```
c                            SG.for
c                     (Using Average Heat Flux)
c This program calculates the surface area of a steam generator, given
c primary-side inlet & outlet temperatures and secondary-side sat.
c pressure (temperatue).  Total rate of heat transfer, total number
c of tubes, number of tube pass per shell (M=2) and tube inside and
c outside diameters must also be specified.  Other notes:
c    1.  Tube diameter is primarily determined from pumping power and
c        other considerations such as containment pressure limit.
c    2.  Tube wall thickness is determined from ASME boiler code.
c    3.  Number of tubes is primarily determined by cost optimization
c    4.  A total fouling factor must be specified.  This accounts not
c        only for actual fouling but also for calculational uncertainty.
c
c The Dittus-Boelter correlation DB is used for the tube-side and the
c Rohsenow pool boiling correlation for the shell-side (secondary).
c
c
      implicit real*8 (a-h,o-z)
      character filea*12
      data Qdot,pi/4.386e9,3.1415927/
      data dip,dop,aN/0.654,0.75,8485./
      data Wp,Tp1,Tp2,Ts,akw/61.E6,604.,550.,525.2,11.00/
      data fi,fo,Ps/0.0,0.0002437,850.00/
      data hin/500.00/
c
1002  continue
      write(*,5)
      print *,'         T/H DESIGN & ANALYSIS OF STEAM GENERATORS (S/G)'
      print *,'         ============================================='
      print *,'  '
      print *,'  '
      print *,'                  0:  Main Menu'
      print *,'  '
      print *,'  '
      print *,'                  1:  T/H Design of a Steam Genartor'
      print *,'                      Using a Sample Input File)'
      print *,'  '
      print *,'  '
      print *,'                  2:  Read Data Via Keyboard'
      print *,'                      (Creates Input File SG.IN)'
      print *,' '
      print *,'  '
      print *,'                  3:  Read Data From An Existing File'
      print *,'                                      '
      print *,' '
      print *,'                  4:  Description To Create Input File'
      print *,'                      Via DOS Editor'
      print *,' '
      print *,' '
      print *,'  '
      print *,'Enter Option:'
      read(*,*) iu
      if(iu.eq.0) return
      if(iu.eq.1) go to 1000
      if(iu.eq.2) go to 1001
      if(iu.eq.3) go to 1900
      call SGdes
      print *,'Enter: 1 For SG Design Menu, 0 For Main Menu'
      read(*,*) iu
      if(iu.eq.0) return
      go to 1002
1001  continue
      write(*,5)
c...  To Write Into File SG.IN
      open(10,file='SG.in')
      print *,'Enter >  Tube-side Mass Flow Rate (lbm/hr)'
      print *,'      >  (0 To EXIT)'
      read(*,*) Wp
      if(Wp.eq.0) go to 1002
      write(10,1010) Wp
      print *,' '
      print *,'      >  Tube-side Inlet Temperature (F)'
      print *,'      >  Tube-side Outlet Temperature (F)'
      read(*,*) Tp1,Tp2
      write(10,1011) Tp1,Tp2
      print *,' '
      print *,'Enter >  Tube Inside Diameter (in)'
      print *,'      >  Tube Outside Diameter (in)'
```

```
      print *,'      >  Total Number Of Tubes'
      print *,'      >  Tube Thermal Conductivity (Btu/hr-ft-F)'
      read(*,*) dip,dop,aN,akw
      write(10,1011) dip,dop,aN,akw
      print *,' '
      print *,'Enter >  Rohsenow Pool Boilig Coefficient, Cws'
      print *,'      >  Secondary-side Specific Heat (Btu/lbm-F)'
      print *,'      >  Secondary-side Pressure (psia)'
      read(*,*) Cws,Cps,Ps
      write(10,1011) Cws,cps,Ps
      print *,' '
      print *,'Enter >  Tube-side Fouling Factor'
      print *,'      >  Secondary-side Fouling Factors'
      read(*,*) fi,fo
      write(10,1010) fi,fo
      go to 1950
c...  To Read From SG.IN
1900  continue
      rewind 10
      print *,'Enter: Full Name Of The Existing Data File'
      read(*,'(a12)') filea
      open(10,file=filea,form='formatted')
      read(10,*) Qdot
      read(10,*) Tp1,Tp2
      read(10,*) dip,dop,aN,akw
      read(10,*) Cws,Ps
