNING OF ITERATION LOOP FOR VELOCITY OF AMMONIA INSIDE
185  THE TUBES OF THE CONDENSER
C
C      FORCED CONVECTION COEFFICIENT ON THE INSIDE OF THE
C      CONDENSER TUBES
190  10 HFC = .023*(VELD*ODC*DENSIV*3600./((12.*VISW))**.8*PRW**.4**12.
      1*THCONW/TID(KGA,LD)
      JI = 0
C
C      INITIAL GUESS FOR THE AMMONIA SIDE TEMPERATURE DROP
195  DELTA = TTD/2.
C
C      BEGINNING OF ITERATION LOOP FOR THE AMMONIA SIDE
C      TEMPERATURE DROP
C
C      HEAT FLUX THROUGH THE INSIDE TUBE WALL
200  20 QAO = (TID(KGA,LD)/ODC)*(HFC*DELTA + HB*DELTA**3)
      IF(LINOR.EQ.1) QAO = (TID(KGA,LD)/ODC)*(HFC*DELTA + HB*DELTA**2.72
      1)
C
C      DETERMINE TEMPERATURE DROP ACROSS THE WALL
205  DELTK = QAO*(ODC/24.)*ALOG(ODC/TID(KGA,LD))/TKCT
C
C      AVERAGE TEMPERATURE DROP ACROSS THE CONDENSATE LAYER
C      DELTS = (QAO/BETA)*1.3333
210  IF(LINOR.EQ.1) DELTS = (QAO/BETA)**2.34
C
C      TOTAL TEMPERATURE DROP BETWEEN THE STEAM AND THE AMMONIA
      DELTT = DELTS + DELTK + DELTA
      JI = JI + 1
C
C      DETERMINATION OF NEXT GUESS FOR THE AMMONIA SIDE
215  TEMPERATURE DROP AS A FUNCTION OF THE LAST TWO TOTAL
      TEMPERATURE DROPS AND THE SPECIFIED TOTAL TEMPERATURE DROP
      DELTT2 = DELTT1
      DELTT1 = DELTT
      DELTA2 = DELTA1
220  DELTA1 = DELTA
      IF (JI .LT. 2) DELTA = DELTA + .25
      IF(JI.LT.2) GO TO 20
      SLOPE = (DELTA1 - DELTA2)/(DELTT1 - DELTT2)
      DELTA = SLOPE*(TTD - DELTT1) + DELTA1
225
C
C      CONVERGENCE CRITERIA FOR THE AMMONIA SIDE TEMPERATURE DROP
      IF(ABS((DELTA-DELTA1)/DELTA) .LT. .0001) GOTO 30

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```

230      GO TO 20
      C
      C      VELOCITY OF AMMONIA BASED ON THE INSIDE WALL HEAT FLUX
      C      AND THE EXIT QUALITY OF THE AMMONIA
      C 30 VEL = ODC*QA0*TLA*XNP/(75.*X*HFG*TID(KGA,LD)**2*DENSIV)
235      C
      C      CONVERGENCE CRITERIA FOR THE VELOCITY OF AMMONIA THRU THE
      C      TUBES
      C      IF (ABS((VELD-VEL)/VEL) .LT. .001) GOTO 40
      C      VELD = VEL
      C      GO TO 10
240      C
      C      NUMBER OF TUBES AND SURFACE AREA PER SHELL AND TOTAL SURFACE
      C      AREA
      C 40 ARPS = CHLD/(XNS*QA0)
      C      XNTS = AINT(ARPS/(3.14159*(ODC/12.)*TLA) + 0.5)
245      C      XNTSX = XNTS*XNS
      C      AST = ARPS*XNS
      C
      C      OVERALL HEAT TRANSFER COEFFICIENT
      C      UCON = QA0/TTD
250      C
      C      OUTSIDE HEAT TRANSFER COEFFICIENT
      C      HOCN = QA0/DELTS
      C
      C      INSIDE HEAT TRANSFER COEFFICIENT
255      C      HICN = (QA0/DELTA) * ODC/TID(KGA,LD)
      C
      C      EFFECTIVE WALL HEAT TRANSFER COEFFICIENT
      C      HWCN = QA0/DELTK
260      C
      C      EXIT VELOCITY OF THE AMMONIA LEAVING THE CONDENSER TUBES
      C      VELDO = VELD*DENSIV*((1. - X)/DENSIV + X/DENSIV)
      C
      C      PRESSURE DROP THROUGH THE CONDENSER/REBOILER TUBING
265      C      GT = VELD*DENSIV*3600.
      C      TLAA = TLA*12.*XNP
      C      CALL IDPCON(GOWS,TID(KGA,LD),TLAA,AVG,GT,0.,X,DENSIV,DENSIV,
      C      1,VISW*.4133,VISV*.4133,DELP,DPF,DPG,DPM,XLM,PHIL,PHIL2,VF,FL,RL,
      C      2RV)
      C      DELP = DELP*144.
270      C
      C      STORAGE OF VARIABLES
      C
      C      TLAX = TLA
      C      VELDX = VELD
275      C      EFFC = 1.0
      C      UCONN = UCON
      C      TTD7 = TTD
      C      VELD7 = VELD
      C      VELDO7 = VELDO
280      C      DELPW7 = DELP
      C      ARPS7 = ARPS
      C      TLA7 = TLA
      C      XNTS7 = XNTS
      C      XNS7 = XNS
285      C      XNP7 = XNP

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SUBROUTINE SPDES 74/74 OPT=1

FTN 4.2+74351

12/18/66

TS7 = TS
RETURN
END

SUBROUTINE SSCALE

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C
C      SUBROUTINE SSCALES 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      CASSS1 - INCREMENTAL COST OF STEAM SUPPLY FOR MAKE UP OF
C              POWER OUTPUT DUE TO INCREASED HEAT RATE AT RATED
C              BACK PRESSURE ($)
C      CSSPKW - COST OF STEAM SUPPLY SYSTEM PER KILOWATT ($/KW)
15      HRFAC1 - HEAT RATE FACTOR OF STEAM TURBINE AT RATED BACK
C              PRESSURE (DIMENSIONLESS)
C      PLANC - COST OF POWER PLANT PER KILOWATT ($/KW)
C      PSIZE - PLANT SIZE (MW)
C      RBP - STEAM TURBINE RATED BACK PRESSURE (IN HGA)
20      SSCD - INCREMENTAL PLANT COST DUE TO INCREASED HEAT RATE
C              AT RATED BACK PRESSURE OF STEAM TURBINE ($)
C      TPO - COEFFICIENTS OF THIRD ORDER HEAT RATE CURVE FIT
C              FOR STEAM TURBINE (DIMENSIONLESS)
C
25      LOGICAL FIRST, FXTMP
COMMON
$  AFTR, ALPHA, ANG(3)
$  CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAP
30      CBU, CTURB, CDANG, CLUVR, CHAILE, CVM
$  DANGLE, DFIN, DEEPL, DESVEL, DESVELV
$  EFPF
$  FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
$  GBEFF
$  HXNP, HPCST
35      ITMAX, ITMIN
$  JCONC
$  KCONV, KALEXT
$  MXEXT
$  NTUCAL(2), NTA
40      COMMON
$  ODR
$  PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
$  POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCN
45      RBP, REDUCE, REDUCV, ROOPLI
$  GREU, GREUCE, GREUCV
$  SIGMAS, SAAF
$  TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFIX
$  TCD, TW
50      UCS, UWS
$  WEFV
$  VAS(5)
$  XDEPA, XW, XD
COMMON /SUPPLY/ VAL(5), CPLV, CPIP, CCOS, W3, COSM, EFF,
$  QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
55      FPOW, DELEC, WIDTH, ELENG, VAIR, VWAT, HI, HO, T4,
$  REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
$  SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,

