```
!     mpc24.des
!     Design paramters and boundary condition data
!     for the HOLTEC HISTAR 100 MPC-24
!
! Required macros and files:
!     mpc24.inp    - main input deck (calls this file)
!     boral.mac    - boral gap radiation/conduction macro
!     fuel.mac     - fuel conductivity macro
!
!   Units: BTU, in, hour, F, lbm
!
!
!
/title,Baltimore Tunnel Fire Accident Simulation - 20 meter - 11/15/02
case='mpc24-20'                    !  Id for this run, appears at the top
                                  !  of each plot
!--------------------------------------------------------------------------------
!tshell=342.42                     !  temperature at mpc shell
!                                  !  (from HI-STORM 100 thermal analysis results)
tshell=332                        ! temperature at mpc shell
                                  ! (from HI-STAR 100 FSAR long term results)
Tgas=598                          ! average canister cover gas temperature (F - S.S. average)
Tgas2=426                         ! average overpack cover gas temperature (F - S.S. average)
!--------------------------------------------------------------------------------
fti=12                            !  conversion factor ft to inch
pi=3.14159265                     !  pi
gr_in=386.4                       !  gravity term
hts=3600                          !  conversion factor from hours to seconds
!
! Basket geometry parameters
!
celptch=10.777                    !  basket cell pitch
fuelwid=8.43                      !  W17x17-OFA fuel assembly width
gtube_i=8.75                      !  inner width of guide tube
fuelgap=(gtube_i-fuelwid)/2       !  gap between guide tube and fuel
lfuel=144                         !  active fuel length (in)
tk1=5/16                          !  thickness of basket plate
tk1a=9/32                         !  thickness of basket plate
tk2=5/16                          !  thickness of basket supports
tk3=0.06                          !  thickness of boral sheathing
wd3=7+11/16                       !  width of boral sheathing (wide)
wd6=6+7/16                        !  width of boral sheathing (narrow)
tk4=0.075                         !  thickness of boral plate
wd4=7.5                           !  width of boral plate (wide)
wd5=6.25                          !  width of boral plate (narrow)
wd34=(wd3-wd4)/4                  !  gap between boral & sheathing @ ends          - assumed -
gp1=(0.082-tk4)/2                 !  gap between boral & sheathing/basket plate
tclad=0.25*tk4/2                  !  thk of boral clad                              - assumed -
tcore=0.75*tk4                    !  thk of boral core                              - assumed -
!
```

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! MPC geometry parameters
!
rinner=33.6875                  ! mpc shell inner radius
router=34.1875                  ! mpc shell outer radius
thkshl=.5                       ! thickness of the mpc shell
cutbac=.15                      ! basket support leg cut-back to rep. 1/8" fillet weld  - assumed -
wd2=rinner-61.78/2              ! basket support 9B stand-off distance
bsratio=.3                      ! ratio of basket support stand-off between 9C/9A      - assumed -
wd2_9A=wd2*2*(1-bsratio)        ! basket support 9C stand-off distance                 - assumed -
wd2_9C=wd2*2*bsratio            ! basket support 9A stand-off distance                 - assumed -
ang2=16                         ! basket support 9A/9B/9C angle                        - assumed -
bri=0.4                         ! basket support 9A/9B/9C inner radius                 - assumed -
bro=bri+tk2                     ! basket support 9A/9B/9C outer radius                 - assumed -
ang_9B_1=317                    ! basket support 9B angle (REF 315?)                   - assumed -
ang_9B_2=133                    ! basket support 9B angle (REF 135?)                   - assumed -
ang_9A=225                      ! basket support 9A angle
ang_9C=45                       ! basket support 9C angle
wd7=rinner-64.20/2              ! basket support 5C stand-off distance
wd8=3                           ! basket support 5C width
ang_5C_1=0                      ! basket support 5C angle
ang_5C_2=90                     ! basket support 5C angle
ang_5C_3=180                    ! basket support 5C angle
ang_5C_4=270                    ! basket support 5C angle
wd9=rinner-32.68                ! basket support 5E stand-off distance
wd10=2.5                        ! basket support 5E width
ang_5E_1=21                     ! basket support 5E angle                              - assumed -
ang_5E_2=69                     ! basket support 5E angle                              - assumed -
ang_5E_3=159                    ! basket support 5E angle                              - assumed -
ang_5E_4=291                    ! basket support 5E angle                              - assumed -
wd11=rinner-33.354              ! basket support 5D stand-off distance
wd12=2.5                        ! basket support 5D width
ang_5D_1=108                    ! basket support 5D angle                              - assumed -
ang_5D_2=198                    ! basket support 5D angle                              - assumed -
ang_5D_3=252                    ! basket support 5D angle                              - assumed -
ang_5D_4=342                    ! basket support 5D angle                              - assumed -
!
