LIGO-E970142 00-V

PROCESS SYSTEMS INTERNATIONAL, INC.					ENGINEERING	NO: V049-1-161
WESTBOROUGH, MA					CALCULATIONS	PAGE 1 OF 13
REV	DEO#	DATE	BY:	CHECK	TITLE:	
0	558	10/17/97	R. Than	D. M[illegible]	TRANSIENT ANALYSIS GATE VALVE WARMUP	
					BY: R. THAN	DEPT: 744
PROJECT: LIGO					PROJECT NO: V59049	

PURPOSE:
To determine ramprate to limit the temperature lag between large gate valve gatemass and rest of system to less than twice the steady state value.

METHOD: Radiation exchange model between adjoining vessels section and valve's gate surface. Transient model

ASSUMPTIONS:
An emmissivity for the gate surface of 0.1 was used
For the low emissivity liner an ε of 0.06 was used.
The chamber vessel surface: ε of 0.7
The open bore to beam tube/manifold: ε of 0.9
The system surfaces heated directly by the blankets are ramped up at a linear rate until 150°C and held at 150°C.

INPUTS:
GNB DGW: 103227, 103879

OCT 22 1997

REFERENCE: TIM66, V49-LP-140

CALCULATIONS:
see Attachments

CONCLUSIONS:
Recommend that the ramprate be limited to 1 °C/hr such that the thermal expansion during the transient case is less than twice the steady state case, and ensure that an additional 3 to 4 ft length of insulation, equivalent to 1" fiberglass, is added beyond the heated 3 ft section on the "other side" of the gate. This will improve temperature uniformity along the spool's wall in the angular direction and milder gradient along the axial direction from the heated section to the unheated section.

NOTES: The emissivity used for the gate surface is conservative, but has less of an effect on the lag for $\alpha=\varepsilon$. The critical parameter is how much length of the beamtube/manifold is heated. This dictates the viewfactor from the gatesurface to the open bore, ambient temperature sink.

Revision History

Rev.	Comments	Date
0	Release for review	10/10/97

Simulation Model

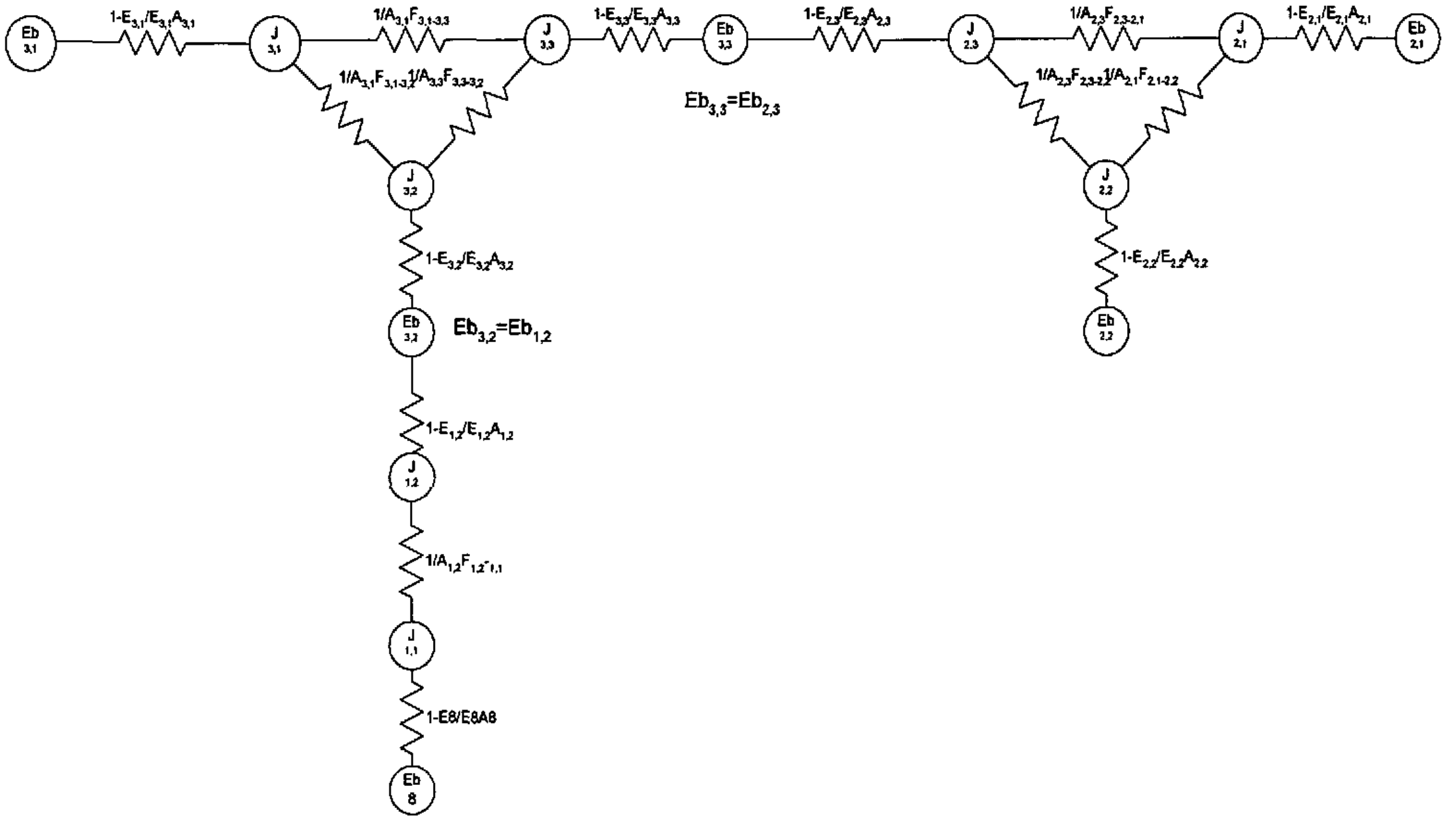
For the 44 inch gatevalve, one side of the gate sees a low e liner (cryopump) and the other side sees a short (0.6 m) heated section of the beamtube.