      read(10,*) fi,fo
1950  continue
c
      Call PRP(Ps, HIN ,HFs ,HGs ,KSTAT ,Tsdum ,VSs ,Xs ,ALPHAs,
     1                       VFs ,VGs ,DVDHP ,DVDPH ,TS,SFs,SGs)
      hfg=hgs-hfs
1000  continue
c
      di=dip/12.00
      do=dop/12.00
      areai=pi*di*di*aN/4.00
c
      Tavp=0.5*(tp1+tp2)
      Tw=0.5*(tavp+ts)
      Tfilm=0.5*(Tavp+Tw)
      T=Tavp
c
      call intrpl(T,cpp,cpg,amufp,amug,akfp,akg,prp1,prg,sigf,
     1                    betaf,rof,rog,anuf,anug,vf,vfg,vg)
      call intrpl(Ts,cps,cpg,amufs,amug,akfs,akg,prs,prg,sigfs,
     1                    betaf,rofs,rogs,anuf,anug,vf,vfg,vg)
c
      Wp=Qdot/(cpp*(Tp1-Tp2))
      effec=(Tp1-Tp2)/(Tp1-Ts)
      aLMTD=(Tp1-Tp2)/alog((Tp1-Ts)/(Tp2-Ts))
      if(aLMTD.lt.0) aLMTD=aLMTD*(-1.00)
      Cmin=Wp*Cpp
      Y1=1./(Cmin*alog(1.-effec))
c
      Rep=4.*Wp/(pi*amufp*di*aN)
      hi=0.023*akfp*(Rep**0.8)*(Prp1**0.3333333)/di
c
      termb=sqrt(sigfs/(rofs-rogs))
      terma=(termb/(amufs*hfg))**0.333333
c     Z1=Cws*hfg*(Prs)*terma/Cps
      Z1=Cws*hfg*(Prs**1.7)*terma/Cps
      Y3=Z1/(Qdot**0.66666)
c
      terma=do/(di*hi)
      termb=do*alog(do/di)/(2.*akw)
      Y2=terma+termb+(do*fi/di)+fo
      z=Y2/Y1
c
      i=0
      x=10000.00
1     continue
      i=i+1
      fofx=Y1*x+(Y3*(x**0.666666))+Y2
      fpox=Y1+(0.6666666*Y3*(x**(-0.3333333)))
      xn=x-(fofx/fpox)
      diff=abs((xn-x)/xn)
      if(diff.le.1.E-6) go to 2
      if(i.gt.60) go to 3
```

```
      x=xn
      go to 1
2     continue
c
      aNTU=-alog(1.-effec)
      Rp=terma
      Rfp=fi+fo
      Rw=do*alog(do/di)/(2.*akw)
      Rs=Y3*(x**0.66666)
      sigR=Rp+Rfp+Rw+Rs
      U=aNTU*Cmin/x
      Up=Qdot/(x*aLMTD)
      Upp=1./sigR
      area=x
      aL=x/(pi*do*aN)
      fric=0.184/(Rep**0.2)
      dpi=fric*(aL/di)*(Wp*Wp/(2.*rof*32.20*areai*areai*144.00*12.96e6))
      hs=1./Rs
      Ws=Qdot/hfg
      write(*,5)
      write(*,15)
      open(11,file='SG.OUT')
      write(11,15)
15    format( '         T/H DESIGN & ANALYSIS OF STEAM GENERATORS',/,
     1        '         ========================================',/)
      print *,' '
      print *,'                    (Results, Page 1 of 3) '
      print *,' '
      write(11,6) Wp,Tp1,Tp2,Ps,Ts,aN,dip,dop,aL,area,Rp,Rs,Rw,Rfp,Upp
      write(*,6)  Wp,Tp1,Tp2,Ps,Ts,aN,dip,dop,aL,area,Rp,Rs,Rw,Rfp,Upp
6     format(
     1'  Primary-side flow rate (lbm/hr):.............',e11.3,/,
     2'  Primary-side inlet temperature (F):...........',f11.3,/,
     3'  Primary-side outlet temperature (F):..........',f11.3,/,
     4'  Secondary-side pressure (psia):..............',f11.3,/,
     5'  Secondary-side temperature (F):..............',f11.3,/,
     6'  Total number of tubes:.....................',f11.2,/,
     7'  Tube inside diameter (in):..................',f11.3,/,
     7'  Tube outside diameter (in):.................',f11.3,/,
     8'  Tube average heated length (ft):............',f11.3,/,
     9'  Tube heat transfer area (ft2):..............',f11.0,/,
     1'  Inside thermal resistance (hr-ft2-F/Btu).....',f11.6,/,
     3'  Bundle thermal resistance (hr-ft2-F/Btu).....',f11.6,/,
     4'  Tube thermal resistance (hr-ft2-F/Btu).......',f11.6,/,
     5'  Fouling/contingency  (hr-ft2-F/Btu)..........',f11.6,/,
     6'  Overall heat transfer coeff. (Btu/hr-ft2-F):....',f11.2)
      print *,' '
      print *,' '
      print *,'Enter >  1: More S/G Info., 0: S/G Menu'
      read(*,*) iu
      if(iu.eq.0) go to 1002
      write(*,5)
      write(*,15)
      print *,'                    (Results, Page 2 of 3) '
      print *,' '
      xavge=xavge*100.00
      write(11,7) Qdot,Ws,aLMTD,effec,aNTU,Tavp,Tfilm,Rep,hi,hs,U,Up,dpi
      write(*,7)  Qdot,Ws,aLMTD,effec,aNTU,Tavp,Tfilm,Rep,hi,hs,U,Up,dpi
7     format(
     1'  Total rate of heat transfer (Btu/hr):.......',e11.3,/,
     1'  Steam flow rate (lbm/hr):....................',e11.3,/,
     2'  Logarithmic Mean Temperature Difference (F):....',f11.3,/,
     3'  Effectiveness:...............................',f11.3,/,