! Overpack geometry parameters
!
ri_opack=68.75/2                ! overpack inner radius
shtki=2.5                       ! overpack inner shell thickness
ish1=1.25                       ! overpack intermediate shell 1 thickness
ish2=1.25                       ! overpack intermediate shell 2 thickness
ish3=1.25                       ! overpack intermediate shell 3 thickness
ish4=1.25                       ! overpack intermediate shell 4 thickness
ish5=1                          ! overpack intermediate shell 5 thickness
ishtk=ish1+ish2+ish3+ish4+ish5  ! thickness of gamma shield plates
cutbac2=.15                     ! channel leg cut-back to rep. 1/4" fillet weld        - assumed -
rsho=ri_opack+shtki+ishtk       ! outer radius of overpack plates
rchtk=0.5                       ! plate thickness of radial channels
eshtk=0.5                       ! enclosure shell thickness
```

```
eshleng=8                          ! enclosure shell length
rchdp=4+7/16                       ! inside depth of radial channels
rchbri=1                           ! inside bend radius of radial channel         - assumed -
rchbro=rchbri+rchtk                ! outside bend radius of radial channel        - assumed -
numch=20                           ! number of radial channels
fmtk=0.125                         ! thickness of thermal expansion foam (HT-870)  - assumed -
ro_opack=96/2                      ! overpack outer radius
!
! Fuel heat generation parameters
!
heatld=20                          !  max. heat load (kW)
numfuel=24                         !  max. number of fuel assemblies
qpeak=1.1                          !  peaking factor for the fuel
qtot=heatld*3413                   !  total heat load   (btu/hr)
arfuel=numfuel*fuelwid*fuelwid     !  total area of fuel region (in**2)
qfuel=qpeak*qtot/(lfuel*arfuel)    !  heat generation for the fuel (btu/hr-in**3)
!
! Basket radiation parameters
!
sbc=(.119e-10)                      !  SB radiation constant (btu, in, F)
formf=1                             !  form (view) factor
esstl=0.36                          !  emissivity of the basket internals (FSAR: 0.36)
ebor=0.55                           !  emissivity of boral plate (Aluminum Clad)
est12=0.36                          !  emissivity of the shell interior
efuel=0.8                           !  emissivity of zircaloy clad fuel (FSAR: 0.8)
ecarb=0.66                          !  emissivity of carbon steel
emis_b=1/(1/esstl+1/ebor-1)         !  effective emissivity of sst/boral
!
! Helium conduction parameters
!
zc=1                                ! mult for Helium conduction due to velocity
fk=0.957                            ! 1% rod failure
fill_p=28.3                         ! initial MPC He fill pressure (gauge)
fill_t=70                           ! temperature at MPC fill (F)
p_atm=14.696                        ! atmospheric pressure (gauge)
fill_d=4.00260*p_atm*fti**2/1545.3/(Tgas+460)
                                    ! initial density of MPC fill (lbm/ft^3)
gtmult=((Tgas+460)*(fill_p+p_atm)/(fill_t+460))/p_atm
                                    !  MPC pressurization in atmospheres
fk=fk+gtmult-1                      !  multiplier for Helium conduction due to enhanced
                                    !  pressurization in remaining canister region
                                    !  (accounts for fission gas too)

fillo_p=10                          ! initial overpack He fill pressure (gauge)
fillo_t=70                          ! temperature at overpack fill (F)
p_atm=14.696                        ! atmospheric pressure (gauge)
fill_d=4.00260*p_atm*fti**2/1545.3/(Tgas2+460)
                                    ! initial density of overpack fill (lbm/ft^3)
gtmult2=((Tgas2+460)*(fillo_p+p_atm)/(fillo_t+460))/p_atm
                                    !  overpack pressurization in atmospheres
```

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fk2=gtmult2-1                          !  multiplier for Helium conduction due to enhanced
                                       !  pressurization in overpack region
!