For the 48 inch gatevalve, one side of the gate see a completely heated section and the other side sees a short (0.6m) heated section of the spoolpiece/beammanifold.

An emmissivity for the gate surface of 0.1 was used.
For the low emissivity liner an ε of 0.06 was used.
For the chamber vessel surface an ε of 0.7 was used.
For the open bore to beam tube/manifold an ε of 0.9 was used.
The system surfaces heated directly by the blankets are ramped up at a linear rate until 150°C and held at 150°C.
The time interval used for the each step is 10 seconds.
The net energy to each floating surface was computed using the temperatures of specified ramping surfaces and the current temperatures of the floating surfaces.
The new temperature for each floating surface was computed using the net energy to these surfaces , the heat capacity, and time interval.

The maximum lag occur at the end of the ramp, top of the heating cycle just as the the ramping surfaces reaches the maximum soak temperature.
The lag between the gate surface and rest of the ramping surfaces are:
For 44" gate with the maximum lag is 47°C at a 2°C/hr ramprate.
For 44" gate with the maximum lag is 31°C at a 1°C/hr ramprate
For 48" gate with the maximum lag is 51°C at a 2°C/hr ramprate
For 48" gate with the maximum lag is 34°C at a 1°C/hr ramprate

We should be cautious and proceed with a ramprate that is conservative.
The is some additional mass and surface that needs to be heated, the carriage frame which was not modeled. Therefore, even with a 1°C/hr ramprate, the lag temperature may exceed 34°C.
The following is recommended: ramprate of 1°C and ensure that some additional insulation is added beyond the heated 3 ft section on the "other side" of the gate.
<u>Thermal expansion</u>
With a 50°C lag the body at the gate opening will be expanded by 0.030" more than the gate surface. The carriage frame may lag the gate also because of a smaller surface to mass ratio. The thermal expansion difference between the gate and carriage frame is taken up by the linkages. The carriage frame is on wheels. There are two sets of guide wheels, one for each direction.(up/down, sideways). The thermal expansion difference between the body and carriage frame is taken up by the up/down wheels sliding sideways. On warmup the body leads the carriage, so the sideways direction wheels will trail not touch the body walls. On cooldown the gate will lead if the ramprate is small enough otherwise for high enough cooldown rate, at some point the gate surface will lag and the sideways wheels will start to undergo loading from the body.


Eb 3,1
1-E3,1/E3,1A3,1
J 3,1
1/A3,1F3,1-3,3
J 3,3
1/A3,1F3,1-3,2
1/A3,3F3,3-3,2
1-E3,3/E3,3A3,3
Eb 3,3
Eb3,3=Eb2,3
1-E2,3/E2,3A2,3
J 2,3
1/A2,3F2,3-2,1
J 2,1
1/A2,3F2,3-2,2
1/A2,1F2,1-2,2
1-E2,1/E2,1A2,1
Eb 2,1
J 2,2
1-E2,2/E2,2A2,2
Eb 2,2
J 3,2
1-E3,2/E3,2A3,2
Eb 3,2
Eb3,2=Eb1,2
1-E1,2/E1,2A1,2
J 1,2
1/A1,2F1,2-1,1
J 1,1
1-E8/E8A8
Eb 8

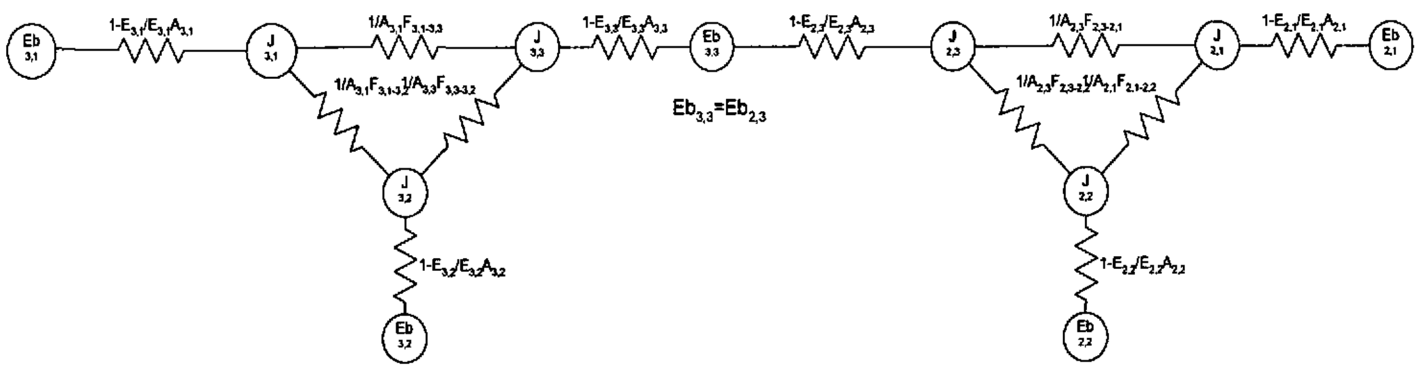
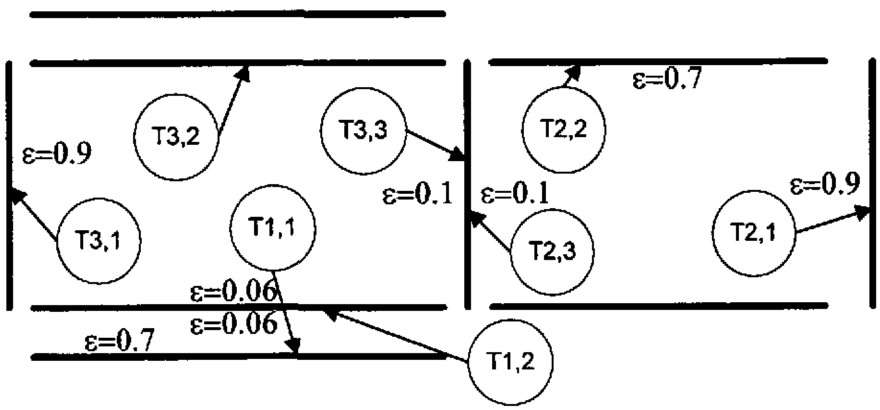