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60      $ B22, NW2, TCOS, DELPA,DELPWT,DELPWC,CONBAS, XNTSX, VELOX
      $ , TLAX, UCON, PMOST, FMCST, FBACC, EFFC, CH, CA, CS
      $ , CLTC, CFC, CPCC, FITCO, CSC,CEPREP,DEPIP, AST,OLDCST
      $,CAPCST,XNFAN,BLOANG,CLEN,DPFEL,WHX,WTUUB,ADIA,ABLW
      $, WTHDR, WFERM,STRUCC,CFPERF,HPPERF,TOTCF,TPC,EFFIN,ANTU
      $, AIRFF, WATFF, XNMOD, TCTPF, FOCPE, FMTRC, ACCTTP, ADJTP
      $, ACTBD, ADJBD, ACTVH, ADJVH, ADJPP, HPAIR, TCTF, AFCST
65      $, CSRD, WATERW, WSTRCT, CFOWN, HUBDIA, TOWLEN, NUMTOW, CTOWD
      $, SQRJ, SQRJS, ATUBC, CRA, ITD1, ITD2, DELPS, CSTLVR
      $, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST
      $ COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSH1, EFF1,
      $ QIN1, CLAN1, REA1, Z1,HRFA2S, W41, U1, DEPW1, PPW1,
70      $ FFW1, DEFC1, WID1, ELN1, VAIR1, VWAT1, HI1, HD1, T41,
      $ REW1, NW1, NT1, NP1,ZPLNC2,ZSZ12, ZSPBP, SW41, SW31,
      $ SPC1, PTOT1,PLNC31, AFRO1, AAIR1,YFPMIN,SPCD1,SPS13,WT2MIN,
      $ B22MIN,NW2MIN,TCOS1,DEPA1,DPWT1,DPWC1,CONBA1,XNTS1,VELO1
      $ , TL1, UCON1, PMCS1, FMC1, FBAC1, EFFC1, CH1, CA1, CS1
75      $ , CLTC1, CFC1, CPCC1,FITC1, CSC1,CEPRE1,DEPIP1, AST1,OLDCS1
      $,CAPCS1,XNFAN1,BLOAN1,CLEN1,DPFEL1,WH1,WTU1,AD11,ABL1
      $, WTHD1, WFER1,STRUC1,CFMPE1, HPPF1,TOTCF1,TP1,EFFIN1,ANTU1
      $, AIRFF1, WATFF1, XNMOD1, TCTPF1, FOCPE1, FMTRC1, ACCTP1, ADJTP1
      $, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, HPA11, TCTF1, AFCST1
80      $, CSR1, WATER1, WSTRC1, CFOWN1, HUBD1, TOWLE1, NUMTO1, CTOWD1
      $, SQRJ1, SQRJS1, ATUBC1, CRA1, ITD1, ITD2, DELPS1, CSTLV1
      $, CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPCS1, RPTPL1, SEPCS1
      $ COMMON /SCALER/HRFAC1, ATUB, CPERA, SSCD,PLANC1,CASSS1,
      $ GAIR, FAIR, HPAIR, HPWAT, WLRTP, PLANCT1

85      C
      C      EQUATION FOR HEAT RATE FACTOR AS A FUNCTION OF TURBINE .
      C      BACK PRESSURE
      C
      C      HRF(P)=TPO(1) + TPO(2)*P + TPO(3)*P**2 + TPO(4)*P**3
90      C
      C      HEAT RATE FACTOR AT RATED BACK PRESSURE
      C
      C      HRFAC1=HRF(RBP)
      C
95      C      INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
      C      FACTOR AT RATED BACK PRESSURE ($)
      C
      C      DTURBC = CTURB * PSIZE * 1000.
      C      CASSS1 = CSSPKW * (HRFAC1 - 1.) * PSIZE * 1000.
100      C      SSSPC = PLANC * PSIZE * 1000. + CASSS1
      C
      C      PLANT COST TAKING INTO ACCOUNT INCREASED STEAM SUPPLY
      C      COST ($/MW)
      C
105      C      PLANCT1 = SSSPC + DTURBC
      C      PLANCL = PLANCT1 / (PSIZE * 1000.)
      C
      C      INCREMENTAL STEAM SUPPLY COST DUE TO INCREASED HEAT RATE
      C      OF TURBINE ($)
110      C
      C      SSPLC =SSSPC/(PSIZE*1000.)
      C      SSCD1 = (SSPLC - PLANC) * PSIZE * 1000.
      C      TCD = DTURBC
      C

```

SUBROUTINE SSCALE 74/74 OPT=1

FTN 4.2+74351

12/18/76

115

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
5
C
      COMMON /RPTSUP/ XPS(2021)
      COMMON /RPTRET/ XPR(2020)
      COMMON /RPRT2/ R2(15)
10      COMMON /RPRT3/ R3(4)
      COMMON /KPTSUP/ HPS(2021)
      COMMON /KPTRET/ HPR(2020)
      COMMON /KPRT2/ SPRT2(15)
      COMMON /KPRT3/ SPRT3(4)
      COMMON /SINK/ VSTO(132)
15      COMMON /SUPPLY/ VIN(132)
      LOGICAL FIRST, EXTEMP
      COMMON
      $ AFTR, ALPHA, ANG(3)
      $ ,CAPF, CSSPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONM2, CAFI
20      $ ,CBJ, CTURB, CDANG, CLUVR, CHAILS, CVM
      $ ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
      $ ,EEFF
      $ ,FCR, FIRST, FIXL, FCOS, FFHX, EXTEMP
      $ ,GREFF
25      $ ,HXNP, HPCST
      $ ,ITMAX, ITMIN
      $ ,JCONS
      $ ,KCONV, KALEXT
      $ ,MXEXT
30      $ ,NTUCAL(2), NTA
      COMMON
      $ ODR
      $ ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPL
      $ ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCF
35      $ ,RRP, REDUCE, REDUCV, ROOFLI
      $ ,GREJ, GREduce, GREduceV
      $ ,SIGMAG, SAAF
      $ ,TD, TPO(4), TEFF, TLIM, THFIN, TLPRA, TFI
40      $ ,TCD, TW
      $ ,UCS, UWS
      $ ,WTV
      $ ,VAS(5)
      $ ,XDEPA, XW, XD
      DO 1 I=1,132
45      VSTO(I)=VIN(I)
1 CONTINUE
      DO 3 I = 1, 15
      SPRT2(I)=R2(I)
3 CONTINUE
      DO 4 I=1,4
50      SPRT3(I)=R3(I)
4 CONTINUE
      DO 50 I=1,2021
      HPS(I) = XPS(I)
55      50 CONTINUE
C
      DO 50 I=1,2020

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SUBROUTINE STORE

74/74 OPT=1

FTN 4.2+74351

12/18/76

60

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      HPR(I) = XPR(I)
60    CONTINUE
      JCONS=1
      RETURN
      END
```

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SUBROUTINE SUMCOS(FCR,PSIZE,CAPF,CCOS1,CPIP1,CONB1,ATUBC,CPLEN,
$FBACC,FMCST,STRUCC,CFOUND,CAPCST,SPCD1,SSCD,HRFAC1,HRFAC2,YFP,
$PLANC,CLAN1,CLSUM,FCSUM,COSM1,CSTLV1,CSTHS1,CFANE1,CYLRNH
$)

```

```

5      C
6      C      THIS ROUTINE REPORTS THE FINAL COST SUMMARY
7      C
8
9      6001 FORMAT(1H1///,T17,"C A P I T A L   C O S T   S U M M A R Y "
10     $,T72,"U N I T   E N E R G Y   C O S T   S U M M A R Y"/
11     $,T15,43(" ").T71,52(" ")///)
12     6010 FORMAT(
13     L T2,"COOLING SYSTEM CAPITAL",T48,F13.0
14     R,T69,"COOLING SYSTEM CAPITAL",T119,G12.6/)
15     6020 FORMAT(
16     L T4,"TOWER",T35,F13.0
17     R,T72,"TOWER",T106,G12.6)
18     6030 FORMAT(
19     L T7,"HEAT EXCHANGER",T23,F13.0
20     R,T75,"HEAT EXCHANGER",T93,G12.6)
21     6040 FORMAT(
22     L T7,"PLENUM",T23,F13.0
23     R,T75,"PLENUM",T93,G12.6)
24     6042 FORMAT(
25     L T7,"LOUVERS",T23,F13.0
26     R,T75,"LOUVERS",T93,G12.6)
27     6044 FORMAT(
28     L T7,"HAIL SCREENS",T23,F13.0
29     R,T75,"HAIL SCREENS",T93,G12.6)
30     6050 FORMAT(
31     L T7,"FAN SYSTEM",T23,F13.0
32     R,T75,"FAN SYSTEM",T93,G12.6)
33     6060 FORMAT(
34     L T7,"STRUCTURE",T23,F13.0
35     R,T75,"STRUCTURE",T93,G12.6)
36     6070 FORMAT(
37     L T7,"FOUNDATION",T23,F13.0
38     R,T75,"FOUNDATION",T93,G12.6/)
39     6080 FORMAT(
40     L T4,"PIPING",T35,F13.0
41     R,T72,"PIPING",T106,G12.6)
42     6090 FORMAT(
43     L T4,"CONDENSER",T35,F13.0
44     R,T72,"CONDENSER",T106,G12.6)
45     6100 FORMAT(
46     L T2,"CAPACITY PENALTY",T48,F13.0
47     R,T69,"CAPACITY PENALTY",T119,G12.6/)
48     6110 FORMAT(
49     L T2,"PLANT SCALING",T48,F13.0
50     R,T69,"PLANT SCALING",T119,G12.6)
51     6120 FORMAT(
52     L T4,"STEAM SUPPLY",T35,F13.0
53     R,T72,"STEAM SUPPLY",T106,G12.6)
54     6130 FORMAT(
55     L T4,"BASE PLANT",T35,F13.0
56     R,T72,"BASE PLANT",T106,G12.6/)
57     6140 FORMAT(
58     L T2,"LAND",T48,F13.0/)

```