! Transient loading parameters
!
! insolation parameters
abso_sol=0.90                            ! asorptivity of overparck surface coating (HEA)
thik_sol=0.1                             ! thickness of solar layer
solm=1.00                                ! solar insolation correction multiplier
rate_sol=solm*1.49095*abso_sol           ! surface heat rate for solar (Btu/in^2/hr over 24hours)
! ambient parameters
temp_amb=100                             ! ambient temperature
film_amb=0.891/fti**2                    ! film coefficient for convection to ambient
emis_amb=0.85                            ! emissivity for radiation to ambient (FSAR: 0.85)
view_amb=1                               ! radiation view factor for radiation to ambient
! fire parameters
time_fir=300                             ! total time of fire (hr)
emis_fir=0.9                             ! emissivity for fire
! cooldown to ambient properties
time_am2=100                             ! time for cooldown after fire (hr)
temp_am2=100                             ! ambient temperature
film_am2=0.891/fti**2                    ! film coefficient for convection to ambient after fire
emis_am2=0.9                             ! emissivity for ambient after fire
view_am2=1                               ! radiation view factor for ambient after fire
!
! Material properties
!
fini
/prep7
!-------------------------------------------------------------------------------
!     material 1  = Fuel region
!     material 2  = Stainless steel for basket plates
!     material 3  = Stainless steel for basket supports
!     material 4  = Stainless steel for boral plate sheathing
!     material 5  = Helium - gas conduction in central core region
!     material 6  = Helium - gas conduction between MPC and cask
!
!     material 7  = Helium - gas conduction in region between guide tubes & basket plates
!     material 8  = Helium - gas conduction in region between basket & MPC shell
!     material 9  = Boral plates (parallel to thickness)
!     material 10 = Boral plates (parallel to cross-width)
!     material 11 = Stainless steel for MPC shell
!     material 12 = Gussetted cradle (steel/air equivalency)
!
!     material 17 = Reduced 5/16" radial basket support conductivity (1/8" fillet weld)
!     material 18 = Reduced 3" radial basket support conductivity (1/8" fillet weld)
!     material 19 = Reduced 2.5" radial basket support conductivity (1/8" fillet weld)
!
!     material 20 = Stainless steel for inner shell of overpack
!     material 21 = Carbon steel for intermediate shells of overpack (with gaps)
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!     material 22 = Stainless steel for radial channels of overpack
!     material 23 = Stainless steel for enclosure shells of overpack
!     material 24 = Holtite A for neutron shield
!     material 25 = HT-870 for foam
!     material 26 = Air for degraded Holtite A after fire
!     material 27 = Reduced radial channel conductivity (1/4" fillet weld)
!     material 28 = Carbon steel for intermediate shells of overpack (intimate contact)
!
!     material 31 = emissivity of fuel based on value for zircaloy
!     material 32 = emissivity of basket based on value for Alloy X
!     material 42 = emissivity of support bracket based on value for Alloy X
!     material 52 = emissivity of MPC wall based on value for Alloy X
!
!     material 70 = emissivity during fire
!