Eb 3,1
1-E3,1/E3,1A3,1
J 3,1
1/A3,1F3,1-3,3
J 3,3
1/A3,1F3,1-3,2
1/A3,3F3,3-3,2
1-E3,3/E3,3A3,3
Eb 3,3
Eb3,3=Eb2,3
1-E2,3/E2,3A2,3
J 2,3
1/A2,3F2,3-2,1
J 2,1
1/A2,3F2,3-2,2
1/A2,1F2,1-2,2
1-E2,1/E2,1A2,1
Eb 2,1
J 3,2
1-E3,2/E3,2A3,2
Eb 3,2
J 2,2
1-E2,2/E2,2A2,2
Eb 2,2

Figure.1



44"GateValve with low e liner on one side, Ramprate: 2°C/hr

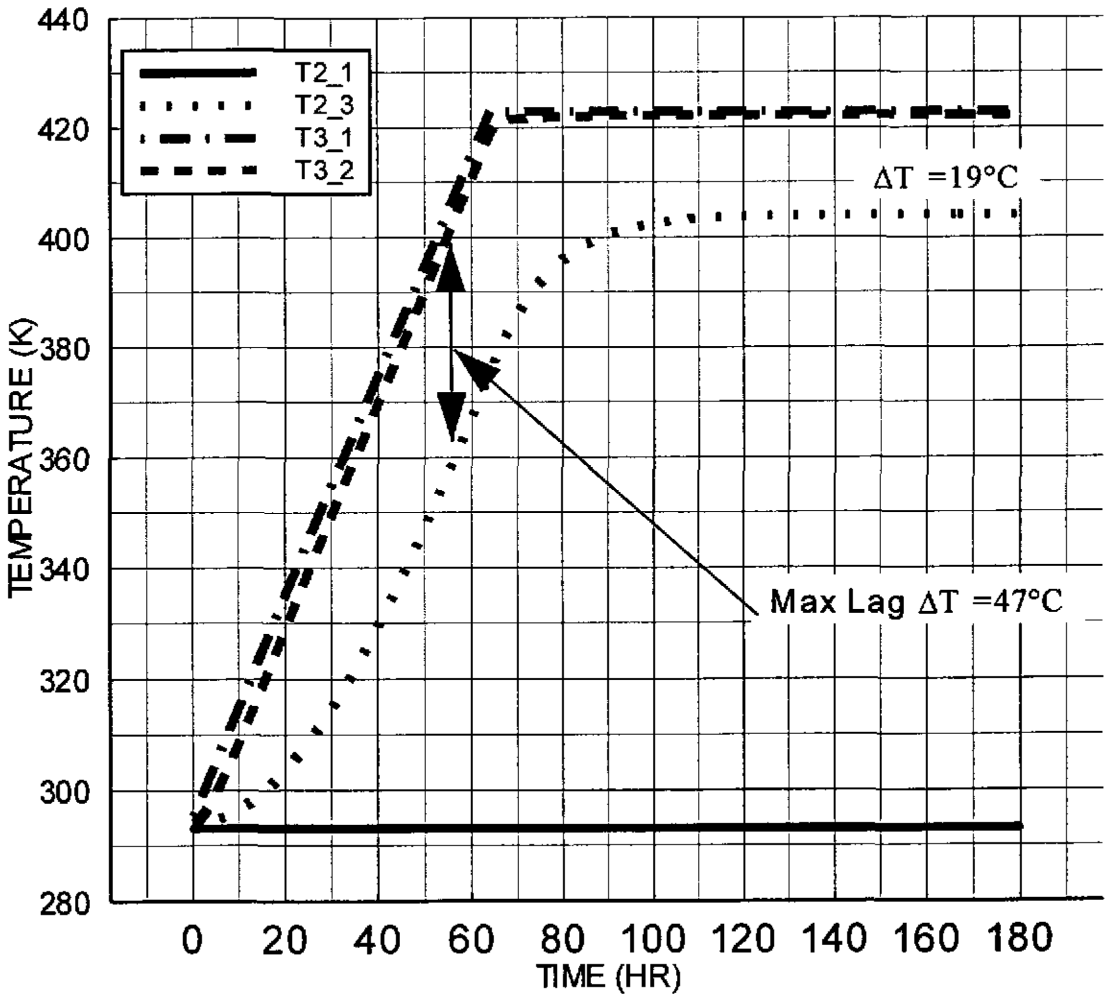
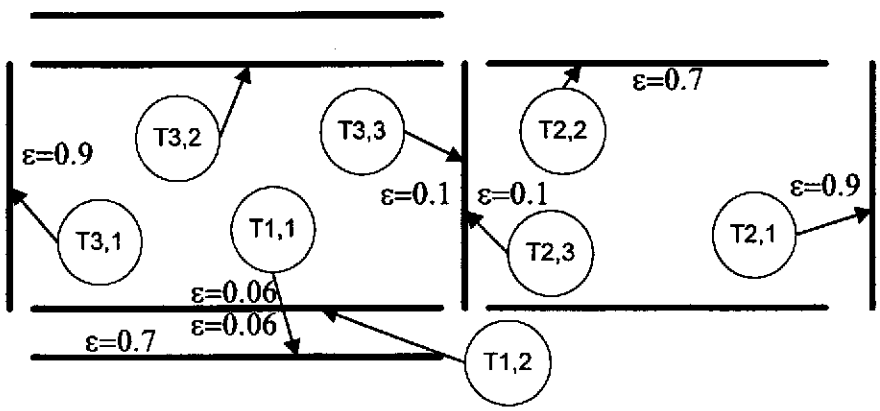


