

(5)

mpc24-5.des

04/11/2003

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!      mpc24-5.des
!      Design paramters and boundary condition data
!      for the HOLTEC HISTAR 100 MPC-24
!
! Required macros and files:
!      mpc24-5m.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 - 5 meter - 11/15/02
case='mpc24-5m'      ! 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
gp1=(0.082-tk4)/2   ! gap between boral & sheathing/basket plate
tclad=0.25*tk4/2    ! thk of boral clad
tcore=0.75*tk4      ! thk of boral core
!

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- assumed -
- assumed -
- 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

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eshleng=8          ! enclosure shell length
rchdp=4+7/16       ! inside depth of radial channels
rchbri=1           ! inside bend radius of radial channel
rchbro=rchbri+rchtk ! outside bend radius of radial channel
numch=20           ! number of radial channels
fmtk=0.125         ! thickness of thermal expansion foam (HT-870)
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
esst1=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/esst1+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=150       ! 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

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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=esst1
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

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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=esst1
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

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! 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=esst1
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

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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
mpdata,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
mpdata,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
mpdata,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
mpdata,1,200,450,700,1400
mpdata,kxx,23,1,29.2/fti,27.1/fti,24.6/fti,17.6/fti

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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
mpdata,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
!-----
! 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
mpdata,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
mpdata,1,200,450,700
mpdata,kxx,12,1,kx200,kx450,kx700
mpdata,ky,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,esst1      ! 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

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```
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
```