Computer Simulation and Optimization of a Refrigeration System

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COMPUTER SIMULATION AND OPTIMIZATION OF A REFRIGERATION SYSTEM

by

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APPENDIX-9

LISTING OF COMPUTER PROGRAMMES

COMPONENT SIMULATION

```
   SEND TO (SIMULATION  .SM22)
   PROGRAM(GR16)
   INPUT1=CRU
   OUTPUT2=LPU
   TRACE
   END



   MASTER ANALYSIS OF FLOODED CHILLER


   DIMENSION NTPE(10),IPASSN(10)
   REAL NF
   GR16
   COMMON/FINT/    DO,NF,DF,T1,T2,FEFF,TKT
   COMMON/EVP/NE,NPASSE,TUBELE,TUBEWE,NTPE,FFE
   COMMON/CONST/PIE,GC
   COMMON/BLK6/DI
   COMMON/BLK7/STRL
   READ(1,5)NR
   READ(1,4)NF,DF,T1,T2,FEFF
   READ(1,5)NPASSE
   READ(1,1)NE         ,DI,DO,TKT
   READ(1,4)TUBELE
   READ(1,4)STRL
   READ(1,5)(NTPE(I),I=1,NPASSE)
   READ(1,4)DSUBC,TD
   LL=10
   DO 100 KK=1,LL
   READ(1,4)TSE,TWITE,RMFWGE,FFE
   READ(1,4)RCAPE,RPDE
 1 FORMAT( I0,5F0.0)
 2 FORMAT(11I0,4F0.0)
 3 FORMAT(10I0)
 4 FORMAT(10F0.0)
 5 FORMAT(I0)
   TUBEWE=TUBELE+2.5
```

```
      DO11I=1,NPASSE
   11 IPASSN(I)=I
      WRITE(2,20)NR,NE,TKT,NPASSE,DI,DO,TUBELE,TUBEWE,
     1NF,DF,T1,T2,FEFF,FFE
   20 FORMAT(1H ,'A.  PHYSICAL DATA OFEVAPORATOR'/1H ,30(1H-)/
     11H ,'REFRIGERANT,NR=',I5,2X,'NE   =',I5,2X,'TKT  =',F10.5,2X,
     1'NPASSE=',I5/1H , 'DI   =',F10.5,2X,'DO   =',F10.5,2X,
     2 'TUBELE=',F10.5,2X,'TUBEWE=',F10.5,2X,'NF   =',F10.5/1H ,
     3'DF   =',F10.5,2X,'T1   =',F10.5,2X,'T2   =',F10.5,2X,
     4'FEFF =',F10.5,2X,'FFE  =',F10.5)
      WRITE(2,21)(IPASSN(I),NTPE(I),I=1,NPASSE)
   21 FORMAT(1H ,'PASS NUMBER',4X,I10,5X,'NUMBER OF TUBES',I10)
      PIE=4.0*ATAN(1.0)
      GC=32.1740
      TSUBC=TD-DSUBC
      CALL SATPRP(NR,TD,PD,VFD,VGD,HFD,HFGD,HGD,SFD,SGD)
      CPRLD=CPL(NR,TD)
      HINE=HFD-CPRLD*(TD-TSUBC)
      CALL EVAP(NR,TSE,TWITE,RMFWGE,HINE,CAPE,PDE,AMRE)
      ERRCAPE=(CAPE-RCAPE)/RCAPE*100.0
      ERRPDE=(PDE-RPDE)/RPDE*100.0
      WRITE(2,25)CAPE,RCAPE,ERRCAPE,PDE,RPDE,ERRPDE
   25 FORMAT(1H ,'   RESULTS'/1H ,10(1H-)/
     31H ,'5, CAPICITY OF EVAPORATOR IN TONS,,.CALCULATED=',F10.5
     6,'RATED=',F10.5,'ERROR=',F10.5/
     71H ,'7, WATER SIDE PRESSURE DROP.........CALCULATED=',F10.5
     8,'RATED=',F10.5,'ERROR=',F10.5)
      WRITE(2,26)AMRE,RMFWGE
   26 FORMAT(1H ,'MASSFLOW RATE,AMRE=',F10.5,2X,'WATER FLOW RATE=',F10.5
     1)
  100 CONTINUE
      STOP
      END
```

```
      SUBROUTINE EVAP(NR ,TS,TWI1,RMFWG,HINE,CAPE,PDE,AMR)

C THIS PROGRAMME IS USED TO SIMULATE THE PERFORMANCE OF THE EVAPORAROR
C     GR10:VARIABLE HTC
C     S&F$SATPRP,TKL,VISCO,NRAPH,FQ1,DFQ1,FQ2,DFQ2
      DIMENSION NTPE(10),IPASSN(10)
      REAL NF
      EXTERNAL  FQ1,DFQ1,FQ2,DFQ2
      COMMON/BLOCK1/V1,V2
      COMMON/BLOCK2/P1,P2,QI,TLP
      COMMON/BLOCK3/ANR1,ANR2,ANR3,ANR4
      COMMON/FINT/   DO,NF,DF,T1,T2,FEFF,TKT
      COMMON/EVP/NE,NPASSE,TUBELE,TUBEWE,NTPE,FFE
      COMMON/CONST/PIE,GC
      COMMON/BLK6/DI