Figure.2


ε=0.7
ε=0.9
T3,2
T3,3
T2,2
ε=0.1
ε=0.1
ε=0.9
T3,1
T1,1
T2,3
T2,1
ε=0.06
ε=0.06
ε=0.7
T1,2

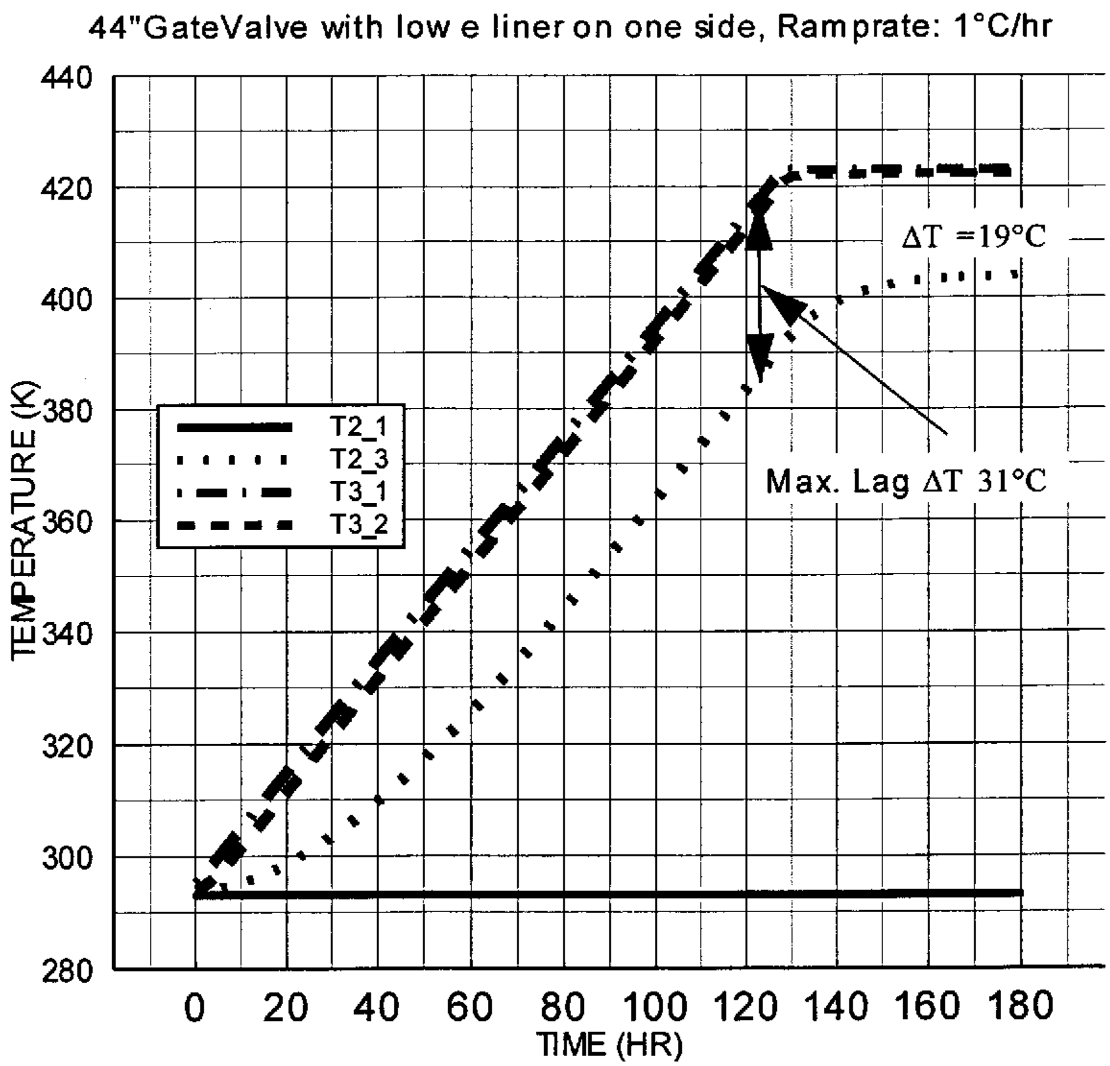
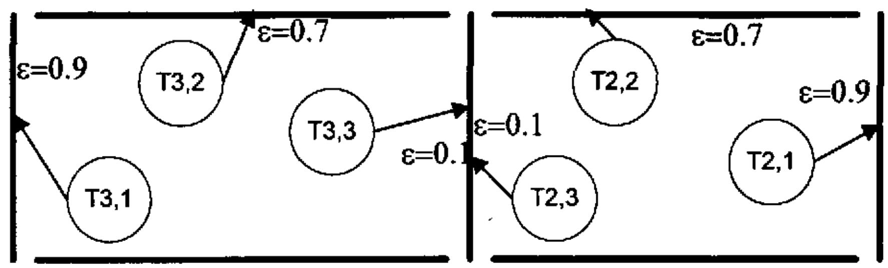

44"GateValve with low e liner on one side, Ramprate: 1°C/hr
TEMPERATURE (K)
TIME (HR)
T2_1
T2_3
T3_1
T3_2
ΔT =19°C
Max. Lag ΔT 31°C
440
420
400
380
360
340
320
300
280
0
20
40
60
80
100
120
140
160
180