!     material 999= dummy material number to give ANSYS the capability of using higher numbers
!---------------------------------------------------------------------------
! Fuel Region
fuel,1,fk
!---------------------------------------------------------------------------
! Stainless steel for Basket (Alloy X)
! FSAR: 501 lbm/ft^3, 0.12 Btu/lbm-F, 200,450,700/8.4,9.8,11.0 F Btu/ft-hr-F
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,2,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,2,501/fti**3
mp,c,2,0.12
! Stainless steel for basket supports (Alloy X)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,3,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,3,501/fti**3
mp,c,3,0.12
! Stainless steel for boral plate sheathing (Alloy X)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,4,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,4,501/fti**3
mp,c,4,0.12
! Stainless steel for MPC shell (Alloy X)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,11,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,11,501/fti**3
mp,c,11,0.12
! Stainless steel for basket supports (Alloy X)
! reduced radial-direction basket support conductivity (1/8" fillet weld)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,17,1,8.4/fti*.4,9.8/fti*.4,11.0/fti*.4,14.36/fti*.4
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```
mpdata,kyy,17,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,17,501/fti**3
mp,c,17,0.12
!  Stainless steel for basket supports (Alloy X)
!  reduced radial-direction basket support conductivity (1/8" fillet weld)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,18,1,8.4/fti*0.0833,9.8/fti*0.0833,11.0/fti*0.0833,14.36/fti*0.0833
mpdata,kyy,18,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,18,501/fti**3
mp,c,18,0.12
!  Stainless steel for basket supports (Alloy X)
!  reduced radial-direction basket support conductivity (1/8" fillet weld)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,19,1,8.4/fti*0.1,9.8/fti*0.1,11.0/fti*0.1,14.36/fti*0.1
mpdata,kyy,19,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,19,501/fti**3
mp,c,19,0.12
!  Stainless steel for inner shell of overpack (Alloy X)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,20,1,8.4/fti,9.8/fti,11.0/fti,14.36/fti
mp,dens,20,501/fti**3
mp,c,20,0.12
!--------------------------------------------------------------------------------
!  Helium - gas conduction in central core region
!  density calculated at standard pressure using ideal gas law and then scaled
!  for an average pressure using the zc*fk factor
!  FSAR: 1.24 Btu/lbm-F 200,450,700/0.0976,0.1289,0.1575 F Btu/ft-hr-F
den_h000=(4.00260*p_atm*fti**2/1545.3/(0+460))/(fti**3)
den_h200=(4.00260*p_atm*fti**2/1545.3/(200+460))/(fti**3)
den_h400=(4.00260*p_atm*fti**2/1545.3/(400+460))/(fti**3)
den_h600=(4.00260*p_atm*fti**2/1545.3/(600+460))/(fti**3)
den_h800=(4.00260*p_atm*fti**2/1545.3/(800+460))/(fti**3)
mptemp
mptemp,1,0,200,400,600,800,1400
mpdata,kxx,5,1,0.0065*zc*fk,0.00808*zc*fk,0.00958*zc*fk,0.01075*zc*fk,0.0115*zc*fk,0.01375*zc*fk
mpdata,dens,5,1,den_h000,den_h200,den_h400,den_h600,den_h800
mp,c,5,1.24
!   Helium - gas conduction between MPC and cask
mptemp
mptemp,1,0,200,400,600,800,1400
mpdata,kxx,6,1,0.0065*fk2,0.00808*fk2,0.00958*fk2,0.01075*fk2,0.0115*fk2,,0.01375*fk2
mpdata,dens,6,1,den_h000,den_h200,den_h400,den_h600,den_h800
mp,c,6,1.24
!   Helium - gas conduction in region between guide tubes & basket
mptemp
mptemp,1,0,200,400,600,800,1400
mpdata,kxx,7,1,0.0065*zc*fk,0.00808*zc*fk,0.00958*zc*fk,0.01075*zc*fk,0.0115*zc*fk,0.01375*zc*fk
```

```
mpdata,dens,7,1,den_h000,den_h200,den_h400,den_h600,den_h800
mp,c,7,1.24
!   Helium - gas conduction in region between basket & MPC shell
mptemp
mptemp,1,0,200,400,600,800,1400
mpdata,kxx,8,1,0.0065*zc*fk,0.00808*zc*fk,0.00958*zc*fk,0.01075*zc*fk,0.0115*zc*fk,0.01375*zc*fk
mpdata,dens,8,1,den_h000,den_h200,den_h400,den_h600,den_h800
mp,c,8,1.24
!---------------------------------------------------------------------------------
!   data for helium conductivity (btu/hr-in-F)
!   to be used in boral.mac
*set,kxxx
*dim,kxxx,table,6
kxxx(1,0)=0,200,400,600,800,1400
kxxx(1,1)=0.0065*zc*fk,0.00808*zc*fk,0.00958*zc*fk,0.01075*zc*fk,0.0115*zc*fk,0.01375*zc*fk
!
!  boral plates (parallel to thickness)
boral,9,emis_b*formf*sbc,gp1,tclad,tcore,1
!