      COMMON/BLK7/STRL
      DATA TKW,CW,AMU,ROW/0.354,1.0,2.43,62.4/
      IF(NR.EQ.12)PK=596.9
      IF(NR.EQ.22)PK=721.9
      CALL SATPRP(NR,TS,PS,VF,VG,HF,HFG,HG,SF,SG)
      RORL=1/VF
      RORV=1/VG
      TKRL=TKL(NR,TS)
      CALL VISCO(NR,TS,AMURL,AMURG)
      WRITE(2,20)TKRL,AMURL,STRL,RORL,RORV,HFG,PS,TS
   20 FORMAT(1H ,'EVAPORATOR PERFORMANCE'/1H ,30(1H-)/
     11H ,'TKRL =',F10.5,2X,'AMURL=',F10.5,2X,'STRL =',F10.5,2X,
     2'RORL =',F10.5/1H ,'RORV =',F10.5,2X,'HFG  =',F10.5,2X,
     3'PS   =',F10.5,2X,'TS   =',F10.5)
      FP=1.0/NF
      AFS=PIE*(DF**2-DO**2)/4.0
      AFT=PIE*DF*T1
      ASP=PIE*DO*T2/FP
      APWF=PIE*DO
      AF=(2*AFS+AFT)/FP
9     AT=AF+ASP
      AI=PIE*DI
      AEFF=ASP+FEFF*AF
      WRITE(2,21)FP,AF,ASP,AT,AI,AEFF,APWF
```

```
21 FORMAT(1H ,'FP    =',F10.5,2X,'AF    =',F10.5,2X,'ASP   =',F10.5,2X,
  2'AT    =',F10.5,2X,'AI    =',F10.5,2X,'AEFF =',F10.5,2X,
  1'APWF =',F10.5)
   RF=0.0001*DI/12.0
   ATS=TS+459.67
   AC1=AT/AI
   AC2=AT*ALOG(DO/DI)/(2*PIE*TKT *12.0)
   B1=AEFF/AT
   AFI=AT/APWF
   RP=HS/PK
   AL=SQRT(STRL/(RORL-RORV))
   ANR1=0.75*AFI**(-0.114)*RP**(0.088*AFI**(-0.25))
   ANR2=0.75*AFI**(-0.13)*RP**(-0.28)
   ANR3=0.1
   ANR4=0.155
   RNOLDF=(        AL/(HFG*AMURL))**ANR1
   PHPRF=(ATS*TKRL/(HFG*AMURL        ))**ANR2
   RRF=(RF/AL)**ANR4
   AFIF=AFI**ANR3
   B2=230.0*TKRL/AL*AFIF*RNOLDF*PHPRF*RRF
   B=B1*B2
   WRITE(2,23)AC1,AC2,B1,B2,B,RP,AL,ANR1,ANR2,ANR3,ANR4
  1,AFI,RF
23 FORMAT(1H ,'AC1=  ',F10.5,1H ,'AC2=  ',F10.5,1H ,'B1 =  ',F10.5,
  11H ,'B2  =  ',F10.5,1H ,'B   =  ',F10.5/1H ,'RP  =  ',F10.5,
  21H ,'AL  =  ',F10.5,1H ,'ANR1=  ',F10.5,1H ,'ANR2=  ',F10.5,
  31H ,'ANR3=  ',F10.5/1H ,'ANR4=  ',F10.5,1H ,'AFI =  ',F10.5,
  41H ,'RF  =  ',F10.5)
   ALPHAL=1/FFE
   TWI=TWI1
   RMFW=1155./144.0*RMFWG*ROW
   PDE=0.0
   QO=1000.0
   DO 10 I=1,NPASSE
   AMW=RMFW/NTPE(I)
   G=4.*AMW/(PIE*DI**2)
   TLP=TUBELE/12.0
   TLW=TUBEWE/12.0
   REF=12.0*G*DI/AMU
   FRF=0.0791/REF**0.25
```

```
      PD=G*G/(GC*ROW*3/50.0)*(FRF*TLW/DI+0.4/24)
      ALPHAW=0.023*TKW/DI*(AMU*CW/TKW)**0.4*(DI*G/AMU)**0.8*(12.0**1.8)
      C1=AC2+AC1*(1/ALPHAL+1/ALPHAW)
      P1=(ANR1-1)*AMW*CW/(ANR1*B*AT)*12.0
      P2=C1*AMW*CW/AT *12.0
      V1=1/(C1*B)
      V2=(TWI-TS)/C1
      CALL NRAPH(FQ1,DFQ1,QI,90.0,.01,Q0)
      HTCI=B2*QI**(ANR1)
      Q1=QI
      CALL NRAPH(FQ2,DFQ2,QL,50.0,.01,Q1)
      TWL=TS  +QL*C1+QL**(1-ANR1)/B
      HTCL=B2*QL**(ANR1)
      HTCA=(HTCI+HTCL)/2.0
      WRITE(2,24)I,TWI,AMW,G,ALPHAL,ALPHAW,C1,P1,P2,V1,V2,QI,QL,TWL,TLP
     1,PD,HTCI,HTCL,HTCA
   24 FORMAT(1H ,'C.  ANALYSIS OF PASS NUMBER=  ',I5/ 1H ,35(1H-)/
     11H ,'TWI  =',F10.5,2X,'AMW  =',F10.5,2X,'G    =',F10.5,2X,
     2'ALPHAL=',F10.5,2X,'ALPHAW=',F10.5/1H ,'C1   =',F10.5,2X,'P1   ='
     3,F10.5,2X,'P2   =',F10.5,2X,'V1   =',F10.5,2X,'V2   =',F10.5/
     41H ,'/. HEAT TRANSFER RATE PER UNIT AREA'/1H ,'AT INLET,QI =  ',