```

6150 FORMAT(
      L T48,13("-")/)
60 6160 FORMAT(
      L T2,"TOTAL CAPITAL COST",T46,"$",T48,F13.0
      R,T69,"TOTAL CAPITAL COST",T119,G12.6/)
6170 FORMAT(
      R T69,"ENERGY PENALTY",T119,G12.6/)
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.
      FACTOR = FCR/(PSIZE*CAPF*8760)
      WRITE(4,6001)
      WRITE(4,6010) ((CCOS1+CPIP1+CONBA1),((CCOS1+CPIP1+CONBA1)*FACTOR))
75 6020 CCOS1,CCOS1*FACTOR
      WRITE(4,6030) ATUBC,ATUBC*FACTOR
      WRITE(4,6040) CPLEN,CPLEN*FACTOR
      WRITE(4,6042) CSTLV1,CSTLV1*FACTOR
      WRITE(4,6044) CSTHS1,CSTHS1*FACTOR
80 6050 (FBACC + FMCST + CYLRN1 + CFANE1)
      S (FBACC + FMCST + CYLRN1 + CFANE1) * FACTOR
      WRITE(4,6060) STRUCC,STRUCC*FACTOR
      WRITE(4,6070) CFOUND,CFOUND*FACTOR
      WRITE(4,6080) CPIP1,CPIP1*FACTOR
85 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*
      SFACTOR
90 6130 PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10**3 * PSIZE,
      S PLANC*(HRFAC2/HRFAC1*YFPP1-1.)*10**3 * PSIZE * FACTOR
      WRITE(4,6140) CLAN1
      WRITE(4,6150)
      WRITE(4,6160) CLAN1+SPCD1+CAPCST+CCOS1+CPIP1+CONBA1
95 6170 S,(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) *
      S FACTOR + CLSUM + FCSUM + COSM1
      WRITE(4,6200) TOTAL
      END

```

SUBROUTINE STRUCT(DTOW, WHX, WATERW, ROOFL, CSTRUC, CFND, WSTRC,
\$ ITOWN, ELENG, POHSTC)

```

C
C
5  C      SUBROUTINE STRUCTURES DETERMINES THE COST OF THE STRUCTURES
C      AND THE FOUNDATION FOR THE CIRCULAR TOWERS. THE STRUCTURE
C      COST IS BASED ON THE HEIGHT AND DIAMETER OF EACH TOWER AND
C      THE DESIGN ROOF LOAD. THE FOUNDATION COST IS BASED ON THE
C      TOTAL WEIGHT OF THE HEAT EXCHANGERS AND THE SURFACE AREA
10  C      COVERED BY THE TOWERS.
C
C      DEFINITION OF VARIABLES
C
C      CFND - COST OF FOUNDATION ($)
C      CSTRUC - COST OF STRUCTURES ($)
15  C      DTOW - TOWER DIAMETER (FT)
C      ITOWN - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C      ITOWN - NUMBER OF CIRCULAR TOWERS (DIMENSIONLESS)
C      POHSTC - DIRECT AND INDIRECT CONSTRUCTION COSTS FOR THE
C      STRUCTURES (DECIMAL PERCENT)
20  C      ROOFL - DESIGN ROOF LOAD (LBF/SQ FT)
C      WATERW - WEIGHT OF THE WATER IN THE HEAT EXCHANGER (LBF)
C      WHX - WEIGHT OF MATERIAL IN THE HEAT EXCHANGER (LBF)
C      WSTRC - CIRCULAR TOWERS STRUCTURAL WEIGHT (LBF)
C
25  DATA PJ /3.14156265/
C
C      STRUCTURAL COSTS
C
30  CSTRUC = ELENG * .2458 * PI/4 * DTOW**2 * ITOWN *
C      $ (.00695 * ROOFL + .726)
C
C      FOUNDATION COSTS
C
35  CFND = .019 * (WHX + WATERW) * .92 * PI/4 * DTOW**2 * ITOWN
C
C      STRUCTURAL WEIGHT OF COOLING TOWERS BASED ON 50.63/LB
C
C      WSTRC = CSTRUC / .63
C
40  C      STRUCTURAL COST TAKING INTO ACCOUNT DIRECT AND INDIRECT
C      CONSTRUCTION COSTS
C
C      CSTRUC = CSTRUC * POHSTC
45  RETURN
END

```

SUBROUTINE SURCON (ISUR, KGA, LD, TLA, XNTS, ARPS, XNS, CONCS
S, CONMAT, POHCND)

PROGRAM SURCON DETERMINES THE CAPITAL COST OF A SINGLE
PRESSURE OR SERIES-CONNECTED SURFACE CONDENSER. REFERENCE:
"SURFACE CONDENSERS FOR LAND INSTALLATION", FORM PL1312,
WESTINGHOUSE ELECTRIC CORPORATION, 26 NOVEMBER 1968
UPDATED ON FEBRUARY 12, 1975 TO CURRENT PRICES

DEFINITION OF VARIABLES

ACCF - ACCESSORY COST CORRECTION FACTOR FOR THE CONDENSER
ADDER - INCREASES COST OF TUBING MATERIAL
ARPS - AREA PER SHELL OF THE CONDENSER (SQ FT)
AUXCST - AUXILIARY COST (\$)
CFAC - LENGTH CORRECTION FACTOR (DIMENSIONLESS)
CONCST - CONDENSER COST (\$)
CONMAT - VARIABLE FOR CONDENSER MATERIAL (DIMENSIONLESS)
DSCT - QUANTITY DISCOUNT FOR TUBES (DIMENSIONLESS)
ERTCST - ERECTION COST (\$/SQ FT)
F - TUBING LENGTH PENALTY (DIMENSIONLESS)
FETCST - FIELD ERECTION COST (\$/SQ FT)
FOD - TUBE SIZE FACTOR (DIMENSIONLESS)
POHCND - INDIRECT COST FACTOR FOR THE TUBE, SHELL, AND
FIELD ERECTION COSTS (DIMENSIONLESS)
SHLCST - SHELL COST FOR THE CONDENSER (\$)
TOSTP - TOTAL COST OF TUBING MATERIAL (\$/FT)
WT - WEIGHT OF TOTAL AMOUNT OF TUBES IN THE CONDENSER
(LBF)
XNS - NUMBER OF SHELLS IN THE CONDENSER (DIMENSIONLESS)
XNTS - NUMBER OF TUBES PER SHELL (DIMENSIONLESS)

DEFINITION OF ARRAYS

TUBMA - TUBE MATERIAL (NAMES)
CL - TUBE FIXED COSTS (\$)
CLM - TUBE MATERIAL COSTS (\$/LBM)
ROEL - DENSITY OF TUBE MATERIALS (LBM/CU IN)
GAGLI - TUBE GAGE (DIMENSIONLESS)
THKLIN - THICKNESS OF TUBE (IN)
ODLINE - COMMON DIAMETERS OF TUBES (IN)

LOGICAL FIRST

DIMENSION XLCST(5,2), SCC1(5), SCC2(5)
DIMENSION TUBMA(13), CL(10), CLM(10), ROEL(10), GAGLI(7),
* THKLIN(7), ODLINE(6), FF(10,7)
COMMON /RPT3/ TUBCST,SHLCST,FETCST,CONBA7

TUBING MATERIALS, COSTS, AND DENSITY

DATA CL / 0.00, 0.00, 0.00, 0.09, 0.04, 0.39, 0.12, 0.20, 0.15,
* 0.10 /
DATA CLM / 1.30, 1.52, 1.83, 1.40, 1.36, 0.44, 0.32, 1.63, 7.60,
* 7.00 /
DATA ROEL / 0.303, 0.323, 0.323, 0.0975, .0975, 0.284, 0.284, .290
S .0.163, 0.163 /