Figure.3


ε=0.9
T3,2
ε=0.7
T3,3
ε=0.1
T3,1
ε=0.1
T2,2
ε=0.7
ε=0.9
T2,1
T2,3

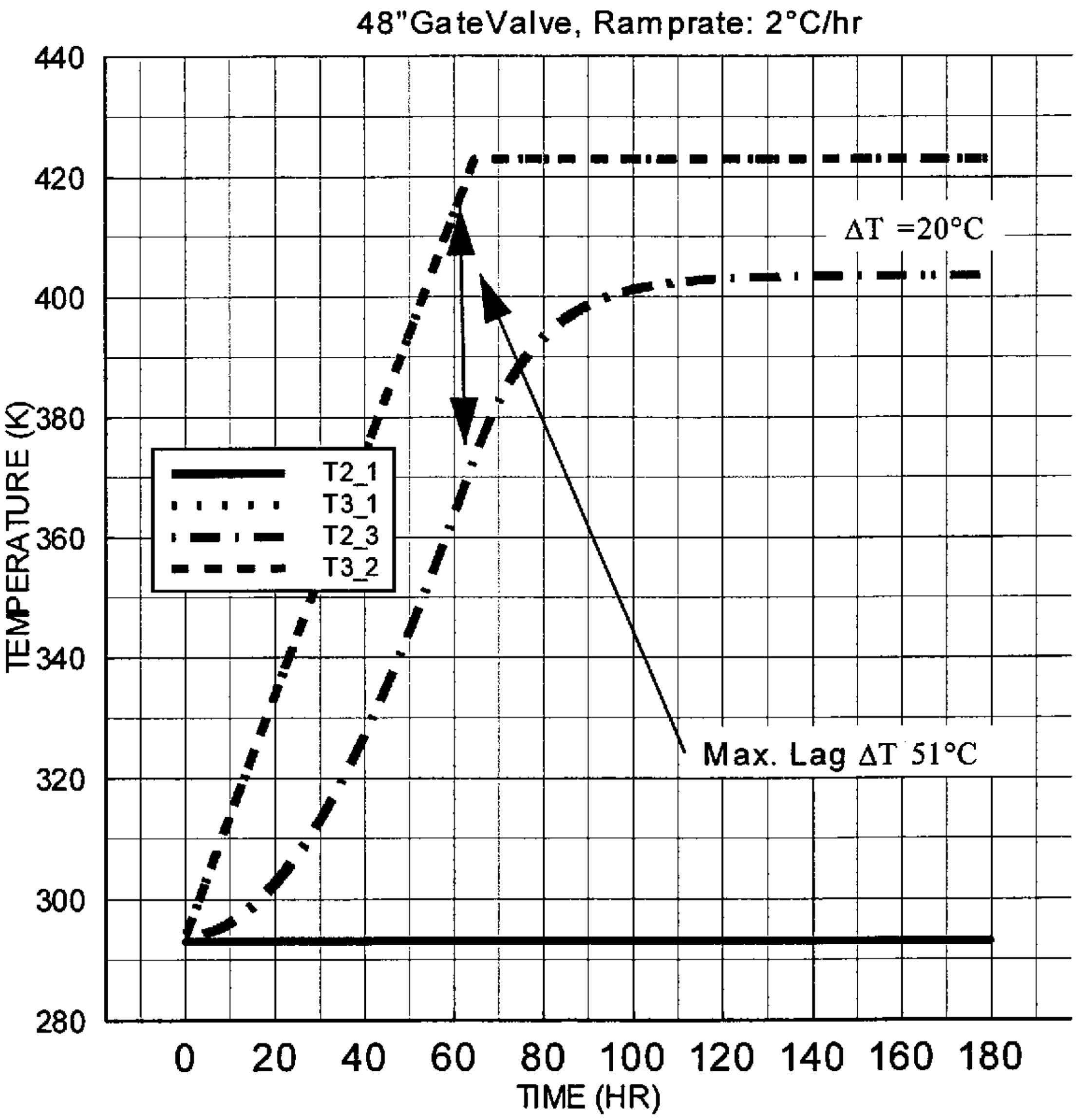