     5F10.5,1H ,'AT OUTLET,QL=  ',F10.5/
     61H ,'TWL  =',F10.5,2X,'TLP  =',F10.5,2X,'PDE  =',F10.5/
     71H ,'11,HEAT TRANSFER COFFICIENT'/1H ,'AT INLET,HTCI=  ',
     8F10.5/1H ,'AT OUTLET,HTCL=   ',F10.5,2X,'AVERAGE,HTCA=',F10.5)
      TWI=TWL
      Q0=QL
      PDE=PDE+PD
   10 CONTINUE
      QT =RMFW*(TWI-TWL)*CW/60.0
      AMR=QT/(HG-HINE)
      CAPE=QT/200.0
      RETURN
      END
```

```
SHORT LIST
READ FROM(MT,PROGRAM GRM1.PROGGM12)
READ FROM(MT,PROGRAM GRM1.PROGGM13)
READ FROM(MT,PROGRAM GRM1.PROGGM15)
READ FROM(MT,PROGRAM GRM1.PROGGM16)

READ FROM(MT,PROGRAM GRM1.PROGGM18)
READ FROM(MT,PROGRAM GRM1.PROGGM20)
READ FROM(MT,PROGRAM GRM1.PROGGM21)
FINISH
```

```
      SEND TO (SIMULATION  ,SM22)
      PROGRAM(G116)
      INPUT1=CRD
      OUTPUT2=LPO
      TRACE
      END



      MASTER ANALYSIS OF FLOODED CHILLER

      DIMENSION NTPE(10),IPASSN(10)
      REAL NF
C     G116
      COMMON/FINT/    DO,NF,DF,T1,T2,FEFF,TKT
      COMMON/EVP/NE,NPASSE,TUBELE,TUBEWE,NTPE,FFE
      COMMON/CONST/PIE,GC
      COMMON/BLK6/DI
      COMMON/BLK7/STRL
      COMMON/RATED/RCAPE,RPDE
      READ(1,5)NR
      READ(1,4)STRL
      READ(1,4)NF,DF,T1,T2,FEFF
      READ(1,4)DSUBC,TD
      L=10
      LL=0
       DO 100 K=1,L
      READ(1,5)NPASSE
      READ(1,5)(NTPE(I),I=1,NPASSE)
      READ(1,1)NE        ,DI,DO,TKT,TUBELE,TUBEWE
       DO 110 KKK=1,LL
      READ(1,4)TSE,TWI1E,RMFWGE,FFE
      READ(1,4)RCAPE,RPDE
    1 FORMAT( I0,5F0.0)
    2 FORMAT(1I0,4F0.0)
    3 FORMAT(10I0)
    4 FORMAT(10F0.0)
    5 FORMAT(I0)
```

```
      DO11I=1,NPASSE
   11 IPASSN(I)=I
      WRITE(2,20)NR,NE,TKT,NPASSE,DI,DO,TUBELE,TUBEWE,NF,DF,T1,T2,FEFF,
     1FFE
   20 FORMAT(1H ,'A.  PHYSICAL DATA OFEVAPORATOR'/1H ,30(1H-)/
     11H ,'REFRIGERANT,NR=',I5,2X,'NE   =',I5,2X,'TKT  =',F10.5,2X,
     1'NPASSE=',I5/1H , 'DI   =',F10.5,2X,'DO   =',F10.5,2X,
     2 'TUBELE=',F10.5,2X,'TUBEWE=',F10.5,2X,'NF   =',F10.5/1H ,
     3'DF   =',F10.5,2X,'T1   =',F10.5,2X,'T2   =',F10.5,2X,
     4'FEFF =',F10.5,2X,'FFE  =',F10.5)
      WRITE(2,21)(IPASSN(I),NTPE(I),I=1,NPASSE)
   21 FORMAT(1H ,'PASS NUMBER',4X,I10,5X,'NUMBER OF TUBES',I10)
      PIE=4.0*ATAN(1.0)
      GC=32.17405
      TSUBC=TD-DSUBC
      CALL SATPRP(NR,TD,PD,VFD,VGD,HFD,HFGD,HGD,SFD,SGD)
      CPRLD=CPL(NR,TD)
      HINE=HFD-CPRLD*(TD-TSUBC)
      CALL EVAP(NR,TSE,TWI1E,RMFWGE,HINE,CAPE,PDE,AMRE)
  110 CONTINUE
  100 CONTINUE
      STOP
      END



      SUBROUTINE EVAP(NR ,TS,TWI1,RMFWG,HINE,CAPE,PDE,AMR)

C THIS PROGRAMME IS USED TO SIMULATE THE PERFORMANCE OF THE EVAPORAROR
C     G116;CONST HTC FOR INDIVIDUAL PASSES
C     S&F$SATPRP,TKL,VISCO,NRAPH,FQ1,DFQ1
      DIMENSION NTPE(10),IPASSN(10)
      REAL NF
      COMMON/FINT/   DO,NF,DF,T1,T2,FEFF,TKT
      COMMON/EVP/NE,NPASSE,TUBELE,TUBEWE,NTPE,FFE
      COMMON/CONST/PIE,GC
      COMMON/BLK6/DI
      COMMON/BLK7/STRL
```

```
      COMMON/RATED/RCAPE,RPDE
      DATA TKW,CW,AMU,ROW/0.354,1.0,2.43,62.4/