```

60      DATA TUBMA / "ADMIRALTY ", "CU-10 NI ", "CU-30 NI ",
      *      "6061-T6 AL", "3003-H14 A", "STEEL SEAM",
      *      "STEEL WELD", "304 S/S WEL", "TITANIUM 1",
      *      "TITANIUM 2", "LINDE CS14", "LINDE AL12",
      *      "LINDE SS16"/

      C
      C      STANDARD TUBE DIAMETERS, GAGE, AND THICKNESSES
      C
65      DATA ONLINE / 0.625, 0.750, 0.875, 1.000, 1.125, 1.250 /
      DATA GAGLI / 12., 14., 16., 18., 20., 22., 24. /
      DATA THKLIN / .109, .083, .065, .049, .035, .028, .021 /

      C
      C      TUBING LENGTH PENALTIES
      C
70      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 /
75      DATA (FF(3,J),J=1,7) / 0.00, 0.00, 0.00, 0.00, 0.07, 0.08, 0.09 /

      C
      C      FOR ALUMINUM
      DATA (FF(4,J),J=1,7) / 1.00, 1.00, 1.06, 1.10, 1.14, 1.18, 1.22 /
      DATA (FF(5,J),J=1,7) / 1.00, 1.00, 1.06, 1.10, 1.14, 1.18, 1.22 /
80      C
      C      FOR STEEL
      DATA (FF(6,J),J=1,7) / 1.00, 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /
      DATA (FF(7,J),J=1,7) / 1.00, 1.00, 1.09, 1.13, 1.17, 1.21, 1.25 /

      C
      C      FOR STAINLESS STEEL
      DATA (FF(8,J),J=1,7) / 1.00, 1.00, 1.00, 1.04, 1.08, 1.12, 1.16 /

      C
      C      FOR TITANIUM
      DATA (FF(9,J),J=1,7) / 0.00, 0.00, 0.00, 1.05, 1.05, 1.10, 1.10 /
85      DATA (FF(10,J),J=1,7) / 0.00, 0.00, 0.00, 1.05, 1.05, 1.10, 1.10 /

      C
      C      CONSTANTS FOR COST EQUATION FOR BASIC CONDENSER SHELL AS A
      C      FUNCTION OF TUBE O.D. (UPDATED FEBRUARY, 1976)
      C
90      DATA SCC1 / 0.00000, 7.69583, 9.805882, 10.83636, 12.954545,
      *      15.22326 /
      DATA SCC2 / 00000.00, 97125.00, 102164.71, 102181.82, 103272.73,
      *      102237.21 /

      C
      C      COST OF FIELD ERECTION AND TUBING PER SQUARE FOOT OF
      C      SURFACE AREA IS BASED UPON INFORMATION SUPPLIED BY
      C      WESTINGHOUSE COMPANY AND AVERAGE WAGE LABOR RATES OBTAINED
      C      FROM JUNE 1975 CONSTRUCTION REVIEW
      C
100      DATA EATCST / 2.50 /

      C
      C      DATA FIRST/.TRUE./
      C
105      C
      C      DEFINING THE CASE UNDER CONSIDERATION
      C
110      IF (.NOT. FIRST) GOTO 55
      LFLAG=0
      DO 10 I = 1, 13
      ITUBMA = I

```

```

115      IF(CONMAT.EQ.TUBMA(I)) GO TO 55
10      CONTINUE
        WRITE(6,11)
        LFLAG=1
120      11 FORMAT(5X,"NO MATCH FOR CONDENSER TUBE MATERIAL")
        IF(LFLAG.NE.0) STOP
55      CONTINUE
        FIRST = .FALSE.

C
C      DETERMINE TOTAL LENGTH OF TUBING REQUIRED AND CORRESPONDING
125      QUANTITY DISCOUNT
C
C      TOTLT=TLA*XNTS*XNS
C
130      IF(TOTLT-60000.)102,101,101
101      DSCT=.04
        GO TO 103
102      IF(TOTLT-30000.)105,104,104
104      DSCT=.02
        GO TO 103
135      105 DSCT=.
103      IF(ITUBMA.GE.1) GO TO 107
        KK = 7
        DO 106 I = 2, 8
          IF(TLA.GE.(10.0*I)) KK = I - 2
140      106 CONTINUE
        F = FF(ITUBMA, KK)
        ADDER = 0.00
        IF(ITUBMA.LT. 4) ADDER = F
        IF(ITUBMA.LT. 4) F = 1.00
145      C
C      DETERMINE TOTAL COST OF TUBING MATERIAL
C
        WT = 12. * 3.14159 * ROEL(ITUBMA) * (ODLINE(LD)-THKLIN(NGA))
        S * THKLIN(KGA)
150      TCSTPF = CLM(ITUBMA)*WT * CL(ITUBMA)
        TCSTPF = TCSTPF*F + ADDER
C
C      TUBE COST ARE F.O.B. COSTS, 1.11 ACCOUNTS FOR PURCHASING
        AND SHIPPING
155      C
        TUBCST = TOTLT * TCSTPF * (1.11 - DSCT) * 1.05
        GO TO 110
C
C
160      107 GO TO (108,109,114), ITUBMA-10
108      TUBCST = TOTLT*1.5*1.05*(1.11-DSCT)
        GO TO 110
109      TUBCST = TOTLT*1.6*1.05*(1.11-DSCT)
        GO TO 110
165      114 TUBCST = TOTLT*2.5*1.05*(1.11-DSCT)
110      TUBCST = TUBCST * POHCND
C
C      DETERMINE SHELL COST INCLUDING LENGTH, MULTIPRESSURE, AND
        ACCESSORY COST CORRECTIONS, AS APPROPRIATE
170      C
        CFAC = .016 * TLA * .58

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```

111 GO TO(100,111,112,113)+ISUR
    CFAC=CFAC+0.08
    GO TO 100
175 112 CFAC=CFAC+0.16
    GO TO 100
    113 CFAC=CFAC+0.03+XNS*0.02
C
180 100 FOD = 1.00
    IF(LD .LT. 4) FOD = 0.95
    IF(LD .EQ. 6) FOD = 1.05
    ACCFI = (0.116*ALOG(XNTS) - 0.485)*FOD
    IF(ITU=MA .EQ. 2) ACCF = (0.239*ALOG(XNTS) - 1.416)*FOD
C
195 C THE CONDENSER SHELL COSTS WERE OBTAINED FROM WESTINGHOUSE'S
    C 1973 PRICE LISTING 1312
    C
    AUXCST = 0.45*ARPS*XNS
    BSHCST = (SCC1(LD)*XNTS + SCC2(LD))
190 SHLCST=BSHCST*(CFAC+ACCF)*XNS + AUXCST
    SHLCST = SHLCST + 1.05
    SHLCST = SHLCST + POHCND
C
195 C DETERMINE COST OF FIELD ERECTION AND TUBING
    C
    FETCST=ERTCST*ARPS*XNS
    FETCST = FETCST + 1.05
    FETCST = FETCST + POHCND
C
200 C DETERMINE TOTAL COST OF CONDENSER
    C
    CONCST=TUBCST+SHLCST+FETCST
    CONBAT=CONCST
C
205 RETURN
    END

```