!  boral plates (parallel to cross-width)
boral,10,emis_b*formf*sbc,gp1,tclad,tcore,2
!---------------------------------------------------------------------------------
!  Carbon steel/Air composite for intermediate overpack shells (with gaps)
!  Equivalent conductivity
!  Carbon FSAR: 200,450,700/24.4    23.9    22.4    F Btu/ft-hr-F
!  Air FSAR:    200,450,700/ 0.0173  0.0225  0.0272 F Btu/ft-hr-F
!  Air Guyer:   200,450,700/ 0.0178  0.0230  0.0314 F Btu/ft-hr-F
!  Air Guyer: 200,450,700/0.0178,(0.02200+0.02401)/2,(0.02963+0.03323)/2 F Btu/ft-hr-F
!  Air Guyer: 200,450,700/0.0602,(0.0462+0.0413)/2,(0.0374+0.0315)/2 lbm/ft^3
!  Air Guyer: 200,450,700/0.2411,(0.2448+0.2473)/2,(0.2504+0.2567)/2 Btu/lbm-F

gam_gap=0.010
gam_form=1

t_t=200
k_12=0.0178/fti
k_23=24.4/fti
! intermediate shell 1
r_1=ri_opack+shtki
r_2=ri_opack+shtki+gam_gap
r_3=ri_opack+shtki+gam_gap+ish1
emis_1=esstl
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_cr_13
! intermediate shell 2
```

```
r_1=ri_opack+shtki+gam_gap+ish1
r_2=ri_opack+shtki+ish1+2*gam_gap
r_3=ri_opack+shtki+ish1+2*gam_gap+ish2
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 3
r_1=ri_opack+shtki+ish1+ish2+2*gam_gap
r_2=ri_opack+shtki+ish1+ish2+3*gam_gap
r_3=ri_opack+shtki+ish1+ish2+3*gam_gap+ish3
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 4
r_1=ri_opack+shtki+ish1+ish2+ish3+3*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap+ish4
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 5
r_1=ri_opack+shtki+ish1+ish2+ish3+ish4+4*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap+ish5
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
K200_eqv=log((ri_opack+shtki+ishtk+5*gam_gap)/(ri_opack+shtki))/(2*pi*R_eqv)

t_t=450
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```
k_12=0.0225/fti
k_23=23.9/fti
! intermediate shell 1
r_1=ri_opack+shtki
r_2=ri_opack+shtki+gam_gap
r_3=ri_opack+shtki+gam_gap+ish1
emis_1=esstl
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_cr_13
! intermediate shell 2
r_1=ri_opack+shtki+gam_gap+ish1
r_2=ri_opack+shtki+ish1+2*gam_gap
r_3=ri_opack+shtki+ish1+2*gam_gap+ish2
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 3
r_1=ri_opack+shtki+ish1+ish2+2*gam_gap
r_2=ri_opack+shtki+ish1+ish2+3*gam_gap
r_3=ri_opack+shtki+ish1+ish2+3*gam_gap+ish3
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 4
r_1=ri_opack+shtki+ish1+ish2+ish3+3*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap+ish4
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
```

```
! intermediate shell 5
r_1=ri_opack+shtki+ish1+ish2+ish3+ish4+4*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap+ish5
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
K450_eqv=log((ri_opack+shtki+ishtk+5*gam_gap)/(ri_opack+shtki))/(2*pi*R_eqv)

t_t=700
k_12=0.0272/fti
k_23=22.4/fti
! intermediate shell 1
r_1=ri_opack+shtki
r_2=ri_opack+shtki+gam_gap
r_3=ri_opack+shtki+gam_gap+ish1
emis_1=esstl
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_cr_13
! intermediate shell 2
r_1=ri_opack+shtki+gam_gap+ish1
r_2=ri_opack+shtki+ish1+2*gam_gap
r_3=ri_opack+shtki+ish1+2*gam_gap+ish2
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 3
r_1=ri_opack+shtki+ish1+ish2+2*gam_gap
r_2=ri_opack+shtki+ish1+ish2+3*gam_gap
r_3=ri_opack+shtki+ish1+ish2+3*gam_gap+ish3
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
```

```
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 4
r_1=ri_opack+shtki+ish1+ish2+ish3+3*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+4*gam_gap+ish4