      IF(NR.EQ.12)PK=596.9
      IF(NR.EQ.22)PK=721.9
      CALL SATPRP(NR,TS,PS,VF,VG,HF,HFG,HG,SF,SG)
      RORL=1/VF
      RORV=1/VG
      TKRL=TKL(NR,TS)
      CALL VISCO(NR,TS,AMURL,AMURG)
      WRITE(2,20)TKRL,AMURL,STRL,RORL,RORV,HFG,PS,TS
   20 FORMAT(1H ,'EVAPORATOR PERFORMANCE'/1H ,30(1H-)/
     11H ,'TKRL =',F10.5,2X,'AMURL=',F10.5,2X,'STRL =',F10.5,2X,
     2'RORL =',F10.5/1H ,'RORV =',F10.5,2X,'HFG  =',F10.5,2X,
     3'PS   =',F10.5,2X,'TS   =',F10.5)
      FP=1.0/NF
      AFS=PIE*(DF**2-DO**2)/4.0
      AFT=PIE*DF*T1
      ASP=PIE*DO*T2/FP
      APWF=PIE*DO
      AF=(2*AFS+AFT)/FP
    9 AT=AF+ASP
      AI=PIE*DI
      AEFF=ASP*FEFF+AF
      WRITE(2,21)FP,AF,ASP,AT,AI,AEFF,APWF
   21 FORMAT(1H ,'FP   =',F10.5,2X,'AF   =',F10.5,2X,'ASP  =',F10.5,2X,
     2'AT   =',F10.5,2X,'AI   =',F10.5,2X,'AEFF =',F10.5,2X,
     1'APWF =',F10.5)
      RF=0.0001*DI/12.0
      ATS=TS+459.67
      AC1=AT/AI
      AC2=AT*ALOG(DO/DI)/(2*PIE*TKT *12.0)
      B1=AEFF/AT
      AFI=AT/APWF
      RP=HS/PK
      AL=SQRT(STRL/(RORL-RORV))
      ANR2=0.75*AFI**(-0.114)*RP**(0.088*AFI**(-0.25))
      ANR3=0.75*AFI**(-0.13)*RP**(-0.28)
      ANR5=0.1
      ANR6=0.133
      RNOUDF=(      AL/(HFG*AMURL))**ANR1
```

```
      PHPRF=(ATS*TKRL/(HFG*AMURL        ))**ANR2
      RRF=(RF/AL)**ANR4
      AFIF=AFI**ANR3
      B2=430.0*TKRL/AL*AFIF*RNULDF*PHPRF*RRF
      B=B2*B2
      WRITE(2,23)AC1,AC2,B1,B2,B,RP,AL,ANR1,ANR2,ANR3,ANR4
     1,AFI,RF
   23 FORMAT(1H ,'AC1=  ',F10.5,1H ,'AC2=  ',F10.5,1H ,'B1 =  ',F10.5,
     11H ,'B2  =  ',F10.5,1H ,'B   =  ',F10.5/1H ,'RP  =  ',F10.5,
     21H ,'AL  =  ',F10.5,1H ,'ANR1=  ',F10.5,1H ,'ANR2=  ',F10.5,
     31H ,'ANR3=  ',F10.5/1H ,'ANR4=  ',F10.5,1H ,'AFI =  ',F10.5,
     41H ,'RF  =  ',F10.5)
      ALPHAL=1/FFE
      RMFW=1155./144.0*RMFWG*ROW
      PDE=0.0
      TLP=TUBELE/12.0
      TLW=TUBEWE/12.0
  507 TWI=TWI1
      DO 10 I=1,NPASSE
      AMW=RMFW/NTPE(I)
      G=4.*AMW/(PIE*DI**2)
      REF=12.0*G*DI/AMU
      FRF=0.0791/REF**0.25
      PD=8*G/(GC*ROW*3750.0)*(FRF*TLW/DI+0.4/24)
      ALPHAW=0.023*TKW/DI*(AMU*CW/TKW)**0.4*(DI*G/AMU)**0.8*(12.0**1.8)
      C1=AC2+AC1*(1/ALPHAL+1/ALPHAW)
      EF=PLP*AT/(AMW*CW*12.0)
      TWL=TWI-2.0
  506 QTP=AMW*(TWI-TWL)*CW
      Q=QTP/(AT*TLP)*12.0
      U=1.0/(C1+1.0/(B*Q**ANR1))
      TWL1=TS+(TWI-TS)*EXP(-U*EF)
      IF(ABS(TWL1-TWL).LT.0.001)GO TO 1000
      TWL=(TWL1+TWL)/2.0
      GO TO 506
 1000 QI,QL=Q
      HTCA=B2*Q**(ANR1)
      HTCI,HTCL=HTCA
      WRITE(2,24)I,TWI,AMW,G,ALPHAL,ALPHAW,C1,V1,V2,QI,QL,Q,TWL,TLP
     1,PD,HTCI,HTCL,HTCA
```

```
24 FORMAT(1H ,'C.  ANALYSIS OF PASS NUMBER=  ',I5/ 1H ,35(1H-)/
  11H ,'TWI  =',F10.5,2X,'AMW  =',F10.5,2X,'G    =',F10.5,2X,
  2'ALHHAL=',F10.5,2X,'ALPHAW=',F10.5/1H ,'C1   =',F10.5,2X,
  3                          'V1   =',F10.5,2X,'V2   =',F10.5/
  41H ,'7. HEAT TRANSFER RATE PER UNIT AREA'/1H ,'AT INLET,QI =  ',