```

      FUNCTION TLU(X,XT,YT,NT)
      C
      C      FUNCTION TLU IS A FOUR-POINT LAGRANGIAN INTERPOLATION
      C      TABLE LOOK-UP ROUTINE
      C
      C      DEFINITION OF VARIABLES
      C
      C      NT      - NUMBER OF DATA POINTS
      C      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 103
      C      107 IF(I-NT)108,109,109
      C      109 I=I-1
      C
      C      DETERMINE FUNCTION VALUES 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=(X-X2)*(X-X3)*(X-X4)/((X1-X2)*(X1-X3)*(X1-X4))*YT(I-2)
          S  + (X-X1)*(X-X3)*(X-X4)/((X2-X1)*(X2-X3)*(X2-X4))*YT(I-1)
          S  + (X-X1)*(X-X2)*(X-X4)/((X3-X1)*(X3-X2)*(X3-X4))*YT(I)
          S  + (X-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//
          S  5X,3HX =,F15.5,5X,7HXT(1) =,F15.5,5X,7HYT(1) =,F15.5)
75      C
          STOP
          END

```

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

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SUBROUTINE VARIT DETERMINES THE PERFORMANCE OF AN OPTIMUM
 POWER PLANT FOR A SPECIFIED AMBIENT TEMPERATURE. THE
 SUBROUTINE ALSO DETERMINES THE INCREMENTAL COST OF
 OPERATING THE OPTIMUM POWER PLANT AT THAT AMBIENT
 TEMPERATURE.

DEFINITION OF VARIABLES

CAPCHG - CAPACITY CHARGE (\$/MEGAWATT)
 CAPCST - CAPITAL COST FOR AUXILIARY POWER (\$)
 CAPF - CAPACITY FACTOR (DIMENSIONLESS)
 CCOS1 - COST OF THE HEAT EXCHANGER AT OPTIMUM DESIGN CON-
 DITIONS (\$)
 CLAND1 - COST OF THE LAND AT OPTIMUM DESIGN CONDITIONS (\$)
 CLSUM - SUM OF THE PRODUCT BETWEEN THE AUXILIARY POWER
 COST AND THE FRACTION OF THE YEAR THAT THE
 AMBIENT TEMPERATURE EXISTS (MILLS/KWH)
 CONSA1 - COST OF THE CONDENSER/REBOILER AT OPTIMUM DESIGN
 CONDITIONS (\$)
 COSM1 - MAINTENANCE COST AT OPTIMUM DESIGN CONDITIONS
 (MILLS/KWH)
 CPA - SPECIFIC HEAT OF THE AIR (BTU/LBM-DEG F)
 CPIPE1 - COST OF THE PIPING AT OPTIMUM DESIGN CONDITIONS (\$)
 CSTCL - AUXILIARY POWER COST (MILLS/KWH)
 DELFC - INCREASED FUEL COST FOR THE PLANT (MILLS/KWH)
 DELPS1 - PRESSURE DROP IN THE SUPPLY PIPING AT THE OPTIMUM
 DESIGN CONDITIONS (LBF/SQ FT)
 DELPS2 - PRESSURE DROP IN THE SUPPLY PIPING AT THE OFF DE-
 SIGN CONDITIONS (LBF/SQ FT)
 DENSIV - DENSITY OF THE VAPOR LEAVING THE CONDENSER/REBOILER
 AT OPTIMUM DESIGN CONDITIONS (LBM/CU FT)
 DENSIV2 - DENSITY OF THE VAPOR LEAVING THE CONDENSER/REBOILER
 AT OFF DESIGN CONDITIONS (LBM/CU FT)
 EFF - EFFECTIVENESS OF THE HEAT EXCHANGER (DIMENSIONLESS)
 EFF1 - EFFECTIVENESS OF THE HEAT EXCHANGER AT OPTIMUM
 DESIGN CONDITIONS (DIMENSIONLESS)
 FCOS - FUEL COST (\$/MM BTU)
 FCR - FIXED CHARGE RATE (DIMENSIONLESS)
 FCSUM - SUM OF THE PRODUCT BETWEEN THE FUEL COST INCREASE
 FOR THE PLANT DUE TO THE OFF DESIGN CONDITIONS
 AND THE FRACTION OF THE YEAR THAT THE AMBIENT
 TEMPERATURE EXISTS (MILLS/KWH)
 FPOW1 - FAN POWER AT OPTIMUM DESIGN CONDITIONS (KWH)
 HFG2 - HEAT OF VAPORIZATION AT OFF DESIGN CONDITIONS
 (BTU/LBM)
 HRFAC1 - HEAT RATE FACTOR AT RATING CONDITION (DIMENSIONLESS)
 HRFAC2 - HEAT RATE FACTOR AT DESIGN CONDITIONS (DIMENSION-
 LESS)
 HRFAC4 - HEAT RATE FACTOR AT OFF DESIGN CONDITIONS
 (DIMENSIONLESS)
 HRFA2S - HEAT RATE FACTOR AT OPTIMUM DESIGN CONDITIONS (DI-
 MENSIONLESS)
 HXITD - HEAT EXCHANGER ITD AT OFF DESIGN CONDITIONS (DEG F)
 HXLMTD - HEAT EXCHANGER LOG MEAN TEMPERATURE DIFFERENCE
 AT OFF DESIGN CONDITIONS (DEG F)

	C	P	- BACK PRESSURE OF THE TURBINE (IN HGA)
60	C	POST	- PERCENT OF THE YEAR AT THE SPECIFIED AMBIENT
	C		TEMPERATURE TIMES THE INCREMENTAL COST AT THIS
	C		TEMPERATURE (MILLS/KWH)
	C	PGEN	- POWER GENERATING BY THE PLANT (MEGAWATTS)
	C	PQOW1	- PUMP POWER AT OPTIMUM DESIGN CONDITIONS (KWH)
	C	PSIZE	- PLANT SIZE (MEGAWATTS)
65	C	PTOT	- TOTAL POWER OUTPUT OF PLANT AT OFF DESIGN
	C		CONDITIONS (MEGAWATTS)
	C	PWCOS	- REPLACEMENT POWER COST (MILLS/KWH)
	C	P12	- AMMONIA PRESSURE AT THE CONDENSER/REBOILER (LBF/
	C		SQ FT)
70	C	P22	- AMMONIA PRESSURE AT THE HEAT EXCHANGER (LBF/SQ FT)
	C	QIN1	- HEAT INPUT INTO THE OPTIMUM POWER PLANT (BTU/HR)
	C	QREJCT1	- HEAT REJECTED AT THE OPTIMUM DESIGN CONDITIONS OF
	C		THE PLANT (BTU/HR)
	C	QREJCT2	- HEAT REJECTED AT THE OFF DESIGN CONDITIONS OF THE
75	C		PLANT
	C	RANGE1	- TEMPERATURE RANGE OF THE AIR AT OPTIMUM DESIGN
	C		CONDITIONS (DEG F)
	C	RANGE2	- TEMPERATURE RANGE OF THE AIR AT THE OFF DESIGN
	C		CONDITIONS (DEG F)
80	C	SPCD1	- DIFFERENTIAL COST OF PLANT EXCLUDING THE COOLING
	C		SYSTEM AT OPTIMUM DESIGN CONDITIONS (\$)
	C	SPS13	- TOTAL POWER OUTPUT OF PLANT AT OPTIMUM DESIGN
	C		CONDITIONS (MEGAWATTS)
	C	TA	- AMBIENT TEMPERATURE (DEG F)
85	C	TAMM	- TEMPERATURE OF THE AMMONIA LEAVING THE CONDENSER/
	C		REBOILER AT THE OPTIMUM DESIGN CONDITIONS FOR THE
	C		PLANT (DEG F)
	C	TCOS	- INCREMENTAL INCREASE IN COST OF THE POWER PRODUCED
	C		BY THE OPTIMUM POWER PLANT DUE TO THE COOLING
90	C		SYSTEM (MILLS/KWH)
	C	Td	- DESIGN AMBIENT TEMPERATURE (DEG F)
	C	TEFF	- BASE THERMAL EFFICIENCY OF THE PLANT (DIMENSIONLESS)
	C	TEFF1	- RATED THERMAL EFFICIENCY OF THE PLANT
	C		(DIMENSIONLESS)
95	C	TEFF3	- DESIGN THERMAL EFFICIENCY OF THE OPTIMUM PLANT
	C		(DIMENSIONLESS)
	C	TEFF4	- OFF DESIGN THERMAL EFFICIENCY OF THE PLANT
	C		(DIMENSIONLESS)
	C	Ti	- TEMPERATURE OF THE AMMONIA AT THE INLET TO THE
100	C		HEAT EXCHANGER (DEG F)
	C	TPER	- FRACTION OF THE YEAR THAT THE CORRESPONDING