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
! intermediate shell 5
r_1=ri_opack+shtki+ish1+ish2+ish3+ish4+4*gam_gap
r_2=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap
r_3=ri_opack+shtki+ish1+ish2+ish3+ish4+5*gam_gap+ish5
emis_1=ecarb
emis_2=ecarb
R_c_12=log(r_2/r_1)/2/pi/k_12
R_r_12=(1/emis_1+(1-emis_2)/emis_2*(r_1/r_2)**2)/(8*pi*sbc*gam_form*r_1*(t_t+460)**3)
R_c_23=log(r_3/r_2)/2/pi/k_23
R_cr_12=R_c_12*R_r_12/(R_c_12+R_r_12)
R_cr_13=R_cr_12+R_c_23
R_eqv=R_eqv+R_cr_13
K700_eqv=log((ri_opack+shtki+ishtk+5*gam_gap)/(ri_opack+shtki))/(2*pi*R_eqv)

mptemp
mptemp,1,200,450,700
mpdata,kxx,21,1,k200_eqv,k450_eqv,k700_eqv
mpdata,kyy,21,1,24.4/fti,23.9/fti,22.4/fti
mp,dens,21,489/fti**3
!  Carbon steel for intermediate overpack shells (intimate contact)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,28,1,24.4/fti,23.9/fti,22.4/fti,18.9/fti
mp,dens,28,489/fti**3
mp,c,28,0.1
!  Carbon steel for radial channels of overpack
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,22,1,29.2/fti,27.1/fti,24.6/fti,17.6/fti
mp,dens,22,489/fti**3
mp,c,22,0.1
!  Carbon steel for enclosure shells of overpack
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,23,1,29.2/fti,27.1/fti,24.6/fti,17.6/fti
```

```
mp,dens,23,489/fti**3
mp,c,23,0.1
! Carbon steel for channels
! reduced radial-direction basket support conductivity (1/4" fillet weld)
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,27,1,29.2*0.5/fti,27.1*0.5/fti,24.6*0.5/fti,17.6*0.5/fti
mpdata,kyy,27,1,29.2/fti,27.1/fti,24.6/fti
mp,dens,27,489/fti**3
mp,c,27,0.1
!----------------------------------------------------------------------------------
! Neutron Shield (Holtite A)
! FSAR: 105.0 lbm/ft^3, 0.39 Btu/lbm-F 200,450,700/0.373,0.373,0.373 F Btu/ft-hr-F
mp,kxx,24,0.373/fti
mp,dens,24,105/fti**3
mp,c,24,0.39
! Neutron Shield (Holtite A) After fire damage
! FSAR: 105.0 lbm/ft^3, 0.39 Btu/lbm-F 200,450,700/0.373,0.373,0.373 F Btu/ft-hr-F
mp,kxx,124,0.373/fti/10
mp,dens,124,105/fti**3
mp,c,124,0.39
!----------------------------------------------------------------------------------
! Thermal expansion foam (BISCO HT-870)
! Rogers Corp web: 15 lb/ft^3, 0.49 BTU in/hr/ft^2/F
mp,kxx,25,0.49/fti**2
mp,dens,25,15/fti**3
mp,c,25,0.39
!----------------------------------------------------------------------------------
! Air
! FSAR: 200,450,700/0.0173,0.0225,0.0272 F Btu/ft-hr-F
! Guyer: 200,450,700/0.0602,(0.0462+0.0413)/2,(0.0374+0.0315)/2 lbm/ft^3
! Guyer: 200,450,700/0.2411,(0.2448+0.2473)/2,(0.2504+0.2567)/2 Btu/lbm-F
! Guyer: 200,450,700/0.0178,(0.02200+0.02401)/2,(0.02963+0.03323)/2 F Btu/ft-hr-F
mptemp
mptemp,1,200,450,700,1400
mpdata,kxx,26,1,0.0178/fti,0.0225/fti,0.0272/fti,.04036/fti
mpdata,dens,26,1,0.0602/fti**3,0.04375/fti**3,0.03445/fti**3,0.00841/fti**3
mpdata,c,26,1,0.2411,.24605,.25355,.27455
!----------------------------------------------------------------------------------
! Steel/Air equivalent conductor for cradle
! FSAR steel: 489 lbm/ft^3, 0.1 Btu/lbm-f 200,450,700/29.2,27.1,24.6 F Btu/ft-hr-F
! FSAR air: 200,450,700/0.0173,0.0225,0.0272 F Btu/ft-hr-F
st_ar=3*(12*0.75*(6.12-0.75*2)+2*0.75*101)
tot_ar=101*173.125
st_rat=st_ar/tot_ar
ar_rat=1-st_rat
conv_mult=10

ky200=(29.2*st_rat+0.0178*conv_mult*ar_rat)/fti
ky450=(27.1*st_rat+0.0225*conv_mult*ar_rat)/fti
```

```
ky700=(24.6*st_rat+0.0272*conv_mult*ar_rat)/fti

! average kxx over cradle and air -> very small conductivity?