  5F10.5,1H ,'AT OUTLET,QL=  ',F10.5,2X,'AVERAGE,Q= ',F10.5/
  61H ,'TWL  =',F10.5,2X,'TLP  =',F10.5,2X,'PDE  =',F10.5/
  /1H ,'11.HEAT TRANSFER COFFICIENT'/1H ,'AT INLET,HTCI=  ',
  8F10.5/1H ,'AT OUTLET,HTCL=  ',F10.5,2X,'AVERAGE,HTCA=',F10.5)
   TWI=TWL
   QU=QL
   PDE=PDE+PD
10 CONTINUE
   QT =RMFW*(TWI1-TWL)*CW/60.0
   AMR=QT/(HG-HINE)
   CAPE=QT/200.0
   ERRCAPE=(CAPE-RCAPE)/RCAPE*100.0
   ERRPDE=(PDE-RPDE)/RPDE*100.0
   WRITE(2,25)CAPE,RCAPE,ERRCAPE,PDE,RPDE,ERRPDE
25 FORMAT(1H ,'   RESULTS'/1H ,10(1H-)/
  51H ,'5. CAPICITY OF EVAPORATOR IN TONS,,,CALCULATED=',F10.5
  6,'RATED=',F10.5,'ERROR=',F10.5/
  /1H ,'7. WATER SIDE PRESSURE DROP.........,CALCULATED=',F10.5
  8,'RATED=',F10.5,'ERROR=',F10.5)
   WRITE(2,26)AMRE,RMFWG
26 FORMAT(1H ,'MASSFLOW RATE,AMRE=',F10.5,2X,'WATER FLOW RATE=',F10.5
  1)
   RETURN
   END
```

```
SHORT LIST

READ FROM(MT,PROGRAM GRM1.PROGGM12)

READ FROM(MT,PROGRAM GRM1.PROGGM13)
```

```
READ FROM(MT,PROGRAM GRM1,PROGGM15)
READ FROM(MT,PROGRAM GRM1,PROGGM16)
READ FROM(MT,PROGRAM GRM1,PROGGM18)
FINISH
```

```
      PROGRAM(G414)
      INPUT1=CRD
      OUTPUT2=LPO
      END



      MASTER CONDENSER ANALYSIS
      DIMENSION NTP(10),IPASSN(10),TNVR(10)
      REAL NF
C     GR14,G414
      COMMON/FINT/   DO,NF,DF,T1,T2,FEFF,TKT
      COMMON/BLK8/N1,TNVR,TNVRS,BTARL
      COMMON/VTEMP/TV
      COMMON/CND/NC,NPASS,TUBEL,TUBEW,FF
      COMMON/CONST/PIE,GC
      COMMON/BLK4/NTP
      COMMON/BLK6/DI
      COMMON/BLK9/DPIC,DPEC
      COMMON/AS/AS1,AS2
      L=25
C                          AS1=CROSS-SECTION AREA OF SUBCOOLER DUCT(IN.SQ.)
C                          DF=DIAMETER OVER THE FINS(IN.)
C                          DI=INNER DIAMETER OF TUBE (IN.)
C                          DPEC=DIAMETER OF PIPE CARRYING COOLANT OUT
C                          OF THE CONDENSER(IN.)
C                          DPERM=SUBCOOLER DUCT PERIMETER(IN.)
C                          DPIC=DIAMETER OF PIPE CARRYING COOLANT TO
C                          THE CONDENSER(IN.)
C                          DO=OUTER DIAMETER OF TUBE (IN.)
C                          FEFF=FIN EFFICIENCY
C                          FF=FOULING FACTOR(HR.*FT**2*F/BTU)
C                          N=TOTAL NUMBER OF TUBES
C                          N1=NUMBER OF TUBES IN THE SUBCOOLER
C                          NF=NUMBER OF FINS PER INCH OF TUBE LENGTH
C                          NPASS=NUMBER OF TUBE PASSES
C                          NR= REFRIGERANT NUMBER
C                          NTP=NUMBER OF TUBES IN A PASS
```

```
C                               RMFWG=MASS FLOW RATE OF COOLANT(GPM)
C                               RPDC=RATED COOLANT PRESSURE DROP
C                                    IN THE CONDENSER
C                               RTHR= RATED TOTAL HEAT REJECTION
C                                    IN THE CONDENSER
C                               T1=FIN THICK NESS(IN.)
C                               T2=FIN SPACING(IN.)