	C		AMBIENT TEMPERATURE EXISTS (DIMENSIONLESS)
	C	TTD1	- TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
105	C		STEAM AND AMMONIA IN THE CONDENSER/REBOILER
	C		AT DESIGN CONDITIONS (DEG F)
	C	TTD11	- TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
	C		STEAM AND AMMONIA IN THE CONDENSER/REBOILER
	C		AT OPTIMUM DESIGN CONDITIONS (DEG F)
	C	TTD12	- TEMPERATURE DIFFERENCE BETWEEN THE SATURATED
110	C		STEAM AND AMMONIA IN THE CONDENSER/REBOILER
	C		AT OFF DESIGN CONDITIONS (DEG F)
	C	TTD2	- TEMPERATURE DROP OF THE AMMONIA IN THE SUPPLY
	C		PIPING (DEG F)
	C	TTD21	- TEMPERATURE DROP OF THE AMMONIA IN THE SUPPLY

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115      C      PIPING AT OPTIMUM DESIGN CONOTIONS (DEG F)
      C      TTD22 - TEMPERATURE DROP OF THE AMMONIA IN THE SUPPLY
      C      PIPING AT OFF DESIGN CONDITIONS (DEG F)
      C      TI - SATURATED STEAM TEMPERATURE IN THE CONDENSER/
120      C      REBOILER (DEG F)
      C      W31 - MASS FLOW RATE OF AMMONIA AT OPTIMUM DESIGN
      C      CONDITIONS (LBM/HR)
      C      W32 - MASS FLOW RATE OF AMMONIA AT OFF DESIGN CONDITIONS
      C      (LBM/HR)
      C      W41 - MASS FLOW RATE OF AIR THROUGH THE HEAT EXCHANGER
125      C      AT OPTIMUM DESIGN CONDITIONS (LBM/HR)
      C      YFPMIN - OPTIMUM PLANT SCALING FACTOR FOR FAN AND PUMP
      C      POWER LOSS (DIMENSIONLESS)
      C
      LOGICAL FIRST, FXTMP
130      COMMON
      S ,AFTR, ALPHA, ANG(3)
      S ,CAPF, C5SPKW, CONF, CONL, COSTL, CAPCHG, CONMAT, CONMA2, CAFI
      S ,CDU, CTUR3, CDANG, CLUVR, CHAILS, CVM
      S ,DANGLE, DFIN, DEEPL, DESVEL, DESVELV
135      S ,EFFP
      S ,FCR, FIRST, FIXL, FCOS, FFHX, FXTMP
      S ,GBEFF
      S ,HXVP, HPCST
      S ,ITMAX, ITMIN
140      S ,JCONS
      S ,KCONV, KALEXT
      S ,MXEXT
      S ,NTUCAL(2), NTA
      COMMON
145      S ,ODR
      S ,PSIZE, PER, PWCOS, PLANC, PFACT, POMDPLI
      S ,POHBAF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCB
      S ,REP, REDUCE, REDUCV, ROQFLI
      S ,GREU, GREduce, GREduceV
150      S ,SIGMA6, SAAF
      S ,TD, TPO(4), TEFF, TLI4, THFIN, TLPRA, TFIx
      S ,TCD, TW
      S ,UCS, UWS
      S ,WTV
155      S ,VAS(5)
      S ,XDEPA, XW, XD
      COMMON /SCALER, HRFAC1, ATUB, OPERA, SSCD, PLANC1, CASSSI,
      S ,GAIR, FAIR, HPAIR, HPWAT, WL RTP, PLANC1
      COMMON /SUPPLY, VAL(5), CPLN, CPIP, CCOS, W3, COBM, EFF,
160      S ,QIN, CLAND, REAIR, Z, HRFAC2, W4, U, DELPW, PPOW,
      S ,FPOW, DELFC, WIDTH, ELENG, VAIR, VBAT, HI, HO, T4,
      S ,REWAT, NW, NT, NP, PLANC2, PSIZ12, SPBP, SW4, SW3,
      S ,SPC, PTOTAL, PLANC3, SAFRON, AAIR, YFP, SPCD, PSIZ13, WT2,
      S ,BP2, VW2, TCOS, DELPA, DELPWT, DELPW, CONBAS, XNTSX, VELDX
165      S ,TLAX, UCON, PMOST, FMOST, FBACC, EFFC, CH, CA, CS
      S ,CLTC, CFC, CPCC, FITCO, CSC, CEPREP, DELPID, AST, OLDCST
      S ,CAPCST, XNFAN, BLDANG, CPLEN, DPFEI, WHX, WTTUB, ADIA, ABLN
      S ,WTHAR, WTERM, STRUCC, CPERF, HPPERF, TOTCF, TPC, EFFIN, ANTU
      S ,AIRFF, WATFF, XNMOD, TOTPF, FOCPE, FMTRC, ACCTP, ADJTP
170      S ,ACTBPD, ADJBPD, ACTVH, ADJVH, ADJPPF, THPAIR, TCTF, AFCST
      S ,CSRD, WATERW, WSTRCT, CFOUND, HJBDIA, TOWLEN, NUMTOW, CTOWD

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175 S, SQRJ, SQRJS, ATUBC, CBA, TTD1, TTD2, DELPS, CSTLVR
S, CSTHS, CYLRNG, CFANEL, PSTACS, PUFITC, PMPST, RPTPL, SEPCST
COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,
S QIN1, CLAN1, REA11, Z1, HRFA2S, W41, U1, DEPW1, PPOW1,
S FPOK1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, HI1, HO1, T41,
S REWA1, NW1, NT1, NP1, ZPLNC2, ZSIZ12, ZSPDE, SW41, SW31,
S SPC1, PTOT1, PLNC31, AFRO1, AAIR1, YFPMIN, SPCD1, SPS13, WT2MIN,
S B22MIN, NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1, CONBA1, XNTS1, VELD1
180 S, TLA1, UCON1, PMCS1, FMCS1, FBAC1, EFFC1, CH1, CA1, CSI
S, CLT1, CFC1, CPC1, FITC1, CSC1, CEPRE1, DEPI1, AST1, OLOC1
S, CAPCS1, XNFAN1, BLOAN1, CPLEN1, DPFE1, WH1, WTTU1, AD11, AB11
S, WTHD1, WTER1, STRUC1, CFMPF1, HPPF1, TOTCF1, TP1, EFFIN1, ANTU1
185 S, AIRFF1, WATFF1, XNMOD1, TCTPF1, FOCPF1, FMTRC1, ACTTP1, ADJTP1
S, ACTBP1, ADJBP1, ACTVH1, ADJVH1, ADJPP1, THPA1, TCTF1, AFCST1
S, CSRI, WATER1, WSTRC1, CFOUN1, HUBD1, TOWLE1, NUMTOL, CTOWD1
S, SQRJ1, SQRJS1, ATUBC1, CBA1, TTD11, TTD21, DELPS1, CSTLVR1
S, CSTHS1, CYLRN1, CFANEL, PSTAC1, PUFIT1, PMPCS1, RPTPL1, SEPC1
190 COMMON /TINE/ XNS, TLA, XNTS, ARPS, TTD2DE, LINDR, XNP, XQUALY
COMMON /PROP/ CPW, THCONW, DENSIW, VISW, HFG,
* CPV, THCONV, DENSV, VISV, SIGMA,
* CPA, THCONA, DENSA, VISA

C
C      DESIGN THERMAL EFFECTIVENESS OF THE POWER PLANT
195 TEFF3=TEFF/HRFA2S

C
C      RATED THERMAL EFFECTIVENESS OF THE POWER PLANT
TEFF1=TEFF/HRFAC1

C
C      HEAT INPUT INTO THE POWER PLANT
200 QIN1=3413.E+3 * SPS13/TEFF1

C
C      HEAT REJECTED AT THE DESIGN THERMAL EFFECTIVENESS OF
C      THE POWER PLANT
205 QREJCT1 = QIN1*(1. - TEFF3)
RANGE = VAR(2)
TAMM = TD + RANGE/EFF1 + TTD21
DENSIW = FLUID(7,1,TAMM,ELEV,"CALC25")

C
C      INITIAL GUESS AT THE SATURATION TEMPERATURE FOR THE ABOVE
C      AMBIENT TEMPERATURE
210 T1 = TA + RANGE/EFF + TTD1 + TTD2

C
C      BACK PRESSURE AT THE SATURATION TEMPERATURE
215 S P = EXP((17.168-9240.)/(T1+460.))

C
C      HEAT RATE FACTOR AT THE ABOVE BACK PRESSURE
HRFAC4=TPO(1)+TPO(2)*P+TPO(3)*P**2+TPO(4)*P**3