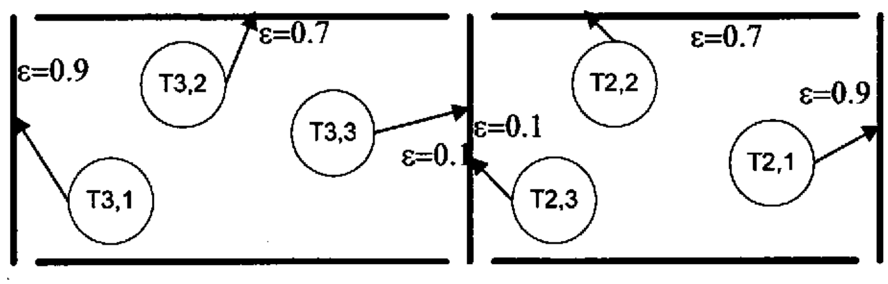
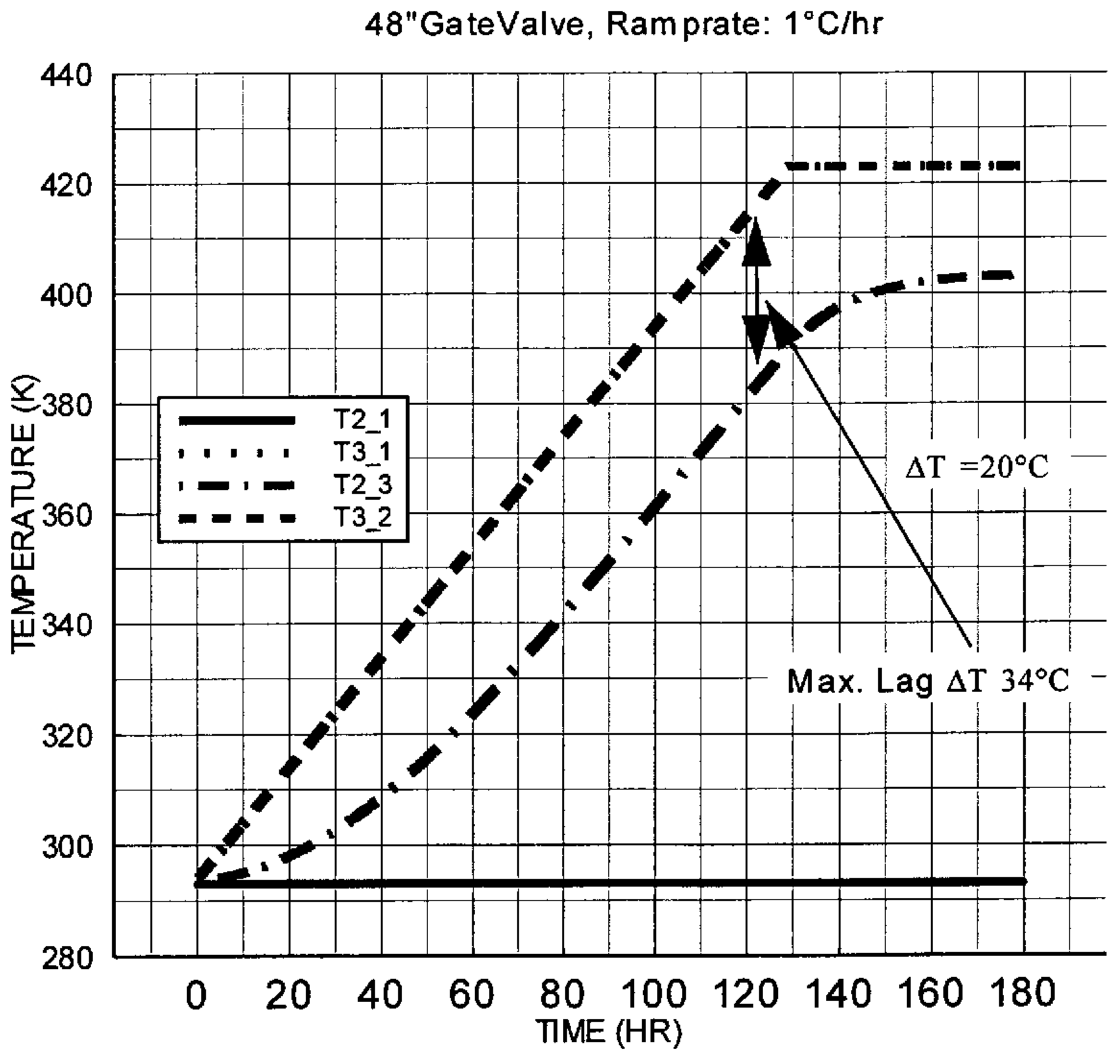