C                               TKT=THERMAL CONDUCTIVITY OF TUBE
C                                   MATERIAL (BTU/HR FT DEGREE F)
C                               TNVR=AVERAGE NUMBER OF TUBES IN A VERTICAL
C                               ROW OF THE CONDENSER
C                               TNVRS=AVERAGE NUMBER OF TUBES IN A VERTICAL
C                               ROW OF THE SUBCOOLER
C                               TS=SATURATION TEMPERATURE CORRESPONDING
C                                  TO CONDENSER PRESSURE (DEGREE F)
C                               TV=TEMPERATURE OF SUPERHEATED VAPOUR
C                                  ENTERING THE CONDENSER (DEGREE F)
C                               TUBEL=TUBE LENGTH USED FOR
C                               TWI1=TEMPERATURE OF COOLANT ENTERING THE
C                               CONDENSER(F)
C                                    HEAT TRANSFER (IN.)
C                               TUBEW=TUBE LENGTH (IN.)
      PIE=4.0*ATAN(1.0)
      GC=32.17405
      READ(1,5)NR
      READ(1,4)CPRL,BTARL
      READ(1,4)DPIC,DPEC
      READ(1,1)N    ,NPASS,DI,DO,TKT
      READ(1,4)(TNVR(I),I=1,NPASS),TNVRS
      READ(1,4)NF,DF,T1,T2,FEFF
      READ(1,4)AS1
       DO 100 K=1,L
      READ(1,3)(NTP(I),I=1,NPASS)
      READ(1,3)N1
      READ(1,4)TUBEL
      READ(1,4)TV,TS   ,TWI1,RMFWG,FF,RTHR,RPDC
    1 FORMAT(2I0,5F0.0)
    2 FORMAT(1I0,4F0.0)
    3 FORMAT(10I0)
    4 FORMAT(10F0.0)
```

```
  5 FORMAT(I0)
    TUBEW=TUBEL+2.5
    DO 11 I=1,NPASS
 11 IPASSN(I)=I
    WRITE(2,20)NR,N ,TKT,NPASS ,DI,DO,TUBEL ,TUBEW ,NF,DF,T1,T2,FEFF,
   1FF,N1,TNVRS
 20 FORMAT(1H ,'A,  PHYSICAL DATA OF CONDENSER'/1H ,30(1H-)/
   11H ,'REFRIGERANT,NR=',I5,2X,'N     =',I5,2X,'TKT  =',F10.5,2X,
   1'NPASS =',I5/1H , 'DI    =',F10.5,2X,'DO    =',F10.5,2X,
   2 'TUBEL =',F10.5,2X,'TUBEW =',F10.5,2X,'NF    =',F10.5/1H ,
   3'DF    =',F10.5,2X,'T1    =',F10.5,2X,'T2    =',F10.5,2X,
   4'FEHF =',F10.5,2X,'FF    =',F10.5,2X,'N1    =',I5,2X,'TNVRS=',F10.5)
    WRITE(2,21)(IPASSN(I),NTP (I),TNVR(I),I=1,NPASS)
 21 FORMAT(1H ,'PASS NUMBER',4X,I10,5X,'NUMBER OF TUBES',I10,
   15X,'TNVR =',F10.5)
    AS2=PIE*DF**2*N1/4.0
    WRITE(2,30)AS1,AS2
 30 FORMAT(1H ,'AS1=',F10.5,5X,'AS2=',F10.5)
    CALL TIME(TT1)
    CALL CONDEN(NR,TS,TWI1,RMFWG,THR,PDC,RCOND,DSUBC)
    ERRTHR=(THR-RTHR)/RTHR*100.0
    ERRPDC=(PDC-RPDC)/RPDC*100.0
    WRITE(2,25)THR,RTHR,ERRTHR,PDC,RPDC,ERRPDC
 25 FORMAT(1H ,' , RESULTS'/1H ,10(1H-)/
   21H ,'5, TOTAL HEAT REJECTION,THR,.....,CALCULATED=',F10.5
   6,'RATED=',F10.5,'ERROR=',F10.5/
   /1H ,'7, WATER SIDE PRESSURE DROP,.........,CALCULATED=',F10.5
   8,'RATED=',F10.5,'ERROR=',F10.5)
    WRITE(2,62)RCOND,RMFWG,DSUBC
 62 FORMAT(1H ,'CONDENSATE FLOW RATE,RCOND=',F10.5,2X,
   1'WATER FLOW RATE,RMFWG=',F10.5/1H ,'DEGREEOFSUBCOOLING=',F10.5)
     CALL TIME(TT2)
    WRITE(2,280)TT1,TT2
280 FORMAT(1H ,A8/1H ,A8)
100 CONTINUE
    STOP
    END
```

```
      SUBROUTINE CONDEN(NR,TS,TWI1,RMFWG,THR,PDC,RCOND,DSUBC)

C THIS PROGRAMME IS USED TO SIMULATE THE PERFORMANCE OF THE CONDENSER,
C CONDENSING THE REFRIGERANT OUTSIDE THE TUBES
C     G414;VARIABLE HTC(V,C,)
      DIMENSION NTP(10),IPASSN(10),TNVR(10)
      REAL NF
      EXTERNAL  FQ1,DFQ1,FQ2,DFQ2
      COMMON/BLOCK1/V1,V2