C
C      THERMAL EFFECTIVENESS OF THE PLANT AT THE ABOVE BACK
C      PRESSURE
220 TEFF4=TEFF/HRFAC4

C
C      HEAT REJECTED AT THE ABOVE THERMAL EFFECTIVENESS OF THE
C      POWER PLANT
225 QREJCT2 = QIN1*(1. - TEFF4)

C
C      TEMPERATURE DIFFERENCE BETWEEN THE SATURATED STEAM AND

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230 C THE AMMONIA IN THE CONDENSER/REBOILER
    TTD12 = (QREJCT2/QREJCT1) * TTD11
C
C PRESSURE OF THE AMMONIA LEAVING THE CONDENSER/REBOILER
P12 = FLUID(10,1,T1-TTD12,ELEV,"CALC 22")
HFG2 = FLUID(9,1,T1-TTD12,ELEV,"CALC 20")
235 DENSIV2 = FLUID(7,1,T1-TTD12,ELEV,"CALC 21")
C
C MASS FLOW RATE OF AMMONIA THROUGH THE COOLING SYSTEM
W32 = QREJCT2/HFG2
C
C PRESSURE DROP OF AMMONIA THROUGH THE SUPPLY PIPING
240 DELPS2 = DELPS1 * (W32**2 * DENSIV/(DENSIV2 * W31**2))
C
C PRESSURE AT THE END OF THE SUPPLY PIPING
P22 = P12 - DELPS2/144.
245 T1 = T1 - TTD1 - TTD2
    DELTI = .001
C
C LOOP TO DETERMINE THE TEMPERATURE OF THE AMMONIA AT THE
    END OF THE SUPPLY PIPING
250 10 FTI = -P22 + FLUID(10,1,T1,ELEV,"CALC 23")
    FTIDEL = -P22 + FLUID(10,1,T1+DELT1,ELEV,"CALC 24")
    TIPI = T1 - DELTI*FTI/(FTIDEL - FTI)
    IF(ABS(TIPI - T1).LT..0001) GO TO 20
    T1 = TIPI
255 GO TO 10
C
C TEMPERATURE DROP IN THE AMMONIA FROM THE BEGINNING TO THE
    END OF THE SUPPLY PIPING
260 20 TTD22 = T1 - TTD12 - TI
C
C TEMPERATURE RANGE OF THE AIR
RANGE2 = QREJCT2 / (W41 * (1.+YFPMIN) * CPA)
C
C SATURATION TEMPERATURE OF THE STEAM IN THE CONDENSER/
    REBOILER
265 T11 = RANGE2/EFF1 + TA + TTD12 + TTD22
C
C CONVERGENCE CRITERIA FOR THE SATURATION TEMPERATURE OF
    THE STEAM IN THE CONDENSER/REBOILER
270 IF(.NOT. FXTMP .AND. (T11-T1)**2 .LE. .001) GOTO 40
    IF( FXTMP .AND. ABS((T11-T1)/T11) .LT. 0.0001) GOTO 40
    T1 = T11
    GO TO 5
C
C POWER OUTPUT OF THE LOW-PRESSURE TURBINE AT THE SPECIFIC
    AMBIENT TEMPERATURE
275 40 PTOT = QIN1 * TEFF4/3413.E+3
C
C POWER OUTPUT OF THE PLANT AT THE SPECIFIC AMBIENT TEM-
    PERATURE
280 PGEN = PTOT - PPOW1/1000. - FPOW1/1000.
    TEFFD=TEFF4
    IF(PGEN.GE.PSIZE) GO TO 50
C
C COST OF THE AUXILIARY POWER REQUIRED TO MAKE UP FOR LOST
285

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C          CAPACITY ON HOT DAYS
C          CSTCL=(PSIZE-PGEN)/PSIZE*PWCOS
C          TEFFD=TEFF3
C          GO TO 60
290      50 CSTCL = 0.0
C
C          INCREASED FUEL COST OF THE PLANT DUE TO OFF DESIGN
C          CONDITIONS
C          60 DELFC = FCOS*3413.E-5 * ((1.+YFPMIN)/TEFFD-1./TEFF)
295      C
C          IF(KALL.NE.1) GO TO 70
C          CAPCST=0.0
C          IF(PSIZE.LE.PGEN) GO TO 70
C
C          CAPITAL CHARGE FOR THE AUXILIARY POWER
C          CAPCST=CAPCHG*(PSIZE-PGEN)
300      70 CONTINUE
C
C          INCREASE IN COST OF OPERATING THE PLANT AT THIS AMBIENT
C          TEMPERATURE DUE TO THE USE OF THE COOLING SYSTEM
C          TCOS = (CCOS1+SPCD1+CLAN1+CPIP1+CONBA1+CAPCST)*FCO/(PSIZE+CAPP+
305      $ 8750.) + COSM1*DEFLC+CSTCL
C
C          FRACTION OF THE YEAR THAT THIS AMBIENT TEMPERATURE EXISTS
C          TIMES THE INCREMENTAL COST OF THE COOLING SYSTEM AT
C          THIS AMBIENT TEMPERATURE
310      PCST=TPER*TCOS
C
C          SUM OF THE PRODUCT BETWEEN THE AUXILIARY POWER COST AND
C          THE FRACTION OF THE YEAR THAT THE AMBIENT TEMPERATURE
C          EXISTS
315      CLSUM = CLSUM + CSTCL * TPER
C
C          SUM OF THE PRODUCT BETWEEN THE FUEL COST INCREASE FOR THE
C          PLANT DUE TO THE OFF DESIGN CONDITIONS AND THE FRACTION
C          OF THE YEAR THAT THE AMBIENT TEMPERATURE EXISTS
320      FCSUM = FCSUM + DELFC * TPER
C          IDB3=0
C          IF(IDB3.EQ.0) GOTO 800
325      935 FORMAT(T2,F6.1, T10,F6.1, T19,F5.2, T26,F7.4, T33,F7.3
C          $,T41,F5.3, T47,F7.2, T54,F7.2, T62,F8.3, T72,F7.5, T81,G11.5,
C          $ T93,F7.4, T106,F7.3, T115,G11.5)
C          936 FORMAT(1H0)
330      937 FORMAT(1X,"HRFAC4=",G11.5,T24,"TEFF4=",G11.5,T46,"QREJ=",G11.5,
C          $ T65,"RANGE=",G11.5,T85,"VAR(3)=",G11.5,T108,"T11=",G11.5,
C          $ 1X,"PTOTAL=",G11.5,T25,"PGEN=",G11.5,T46,"PPOW=",G11.5,
C          $ T65,"FPOW=",G11.5,T97,"QINI=",G11.5,
C          $ 1X," TEFF3=",G11.5,T24,"TEFF1=",G11.5,T44,"YFPMIN=",G11.5)
C          WRITE(6,936)
335      WRITE(6,937) HRFAC4,TEFF4,QREJ,RANGE,VAR(3),T11,PTOTAL,PGEN,
C          $ PPOW,FPOW,QINI,TEFF3,TEFF1,YFPMIN
C          WRITE(6,938) HRFAC2,TEFF,HRFAC,HRFAC1,TEFFD,CCOS1,SPCD1,CLAN1,
C          $ CPIP1,COSM1
340      938 FORMAT(1X,"HRFAC2=",G11.5,T25,"TEFF=",G11.5,T45,"HRFAC=",G11.5,
C          $ T64,"HRFAC1=",G11.5,T86,"TEFFD=",G11.5,T106,"CCOS1=",G11.5,
C          $ 1X," SPCD1=",G11.5,T24,"CLAN1=",G11.5,T45,"CPIP1=",G11.5,T65,
C          $ "COSM1=",G11.5)

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939 FORMAT(T2,"TAI,TAO,TAMM,T11,RANGE,TTD1",6G15.6)
800 CONTINUE
345 TAMM = T1 - TTD12 - TTD22
    HXITD = T1 - TTD12 - TTD22 - TA
    IF(RANGE2.GE.HXITD) WRITE(6,939)TA,TA+RANGE2,TAMM,T11,RANGE2,TTD12
    IF(RANGE2.GE.HXITD) GO TO 810
    HXLMTD = RANGE2/ALOG(HXITD/(HXITD + RANGE2))
350 810 CONTINUE
    WRITE(4,935) TA
    $,T1
    $,P
    $,HREFAC
355 $,RANGE2
    $,TTD12
    $,HXLMTD
    $,HXITD
    $,PGEN
360 $,DELEFC
    $,CSTCL
    $,TCDS
    $,TPER = 100.
    $,PCST
365 IF(IDBG.EQ.0) RETURN
    RETURN
    END
```