48"GateValve, Ramprate: 2°C/hr
440
420
400
380
360
340
320
300
280
TEMPERATURE (K)
0 20 40 60 80 100 120 140 160 180
TIME (HR)
T2_1
T3_1
T2_3
T3_2
ΔT =20°C
Max. Lag ΔT 51°C

Figure.4


ε=0.9
T3,2
ε=0.7
T3,3
ε=0.1
T3,1
ε=0.1
T2,2
ε=0.7
ε=0.9
T2,3
T2,1


48"GateValve, Ramprate: 1°C/hr
TEMPERATURE (K)
440
420
400
380
360
340
320
300
280
T2_1
T3_1
T2_3
T3_2
ΔT =20°C
Max. Lag ΔT 34°C
0
20
40
60
80
100
120
140
160
180
TIME (HR)

APPENDIX A

SIMULATION COMPUTER CODE 44 GATE VALVE

C TRANSIENT RADIATION MODEL FOR GATEVALVE WARMUP

```
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DOUBLE PRECISION A1(100),EM1(100),EB1(100),FV1(100,100),
     +RJ1(100),B1(100),AIJ1(100,100),T1(100),Q1(100),QA1(100)
      DOUBLE PRECISION A2(100),EM2(100),EB2(100),FV2(100,100),
     +RJ2(100),B2(100),AIJ2(100,100),T2(100),Q2(100),QA2(100)
      DOUBLE PRECISION A3(100),EM3(100),EB3(100),FV3(100,100),
     +RJ3(100),B3(100),AIJ3(100,100),T3(100),Q3(100),QA3(100)


C      I INDEX NODE/SURFACE , J INDEX NODE/SURFACE IN OTHER DIRECTION SECOND
SUBSCRIPT
C      # SYSTEM NUMBER
C     A#(I) SURFACE AREA
C     EM#(I) EMISSIVITY
C     EBI#(I) BLACK BODY EMISSIVE POWER
C     FV#(I,J) VIEW FACTOR
C     RJ#(I) RADIOSITY
C     BI#(I) CONSTANT IN LINEAR SET OF EQUATIONS
C     AIJ#(I,J)  COEFFICIENTS FOR LINEAR SET OF EQUATIONS

      BOLTZ=56.7D-9
      PI=3.141592654D0
      OPEN(UNIT=8,FILE="G44W2KPH.PRN",STATUS='OLD',ACCESS='SEQUENTIAL',
     +       FORM='FORMATTED')

C INITIAL CONDITIONS
C  T1(1)  CYLINDER VESSEL WALL BEHIND LOW E SHIELD
C  T1(2)  LOW E SHIELD SURFACE OUTSIDE DIA
C  T2(1)  OPEN BORE
C  T2(2)  CYLINDER VESSEL WALL
C  T2(3)  GATESURFACE
C  T3(1)  OPEN BORE SURFACE
C  T3(2)  LOW E SHIELD SURFACE INSIDE DIA
C  T3(3)    GATE SURFACE

      T1(1)=295.0
      T1(2)=294.0

      T2(1)=293.0
      T2(2)=295.0
      T2(3)=294.0

      T3(1)=295.0
      T3(2)=T1(2)
      T3(3)=T2(3)
      TIME=0.0D0
      DTIME=10.0
C   SYSTEM 1  PARALLEL CYLINDERS VESSEL WALL / LOW SHIELD PARAMETERS

      RAD1S1=0.566
      RAD1S2=0.566
      H1S1=1.0D0
      H1S2=1.0D0

      EM1(1)=0.7D0
      EM1(2)=0.06
```

```
      FV1(1,1)=0.0D0
      FV1(1,2)=1.0
      FV1(2,1)=1.0
      FV1(2,2)=0.0D0

      A1(1)=PI*2.0*RAD1S1*H1S1
      A1(2)=PI*2.0*RAD1S2*H1S2
      L1=2


C SYSTEM 2  SURFACE 1 CIRCLE, SURFACE 2: CYLINDER SURFACE 3: GATE SURFACE CIRCLE

      RAD2S1=0.566
      RAD2S2=0.566
      RAD2S3=0.566
      H2S2=0.60D0

      A2(1)=PI*RAD2S1**2.0
      A2(2)=PI*2.0*RAD2S2*H2S2
      A2(3)=PI*RAD2S3**2.0

      EM2(1)=0.9D0
      EM2(2)=0.7D0
      EM2(3)=0.1D0


C VIEW FACTOR CALCULATIONS
      RATIO1=RAD2S1/H2S2
C BOTH CIRCULAR SURFACES ARE SAME SIZE
      RATIO2=RATIO1
      XX1=1.0D0 + ((1.0 + RATIO1**2.0)/RATIO2**2.0)
      FV2(1,3)=0.5*(XX1-SQRT(XX1*XX1-4.0D0))
      FV2(1,1)=0.0D0
      FV2(1,2)=1.0-FV2(1,3)
      FV2(2,1)=A2(1)/A2(2)*FV2(1,2)
      FV2(2,3)=FV2(2,1)
      FV2(2,2)=1.0D0-FV2(2,1)-FV2(2,3)
      FV2(3,1)=FV2(1,3)
      FV2(3,2)=FV2(1,2)
      FV2(3,3)=0.0D0
      L2=3

C SYSTEM 3  SURFACE 1 CIRCLE, SURFACE 2: LOW SHIELD CYLINDER SURFACE 3:
C           GATE SURFACE CIRCLE


      RAD3S1=0.566
      RAD3S2=0.566
      RAD3S3=0.566
      H3S2=1.0D0

      A3(1)=PI*RAD3S1**2.0
      A3(2)=PI*2.0*RAD3S2*H3S2
      A3(3)=PI*RAD3S3**2.0
C       EM3(1) BORE EMISSIVITY, EM3(2) SHIELD EM, EM3(3) GATE EM
      EM3(1)=0.9D0
      EM3(2)=0.06D0
      EM3(3)=0.1D0


C VIEW FACTOR
      RATIO3=RAD3S1/H3S2
      RATIO4=RATIO3
```

```
      XX3=1.0D0 + ((1.0 + RATIO3**2.0)/RATIO4**2.0)
      FV3(1,3)=0.5*(XX3-SQRT(XX3*XX3-4.0D0))
      FV3(1,1)=0.0D0
      FV3(1,2)=1.0-FV3(1,3)
      FV3(2,1)=A3(1)/A3(2)*FV3(1,2)
      FV3(2,3)=FV3(2,1)
      FV3(2,2)=1.0D0-FV3(2,1)-FV3(2,3)
      FV3(3,1)=FV3(1,3)
      FV3(3,2)=FV3(1,2)
      FV3(3,3)=0.0D0
      L3=3

C#######################################################################
C     GATE MASS, HEAT CAPACITY   J/KG-C
C     SHIELD MASS, HEAT CAPACITY J/KG-C
       GATEWT=0.03175
      GATEDIA=1.132
      GATEDENS=7850.0
      SSCP=500.0
      GATEMASS=PI*0.25*GATEDIA**2.*GATEWT*GATEDENS
      GATECP=SSCP*GATEMASS
      SHIELDWT=0.003175
      SHIELDDIA=2.0*RAD3S2
      SHIELDLEN=H3S2
      SHIELDDENS=2700.0
      ALCP=920.0
      SHIELDMASS=PI*SHIELDDIA*SHIELDLEN*SHIELDWT*SHIELDDENS
      SHIELDCP=SHIELDMASS*ALCP