      COMMON/BLOCK2/P1,P2,QI,TLP
      COMMON/BLOCK3/ANR1,ANR2,ANR3,ANR4
      COMMON/FINT/   DO,NF,DF,T1,T2,FEFF,TKT
      COMMON/BLK8/N1,TNVR,TNVRS,BTARL
      COMMON/VTEMP/TV
      COMMON/CND/NC,NPASS,TUBEL,TUBEW,FF
      COMMON/CONST/PIE,GC
      COMMON/BLK4/NTP
      COMMON/BLK9/DPIC,DPEC
      COMMON/BLK6/DI
      COMMON/BLK5/TLW
      COMMON/AS/AS1,AS2
      DATA TKW,CW,AMU,ROW/0.354,1.0,2.43,62.4/
C                              THE PROPERTIES OF THE REFRIGERANT ARE FOUND
      CALL SATPRP(NR,TS,PS,VF,VG,HF,HFG,HG,SF,SG)
      RORL=1/VF
      CPRL=CPL(NR,TS)
      TKRL=TKL(NR,TS)
      CALL VISCO(NR,TS,AMURL,AMURG)
      WRITE(2,20)TKRL,AMURL,CPRL,RORL,TV  ,HFG,PS,TS,BTARL
   20 FORMAT(1H ,,PERFORMANCE   OF      CONDENSER,/1H ,30(1H=)/
     1 1H ,,TKRL =',F10.5,2X,,AMURL=',F10.5,2X,,CPRL =',F10.5,2X,
     2,RORL =',F10.5/1H ,'TV  =', F10.5,2X,'HFG  =',F10.5,2X,
     3,PS   =',F10.5,2X,,TS   =',F10.5,2X,,BTARL=',F10.5)
C                              VARIOUS CONSTANTS ARE DETERMINED
      CV=0.133
      FP=3.0/NF
      AFS=PIE*(DF**2-DO**2)/4.0
      AFT=PIE*DF*T1
```

```
      ASP=PIE*DO*T2/FP
      AF=12*AFS+AFT)/FP
      AT=AF+ASP
      AI=HIE*DI
      AEFF=ASP*FEFF*AF
      WRITE(2,21)FP,AF,ASP,AT,AI,AEFF
   21 FORMAT(1H ,'FP    =',F10.5,2X,'AF    =',F10.5,2X,'ASP   =',F10.5,2X,
     2'AT    =',F10.5,2X,'AI    =',F10.5,2X,'AEFF =',F10.5)
      AC1=AT/AI
      AC2=AT*ALOG(DO/DI)/(2*PIE*TKT *12.0)
      B1=AEFF/AT
      ANR2=-1.0/3.0
      ANR4,ANR5,ANR4=0.0
      ALMF=AFS/DF
      P=0.25
      ALMFF=ALMF**P
      HFGG=CV*(TV-TS   )+HFG
      DEQL=1.0/((1.3*AF*FEFF/ALMFF+ASP/DO**P)/AEFF)**4
      WRITE(2,22)DEQL
   22 FORMAT(1H ,'EQUIVALENT DIAMETER,DEQL=  ',F10.5)
      AKK=TKRL**3*RORL**2*GC/AMURL
      AK1=.689*(AKK*HFGG/DEQL)**P*(60.0*12.0**P)
      ALPHAL=1/FF
      TWI=TWI1
      RMFW=1155./144.0*RMFWG*ROW
      TLW=TUBEW/12.
      TLP=TUBEL/12.0
C                              THE MASS FLOW RATE OF COOLANT AND ITS
C                              PRESSURE DROP IN BOTH THE BRANCHES OF
C                              CONDENSER ARE EVALUATED
      CALL BRANCHM(RMFW,RMFWB1,RMFWB2,PDC)
      WRITE(2,220)RMFW,RMFWB1,RMFWB2,PDC
  220 FORMAT(1H ,'RMFW  =',F15.5,2X,'RMFWB1=',F15.5,2X,'RMFWB2=',F15.5
     1,2X,'PDC   =',F10.5)
      RMFS=N1*RMFWB2/NTP(4)
      RMFW4=RMFWB2=RMFS
      WRITE(2,901)RMFS,RMFW4
  901 FORMAT(1H ,'RMFS =',F10.5,2X,'RMFW4=',F10.5)
      CK12=RMFS*CW/60.0
      CK11=CK12/CPRL
```

```
      CK2=12.0*60.0*CK12/(AT*TLP*N1)
      DEQS=0.99439*DF/2.0
      DROMU=300.0*DEQS*RORL/AMURL
      PRNR=AMURL*CPRL/TKRL
      PTD=0.023*TKRL*PRNR**0.43/DEQS*12.0
       VELR=3.54166
      RELNR=DROMU*VELR
      HTCH=PTD*RELNR**0.8
      Q0=3000.0
      I=1
C                                THE HEAT TRANSFER IN EACH PASS IS COMPUTED
  110 TR=PS
      AK=AK1/TNVR(I)**P
      B2=AK**(1-ANR1)*B1**(-ANR1)
      B=B2*B2
      WRITE(2,23)AC1,AC2,B1,AK
   23 FORMAT(1H ,'AC1=  ',F10.5,1H ,'AC2=  ',F10.5,1H ,'B1 =  ',F10.5,
     11H ,'AK =  ',F10.5)
      IF(I.LE.3)AMW=RMFWB1/NTP(I)
      IF(I.GE.4)AMW=RMFWB2/NTP(I)
   26 G=44*AMW/(PIE*DI**2)
      ALPHAW=0.023*TKW/DI*(AMU*CW/TKW)**0.4*(DI*G/AMU)**0.8*(12.0**1.8)
      C1=AC2+AC1*(1/ALPHAL+1/ALPHAW)