cr_w=6.12*3
tot_w=173.125
cr_rat=cr_w/tot_w
ar_rat=1-cr_rat
rx1_200=12*.75/29.2/(6.12-2*.75)+(101-12*.75)/(0.0178*conv_mult)/(6.12-2*.75)
rx1_450=12*.75/27.1/(6.12-2*.75)+(101-12*.75)/(0.0225*conv_mult)/(6.12-2*.75)
rx1_700=12*.75/24.6/(6.12-2*.75)+(101-12*.75)/(0.0272*conv_mult)/(6.12-2*.75)
rx2_200=101/29.2/(2*0.75)
rx2_450=101/27.1/(2*0.75)
rx2_700=101/24.6/(2*0.75)
rx_200=rx1_200*rx2_200/(rx1_200+rx2_200)
rx_450=rx1_450*rx2_450/(rx1_450+rx2_450)
rx_700=rx1_700*rx2_700/(rx1_700+rx2_700)
kx200=((101/6.12/rx_200)*cr_rat+0.0178*conv_mult*ar_rat)/fti
kx450=((101/6.12/rx_450)*cr_rat+0.0225*conv_mult*ar_rat)/fti
kx700=((101/6.12/rx_700)*cr_rat+0.0272*conv_mult*ar_rat)/fti

! average kxx over just the cradle -> reasonable conductivity?
!rx1_200=12*.75/29.2/(6.12-2*.75)+(101-12*.75)/(0.0178*conv_mult)/(6.12-2*.75)
!rx1_450=12*.75/27.1/(6.12-2*.75)+(101-12*.75)/(0.0225*conv_mult)/(6.12-2*.75)
!rx1_700=12*.75/24.6/(6.12-2*.75)+(101-12*.75)/(0.0272*conv_mult)/(6.12-2*.75)
!rx2_200=101/29.2/(2*0.75)
!rx2_450=101/27.1/(2*0.75)
!rx2_700=101/24.6/(2*0.75)
!rx_200=rx1_200*rx2_200/(rx1_200+rx2_200)
!rx_450=rx1_450*rx2_450/(rx1_450+rx2_450)
!rx_700=rx1_700*rx2_700/(rx1_700+rx2_700)
!kx200=(101/6.12/rx_200)/fti
!kx450=(101/6.12/rx_450)/fti
!kx700=(101/6.12/rx_700)/fti

mptemp
mptemp,1,200,450,700
mpdata,kxx,12,1,kx200,kx450,kx700
mpdata,kyy,12,1,ky200,ky450,ky700
abc1=(501*st_rat+0.0602*ar_rat)
abc2=(501*st_rat+0.04375*ar_rat)
abc3=(501*st_rat+0.03445*ar_rat)
mpdata,dens,12,abc1/fti**3,abc2/fti**3,abc3/fti**3
mpdata,c,12,(0.1*st_rat+0.2411*ar_rat),(0.1*st_rat+0.24605*ar_rat),(0.1*st_rat+0.25355*ar_rat)
!
! FSAR: Cryo steel 200,450,700/23.8,23.7,22.3 F Btu/ft-hr-F
! FSAR: carbon steel support 200,450,700/29.2,27.1,24.6 F Btu/ft-hr-F
!
!-------------------------------------------------------------------------------
!  Define Aux12/Matrix50 material properties
 mp,emis,31,efuel      ! Fuel based on value for zircaloy
```

```
 mp,emis,32,esstl       ! Basket based on value for Alloy X
 mp,emis,42,est12       ! Support bracket based on value for Alloy X
 mp,emis,70,emis_fir    ! Cask and tunnel during fire
 mp,emis,71,emis_fir    ! Cask and tunnel during fire
 zne1=500               ! number of zones applied to fuel/guide tube radiation computation
 zne2=500               ! number of zones applied to guide tube/basket radiation computation
 zne3=1000              ! number of zones applied to corner radiation computation
 zne4=500               ! number of zones applied to radiation computation inside supports
 zne5=500               ! number of zones applied to MPC/overpack radiation computation
 zne6=500               ! number of zones applied to tunnel radiation computation
 mp,emis,999,nothing    ! high material number so ANSYS won't complain during radiation computation
!--------------------------------------------------------------------------------
!   Define offset temperature
toffst,460
```