SUBROUTINE XTEND(L)

THIS ROUTINE CHECKS EXTREME VALUES AT MINIMAL COST POINT.

C
C
C

5

DIMENSION TTRY(2),RTRY(2),CTRY(2),ATRY(2),WTRY(2)
COMMON /SINK/ VAR(5), CPLN1, CPIP1, CCOS1, W31, COSM1, EFF1,

\$ QIN1, CLAN1, REA11, Z1,HRFA2S, W41, U1, DEPW1, PPW1,

\$ FPOW1, DEFC1, WIDT1, ELEN1, VAIR1, VWAT1, HI1, HO1, T41,

\$ REWA1, NW1, NT1, NP1,ZPLNC2,ZSIZ12,ZSPBP, SW41, SW31,

10

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

\$ BP2MIN,NW2MIN, TCOS1, DEPA1, DPWT1, DPWC1,CONBA1, XNTS1, VELD1

\$, TLX1, UCON1, PMCS1, FMCST, FBACC, EFFC1, CH1, CA1, CS1

\$, CLTC1, CFC1, CPCC1,FITC1, CSC1,CEPRE1,DEPIP1, AST1,OLDCCS1

\$,CAPCS1,XNFAN1,BLDAN1,CPLEN1,DPFEL1, WH1, WTTU1, ADIA1, ABL1

15

\$, WTHD1, WFER1,STRUC1,CFMPF1, HPPF1,TOTCF1, TPC, EFFIN1, ANTU1

\$, AIRFF1, WATFF1, XNM0D1, TCTPF1, FDCPF1, FMTRC1, ACCTTP1, ADJTP1

\$, ACTBP1, ADJBP1, ACTVH1, ADJVV1, ADJPP1, THPA1, TCTF1, AFCST1

\$, CSR1, WATER1, WSTRC1, CFOUN1, HUBD11, TOWLE1, NUMT01, CTOWD1

20

\$, SGRJ1, SGRJ5, ATUBC1, CBA1, ITD11, ITD21, DELPS1, CSTLV1

\$, CSTH1, CYLRN1, CFANEL1, PSTAC1, PUFIT1, PMPC1, RPTPL1, SEPC1

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

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

\$ FPOW, DELFC, WIDTH, ELEN, VAIR, VWAT, HI, HO, T4,

25

\$ REWA, NW, NT, NP,PLANC2,PSIZ12, SPBP, SW4, SW3,

\$ SPC,PTOTAL,PLANC3,SAFRON, AAIR, YFP, SPCD,PSIZ13, NT2,

\$ BP2, NW2, TCOS, DELPA,DELPA1,DELPA2,CONBAS, ANISX, VELDX

\$, TLAX, UCON, PMCST, FMCST, FBACC, EFFC, CH, CA, CS

\$, CLTC, CFC, CPCC, FITC, CSC,CEPREP,DELP1, AST,OLDCCST

30

\$,CAPCST,XNFAN,BLDANG,CPLEN,DPFEL, WHX, WTTU, ADIA, ABLV

\$, WTHD, WFER,STRUC,CFPERF,HPPERF, TOTCF, TPC, EFFIN, ANTU

\$, AIRFF, WATFF, XNM0D, TCTPF, FDCPF, FMTRC, ACCTTP, ADJTP

\$, ACTBP, ADJBP, ACTVH, ADJVV, ADJPP, THPA, TCTF, AFCST

\$, CSRD, WATERW, WSTRCT, CFOUND, HUBDIA, TOWLEN, NUMTOW, CTOWD

35

\$, SGRJ, SGRJ5, ATUBC, CBA, ITD1, ITD2, DELPS, CSTLV

\$, CSTH, CYLRNG, CFANEL, PSTACS, PUFITC, PMPCST, RPTPL, SEPCST

COMMON /TINE/ XNS, TLX, XNTS, ARPS, ITD2QE, LENOR, XNP, XQUALY

LOGICAL FIRST, FXTMP

COMMON

40

\$ AFTR, ALPHA, ANG(3)

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

\$,CBJ, CTURB, CDANG, CLUVR, CHA15, CVM

\$,DANGLE, DFIN, DEEPL, DESVEL, DESVELV

\$,EEFP

45

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

\$,GBEFF

\$,HXNP, HPCST

\$,ITHAX, ITMIN

\$,JCONS

50

\$,KCONV, KALEXT

\$,MXEXT

\$,NTUCAL(2), NTA

COMMON

\$ ORP

55

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

\$,POH3AF, POHFAN, POHLEC, POHCIR, POHCND, POHSTC, POHSCL

\$,RBP, REDUCE, REDUCV, ROOFL

\$,PREU, PREDUCE, QREDUCV

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      $ ,SIGMAG, SAAF
      $ ,TD, TPO(4), TEFF, TLIM, THEIN, TLPRA, TFIX
60      $ ,TCD, TW
      $ ,UCS, UWS
      $ ,WFW
      $ ,VAS(5)
      $ ,XDEPA, XW, XD
65      COMMON /LACALL/ SRN
      TTRY(1)=VAR(1)-20.
      IF (TTRY(1).LE.0.0) TTRY(1)=10.
      TTRY(2)=VAR(1)+20.
      IF (TTRY(2).GE.170.) TTRY(2)=170.
70      IF (XTEMP) TTRY(1) = TFIX
      IF (XTEMP) TTRY(2) = TFIX
      CTRY(1)=VAR(3)-3.
      IF (CTRY(1).LE.0.) CTRY(1)=.5
      CTRY(2)=VAR(3)+2.
75      ATRY(1)=VAR(4)*4.
      ATRY(2)=VAR(4)/4.
      WTRY(1)=VAR(5)+40.
      WTRY(2)=VAR(5)/3.
      DO 3 I=1,2
80      RANGL = TTRY(I) - VAR(3) - TTD2QE - TD
2      RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
      SRN="/XTEND-1/"
      DO 3 I=1,2
85      CALL CALC(TTRY(I),RTRY(IR),VAR(3),VAR(4),VAR(5),1)
      IF (KCONV.EQ.1) GO TO 3
      IF (DELPA.LE.XDEPA) GO TO 3
      IF (TCOS.GT..99*TCOS1) GO TO 3
      TCOS1=TCOS
90      VAS(1)=TTRY(I)
      VAS(3)=VAR(3)
      VAS(4)=VAR(4)
      VAS(5)=VAR(5)
      L=1
95      3 CONTINUE
      DO 10 I=1,2
      RANGL = VAR(1) - CTRY(I) - TTD2QE - TD
9      RTRY(1)=.9*RANGL
      RTRY(2)=.7*RANGL
100      SRN="/XTEND-3/"
      DO 10 IR=1,2
      CALL CALC(VAR(1),RTRY(IR),CTRY(I),VAR(4),VAR(5),I)
      IF (KCONV.EQ.1) GO TO 10
      IF (DELPA.LE.XDEPA) GO TO 10
105      IF (TCOS.GT..99*TCOS1) GO TO 10
      TCOS1=TCOS
      VAS(1)=VAR(1)
      VAS(3)=CTRY(I)
      VAS(4)=VAR(4)
110      VAS(5)=VAR(5)
      L=1
10 CONTINUE
      DO 11 I=1,2
      CALL CALC(VAR(1),VAR(2),VAR(3),ATRY(I),VAR(5),2*I)

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115      IF (KCONV.EQ.1) GO TO 11
          IF (DELPA.LE.XDEPA) GO TO 11
          IF (TCOS.GT..99*TCOS1) GO TO 11
          TCOS1=TCOS
          VAS(1)=VAR(1)
120      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
          IF (DELPA.LE.XDEPA) GO TO 12
130      IF (TCOS.GT..99*TCOS1) GO TO 12
          TCOS1=TCOS
          VAS(1)=VAR(1)
          VAS(3)=VAR(3)
          VAS(4)=VAR(4)
135      VAS(5)=WTRY(I)
          L=L+1
12 CONTINUE
          IF (L.EQ.1) WRITE(6,13)
13 FORMAT(" XTEND CALLED, AND CHANGE MADE")
          IF (L.EQ.1) KALEXT = KALEXT + 1
          IF (KALEXT.GT.MXEXT) STOP "CALLS TO S.R. XTEND EXCEED MXEXT"
          RETURN
          END
```

```
      SUBROUTINE ERRMSG (KEY)
C
C      IF KEY IS 1 INCREMENT THE COUNTER FOR NO FAN FOUND
C      IF KEY IS 2 INCREMENT THE LOOP COUNTER
5      IF KEY IS 3 PRINT THE COUNTERS
C
      IF (KEY .EQ. 1) NFKTR = NFKTR + 1
      IF (KEY .EQ. 2) LPKTR = LPKTR + 1
      IF (MOD (LPKTR,20) .EQ. 0 .AND. LPKTR .GT. 0) WRITE(6,200) LPKTR
10      IF (KEY .EQ. 3) WRITE(6,100) NFKTR, LPKTR
      100 FORMAT(//////" THE NUMBER OF TIMES NO FAN WAS FOUND ",I20/
        $" THE NUMBER OF TIMES LOOP ESCAPE WAS REQUIRED =",I20)
      200 FORMAT(1X,I5," FAN LOOP ESCAPES REQUIRED SO FAR")
      RETURN
15      END
```