      P1=(ANR1-1)*AMW*CW/(ANR1*B*AT)*12.0
      P2=Q1*AMW*CW/AT *12.0
      V1=Z/(C1*B)
   29 V2=(TR-TWI)/C1
      CALL NRAPH(FQ1,DFQ1,QI,50,0.01,Q0)
      HTCI=B2*QI**(ANR1)
      Q1=QI
      CALL NRAPH(FQ2,DFQ2,QL,50,0.01,Q1)
      TWL=TR-QL*C1-QL**(1-ANR1)/B
      HTCL=B2*QL**(ANR1)
      HTCA=(HTCI+HTCL)/2.0
      WRITE(2,24)I,TWI,AMW,G,ALPHAL,ALPHAW,C1,                    TWL,TLP
     1,HTCI,HTCL,HTCA,TD
   24 FORMAT(1H ,'C.  ANALYSIS OF PASS NUMBER=  ',I5/ 1H ,35(1H-)/
     11H ,'TWI  =',F10.5,2X,'AMW  =',F10.5,2X,'G    =',F12.5,2X,
     2'ALPHAL=',F10.5,2X,'ALPHAW=',F10.5/1H ,'C1   =',F10.5/
     61H ,'TWL  =',F10.5,2X,'TLP  =',F10.5/
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```
     /1H /,'11,HEAT TRANSFER COFFICIENT'/1H ,'AT INLET,HTCI=  ',
     *F10.5,1H ,'AT OUTLET,HTCL=   ',F10.5,2X,'AVERAGE,HTCA=',F10.5/
     *1H /,'TD   =',F10.5)
      GO TO (10,10,227,228,10,300)I
   10 I=I+1
      QO=RL
      TWI=TWL
      GO TO 110
C                                THE RATE OF CONDENSATE IS DETERMINED FOR
C                                THE BRANCH 6ITHOUT SUBCOOLER
  227 QT1=RMFWB1*CW*(TWL-TWI1)/60.0
      RCOND1=QT1/HFGG
      RCOND2=RCOND1
      QL=3000.0
      TWL=TWI1
      GO TO 10
C                                ASSUMING INITIALLY THE SAME RATE OF
C                                CONDENSATE IN BOTH THE BRANCHES, THE HEAT
C                                TRANSFER IN THE SUBCOOLER AND HENCE THE
C                                TEMPERATURE OF COOLANT AT THE INLET OF
C                                SUCCESSIVE PASS ARE DETERMINED,
C                                THEN THE RA E OF CONDENSATE IN THE SECOND
C                                BRANCH IS OBT&INED AND COMPARED WITH ITS
C                                ASSUMED VAL E  ILL THE TWO ARE NOT
C                                DEVIATED BY MORE THAN 0.1 PERCENT
  228 IF(N1.EQ.0)GO TO 10
      TWL4=TWL
      HR4=RMFW4*CW*(TWL4-TWI1)/60.0
  229 RCOND=RCOND1+RCOND2
      WRITE(2,500)RCOND,RCOND1,RCOND2
  500 FORMAT(1H ,'RCOND =',F10.5,2X,'RCOND1=',F10.5,2X,'RCOND2=',F10.5)
      HTCU=1.0/(C1*1.0/(B1*HTCR))
      CK1=CK11/RCOND
      CK2=CK22/HTCU
      ACK=EXP((CK1-1.0)/CK2)
      BCK=CK1*ACK
      BCKM1=BCK-1.0
      CCK=(ACK-1.0)/BCKM1
      DCK=(BCK-ACK)/BCKM1
      TWLS=CCK*TS+DCK*TWI1
```

```
      HRIS=CK12*(TWLS-TWI1)
      TWL=(HRIS+HR4)*60.0/(RMFWB2*CW)+TWI1
      TWI5=TWL
      GO TO 10
  500 QT2=RMFWB2*CW*(TWL-TWI5)/60.0+HR4
      RCONDN=QT2/HFGG
      IF(ABS(RCONDN-RCOND2).LT.0.001*RCOND2)GO TO 30
      RCOND2=(RCONDN+RCOND2)/2.0
      I=4
      GO TO 229
   30 QTR=QT1+QT2+HRIS
      THR=QTR/200.0
      TWL=QTR*60.0/(RMFW*CW)+TWI1
      DSUBC=HRIS/(RCOND*CPRL)
      TSUBC=TS-DSUBC
      DT=TS-TWI1
      WRITE(2,52)DT,TWL
   52 FORMAT(1H ,'DT    =',F10.5 ,2X,'TWL =',F10.5)
      RETURN
      END


      SHORT LIST

      READ FROM(MT,PROGRAM GRM1.PROGGM12)

      READ FROM(MT,PROGRAM GRM1.PROGGM13)

      READ FROM(MT,PROGRAM GRM1.PROGGM15)

      READ FROM(MT,PROGRAM GRM1.PROGGM16)

      READ FROM(MT,PROGRAM GRM1.PROGGM18)

      READ FROM(MT,PROGRAM GRM1.PROGGM20)

      READ FROM(MT,PROGRAM GRM1.PROGGM21)

      READ FROM(MT,PROGRAM GRM1.PROGGM34)
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FINISH