C#######################################################################
C     RAMPRATE
      RAMPCPH=2.0
      RAMPRATE=RAMPCPH/3600.0

Cdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdtdt
C                            TIME STEP LOOP
       WRITE(8,9002)
       DO 700 LTIME=1,64800

C======================================================================
C SYSTEM 1  VESSEL CYLINDER WITH LOW E SHIELD CYLINDER

C    CALCULATE AIJ1 COEFFICIENTS
        DO 230 I=1,L1
        DO 231 J=1,L1
         IF(I.NE.J) AIJ1(I,J)=-1.0* (1.0-EM1(I)) * FV1(I,J)
         IF(I.EQ.J) AIJ1(I,J)=1.0-((1.0-EM1(I))*FV1(I,J))
231     CONTINUE
230     CONTINUE

C     calculate B1(I) CONSTANTS

        DO 202 I=1,L1

        EB1(I)=BOLTZ*T1(I)**4.0
        B1(I)=EM1(I)*EB1(I)

202     CONTINUE


        CALL gaussedeil(L1,L1,AIJ1,B1,RJ1)
        DO  210  IL=1,L1
        Q1(IL)=A1(IL)*(EM1(IL)/(1.0-EM1(IL)) ) *( EB1(IL)-RJ1(IL) )
210     CONTINUE
```

```
C      WRITE(6,9001)A1(1),A1(2)
C      WRITE(6,9001)EB1(1),EB1(2)
C      WRITE(6,9001)B1(1),B1(2)
C      WRITE(6,9001)RJ1(1),RJ1(2)
C      DO 211  I=1,L1
C      WRITE(6,9001)(AIJ1(I,J),J=1,L1)
211     CONTINUE
C      WRITE(6,9001)Q1(1),Q1(2)
C      WRITE(6,*)"  "
C=====================================================================
C SYSTEM 2  SURFACE 1 CIRCLE, SURFACE 2: CYLINDER SURFACE 3: GATE SURFACE CIRCLE

C    CALCULATE AIJ2 COEFFICIENTS
        DO 330 I=1,L2
        DO 331 J=1,L2
         IF(I.NE.J) AIJ2(I,J)=-1.0* (1.0-EM2(I)) * FV2(I,J)
         IF(I.EQ.J) AIJ2(I,J)=1.0-((1.0-EM2(I))*FV2(I,J))
331     CONTINUE
330     CONTINUE

C      calculate B2(I) CONSTANTS

        DO 302 I=1,L2

        EB2(I)=BOLTZ*T2(I)**4.0
        B2(I)=EM2(I)*EB2(I)

302     CONTINUE

        CALL gaussedeil(L2,L2,AIJ2,B2,RJ2)
        DO  310  IL=1,L2
        Q2(IL)=A2(IL)*(EM2(IL)/(1.0-EM2(IL)) ) *( EB2(IL)-RJ2(IL) )
310     CONTINUE

C      WRITE(6,9001)A2(1),A2(2),A2(3)
C      WRITE(6,9001)EB2(1),EB2(2),EB2(3)
C      WRITE(6,9001)B2(1),B2(2),B2(3)
C      WRITE(6,9001)RJ2(1),RJ2(2),RJ2(3)
C      DO 311  I=1,L2
C      WRITE(6,9001)(AIJ2(I,J),J=1,L2)
C311     CONTINUE
C      WRITE(6,9001)Q2(1),Q2(2),Q2(3)
C       WRITE(6,*)"  "

C*********************************************************************

C=====================================================================
C SYSTEM 3  SURFACE 1 CIRCLE, SURFACE 2: LOW SHIELD CYLINDER SURFACE 3: GATE SURFACE
CIRCLE
C    CALCULATE AIJ2 COEFFICIENTS
        DO 430 I=1,L3
        DO 431 J=1,L3
         IF(I.NE.J) AIJ3(I,J)=-1.0* (1.0-EM3(I)) * FV3(I,J)
         IF(I.EQ.J) AIJ3(I,J)=1.0-((1.0-EM3(I))*FV3(I,J))
431     CONTINUE
430     CONTINUE

C      calculate B3(I) CONSTANTS

        DO 402 I=1,L3

        EB3(I)=BOLTZ*T3(I)**4.0
```

```
         B3(I)=EM3(I)*EB3(I)

402      CONTINUE


         CALL gaussedeil(L3,L3,AIJ3,B3,RJ3)
         DO  410  IL=1,L3
         Q3(IL)=A3(IL)*(EM3(IL)/(1.0-EM3(IL)) ) *( EB3(IL)-RJ3(IL) )
410      CONTINUE




C       WRITE(6,9001)A3(1),A3(2),A3(3)
C       WRITE(6,9001)EB3(1),EB3(2),EB3(3)
C       WRITE(6,9001)B3(1),B3(2),B3(3)
C       WRITE(6,9001)RJ3(1),RJ3(2),RJ3(3)
C       DO 411  I=1,L3
C       WRITE(6,9001)(AIJ3(I,J),J=1,L3)
C411      CONTINUE
        TIME=TIME+DTIME
        TIMEHR=TIME/3600.0
        IF(NPRINT.EQ.60) THEN
        WRITE(8,9001)TIMEHR,T1(1),T1(2),T2(1),T2(2),T2(3),T3(1),T3(2),
       +T3(3),Q1(1),Q1(2),Q2(1),Q2(2),Q2(3),Q3(1),Q3(2),Q3(3),DTLAG,QSHLD,
       +QGATE
         NPRINT=0
        ENDIF
        NPRINT=NPRINT+1
        QGATE=-Q3(3)-Q2(3)
        QSHLD=-Q3(2)-Q1(2)

        DTRAMP=RAMPRATE*DTIME
        DTGATE=QGATE*DTIME/GATECP
        DTSHLD=QSHLD*DTIME/SHIELDCP
        DTLAG=T2(2)-T2(3)
        T1(1)=T1(1)+DTRAMP
        IF(T1(1).GE.423.0) T1(1)=423.0
        T1(2)=T1(2)+DTSHLD

        T2(1)=T2(1)
        T2(2)=T2(2)+DTRAMP
        IF(T2(2).GE.423.0) T2(2)=423.0

        T2(3)=T2(3)+DTGATE

        T3(1)=T3(1)+DTRAMP
        IF(T3(1).GE.423.0) T3(1)=423.0
        T3(2)=T1(2)
        T3(3)=T2(3)

700     CONTINUE
C*******************************************************************

9002  FORMAT(8X,"TIMEHR",4X,"T1(1)",5X,"T1(2)",5X,"T2(1)",5X,"T2(2)",
     +5X,"T2(3)",5X,"T3(1)",5X,"T3(2)",5X,"T3(3)",5X,"Q1(1)",5X,"Q1(2)",
     +5X,"Q2(1)",5X,"Q2(2)",5X,"Q2(3)",5X,"Q3(1)",5X,"Q3(2)",5X,"Q3(3)",
     +5X,"DTLAG",5X"QSHLD",5X,"QGATE")
9001    FORMAT(3X,20F10.3)

        END
```