     4'  Number of transfer units:....................',f11.3,/,
     5'  Tube-side average temperature (F):...........',f11.3,/,
     6'  Tube-side film temperature (F):..............',f11.3,/,
     7'  Tube-side Reynolds number:..................',e11.3,/,
     8'  Tube-side HTC (Btu/hr-ft2-F):...............',f11.3,/,
     9'  Shell-side HTC (Btu/hr-ft2-F):..............',f11.3,/,
     1'  Overall HTC Based on NTU (Btu/hr-ft2-F):.....',f11.3,/,
     2'  Overall HTC Based on LMTD (Btu/hr-ft2-F):.....',f11.3,/,
     3'  Tube-side skin friction pressure drop (psi):....',f11.3)
      print *,' '
      print *,' '
      print *,' '
      print *,' '
      print *,' '
      print *,'Enter >  1: More S/G Info., 0: S/G Menu'
      read(*,*) iu
```

```
      if(iu.eq.0) go to 1002
      write(*,5)
      write(*,15)
      print *,'                    (Results, Page 3 of 3)  '
      print *,' '
      write(11,8) Tfilm,cpp,amufp,akfp,Prp1,akw,Ts,Cps,amufs,akfs,Prs,
     1           sigfs,rofs,rogs,Cws,y1,y2,y3
      write(*,8)  Tfilm,cpp,amufp,akfp,Prp1,akw,Ts,Cps,amufs,akfs,Prs,
     1           sigfs,rofs,rogs,Cws,y1,y2,y3
8     format(
     1'  Tube-side film temperature (F):.................',f11.3,/,
     2'  Tube-side specific heat (Btu/lbm-F):............',f11.3,/,
     3'  Tube-side viscosity (lbm/ft-hr):................',f11.3,/,
     4'  Tube-side thermal conductivity (Btu/hr-ft-F):...',f11.3,/,
     5'  Tube-side Prandtle number:.....................',f11.3,/,
     6'  Tube thermal conductivity (Btu/hr-ft-F):.......',f11.3,/,
     7'  Shell-side average temperature (F):............',f11.3,/,
     8'  Shell-side specific heat (Btu/lbm-F):..........',f11.3,/,
     9'  Shell-side viscosity (lbm/ft-hr):..............',f11.3,/,
     1'  Shell-side thermal conductivity (Btu/hr-ft-F):..',f11.3,/,
     2'  Shell-side Prandtle number:.....................',f11.3,/,
     3'  Shell-side surface tension (lbf/ft):...........',f11.5,/,
     4'  Shell-side water density (lbm/ft3):............',f11.3,/,
     5'  Shell-side steam density (lbm/ft3):............',f11.3,/,
     6'  Shell-side Rohsenow Constant (Csf):...........',f11.5,/,
     7'  Y1:.....................................',E11.3,/,
     8'  Y2:.....................................',E11.3,/,
     9'  Y3:.....................................',E11.3,/)
      print *,' '
      print *,'Enter: 0 For Steam Generator Menu'
      read(*,*) iu
      go to 1002
3     continue
      write(*,4)
4     format(' Did not converge in 30 iterations')
5     format(/////////////////////////)
1010  format(2e13.4)
1011  format(4f13.4)
9     continue
      return
      end
c.....................................................................
      Subroutine SGdes
      write(*,1)
1     format(////////////////////)
      print *,'  '
      print *,'The "SG.IN" Input File Must Contain The Following Data:'
      print *,'  '
      print *,'  Line 1:   Wp  '
      print *,'  Line 2:   Tp1, Tp2'
      print *,'  Line 3:   Di,  Do,   N,   kw'
      print *,'  Line 4:   Cws, Cps,  Ps'
      print *,'  Line 5:   fi,  fo'
      print *,'                                        '
      print *,' Where: Wp  = Hot Leg Flow Rate (Mlbm/hr)'
      print *,'        Tp1 = Hot Leg Temperature (F)'
      print *,'        Tp2 = Cold Leg Temperature (F)'
      print *,'        Di  = SG Tube Inside Diameter (in) '
      print *,'        Do  = SG Tube Outside Diameter (in) '
      print *,'        N   = Total Number of Tubes          '
      print *,'        kw  = Tube Material Thermal Conductivity (BU)'
      print *,'        Cws = Rohsenow Constant In Pool Boiling'
      print *,'        Cps = Secondary-side Specific Heat (Btu/lbm-F)'
      print *,'        Ps  = Tube Bundle Pressure (psia) '
      print *,'        fi  = Tube-side fouling factor (hr-F-ft2/Btu)'
      print *,'        fo  = Shell-side fouling factor (hr-F-ft2/Btu)'
      print *,' '
      return
      end
```