

## CNS Type B Casks

### HAC Fire Analyses of the 8-120B and 10-160B Casks with Ruptured Impact Limiter Ends

Project Number: 12CV01.1001-01

IDV: Not Required

Contract Number: None

DRCM reference: None

Print Name	
Sign / Date	

REV.	DATE	REVISION STATUS	ORIGINATOR	CHECKER	APPROVER
0		Original Issue	M. Baig	C. Hendrix	J.D. Sohl
1	5/23/12	Revised to Calculate the Average Bulk-Air Temperature	M. Baig	C. Hendrix	M. Baig

## HISTORY SHEET

Rev	Reason for revision	Originator
0	Initial Issue	Mirza Baig
1	Revised to calculate the average bulk-air temperature.	Mirza Baig

## Calculation Summary and Control Sheet

<b>Quality Level / Category:</b> <input checked="" type="checkbox"/> QL-1 <input type="checkbox"/> QL-2 <input type="checkbox"/> QL-3 <input type="checkbox"/> QL-4	
<b>Calculation results rely on a COMPUTER PROGRAM:</b> <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No If "Yes," complete Verification and Validation Information section	<b>Verification and Validation Information</b> Program Used: ANSYS Revision: 13.0 Desktop Computer tag #: 28254-D V&V report (number and rev): SW-072 Rev.1 & SW-073 Rev.1
<b>Results generated using a SOFTWARE TOOL are reported and checked by hand for applications that are not validated and verified:</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No ("No" to be checked only if a software tool is not used)	<b>Note: All calculations, including those generated using a software tool, shall be hand checked unless a computer program was used to perform the calculation AND proper documentation exists confirming that the computer program has been verified and validated in accordance with ES-QA-PR-019, Computer Software Management, and that modeling conditions are within the scope of the verification and validation of the program.</b>
<b>Calculation contains Unverified Assumptions:</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	<b>Note: If calculation contains unverified assumptions identify them in the box below.</b>
<b>Identify and Number Unverified Assumptions:</b> None	
<b>Identify Design Inputs (may reference appropriate calculation section):</b> EnergySolutions Document TH-028.	
<b>Results and Conclusions:</b>  The average bulk air temperature in the 8-120B cask with punctured lower end of the impact limiter is calculated to be 266°F.	

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## 1. INTRODUCTION AND SCOPE

The finite element model analyses of the 8-120B Cask for the hypothetical fire test, performed in the N.R.C. approved Safety Analysis Report (SAR) (Reference 1), uses thermally insulated boundary conditions on the surfaces that are covered by the impact limiters. During the RSI (Request for Supplemental Information) response to the N.R.C. for the renewal of the Certificate of Compliance (CofC) application, it was noticed that the SAR did not address the scenario in which the puncture bar makes contact with the package at the top or bottom central location. At these locations the impact limiters contain a void, which is covered by sheet-metal (see Figure 1). In a puncture bar drop test scenario if the package is dropped at these locations, the sheet metal may rupture. In the subsequent fire test the outside surface of the secondary lid that has been ruptured during the puncture drop test, will be exposed to the fire after a top end drop scenario. In the bottom end drop scenario the portion of the baseplate will be exposed to the fire. Since the temperatures of the secondary lid seals and that of the cask cavity are a concern in these scenarios, thermal evaluations of the package is performed in this document to obtain these temperatures.

The finite element model described in *EnergySolutions* document TH-028 (Reference 2), which was used as a reference document for the CofC renewal, is utilized in the analyses of this document.

Based on the results of the analyses presented in Section 6 of this report it is concluded that, with the conservative assumptions on the heat transfer mode, the secondary lid seal's temperature could reach 581.2°F. This temperature will exceed the seal material temperature limit of 450°F specified in the currently approved SAR, and 235°F proposed in the CofC renewal application (Reference 2). The maximum cask cavity temperature is calculated to be approximately 500°F.

The 10-160B casks also use similar impact limiter and secondary lid seal design. In fact, the 10-160B cask's seals are located on a more vulnerable position than the 8-120B casks. The N.R.C. approved SAR of this cask also did not address the rupture of the impact limiter's ends after the puncture drop tests. Therefore, it is concluded that the 10-160B cask seals temperature will also exceed the maximum working limit of the material.

## 2. ASSUMPTIONS

The assumptions mentioned in Reference 2 have been followed throughout in the analyses performed in this document. In addition, the following assumptions are also made.

1. The heat transfer between the primary and secondary lid by conduction through the

bolts have been neglected. This assumption is conservative for the evaluation of the secondary lid seal's temperature because it eliminates the heat flow through this path. This in turn increases the heat flow towards the secondary lid seals.

2. The heat transfer by radiation between the secondary and primary lid surfaces facing each other has been neglected. As described in 1 above, this is conservative due to eliminating the heat flow away from the secondary lid seals.
3. The secondary lid comprises of two circular plates that are welded only along the circumference. The unwelded interface between the two plates has been examined in two extreme conditions – (1) when they are totally connected, and (2) they are totally disconnected. The larger of the two temperatures is reported as the seal's temperature during the fire event.

### 3. INPUTS

The dimensional and design input are listed in Reference 2.

### 4. CALCULATION METHODOLOGY

The methodology used in the finite element modeling of the cask is described in detail in Reference 2.

### 5. CALCULATIONS

The finite element model described in Reference 2 was modified to include the boundary conditions corresponding to the puncture drop test damage to the package. It was solved for three conditions listed below.

- a. Undamaged impact limiter – This case corresponds to the original analysis of Reference 2. It is referred to as the SAR Analysis.
- b. Damaged Lower Impact Limiter Skin – The sheet-metal covering of the hollow portion of the lower impact limiter is assumed to be totally ruptured. The exposed portion of the outside surface of the baseplate is subjected to the same boundary conditions during the entire thermal transient (fire and cool-down) as the fire-shield on the body of the cask.
- c. Damaged Upper Impact Limiter Skin – The sheet-metal covering of the hollow portion of the upper impact limiter is assumed to be totally ruptured. The exposed portion of the outside surface of the secondary lid is subjected to the same boundary conditions during the entire thermal transient (fire and cool-down) as the fire-shield on the body of the cask.

ANSYS Version 13.0 (Reference 3) was used to construct and analyze the finite element models used in the analyses presented in this document. The printout of the finite

element model data for the undamaged impact limiter scenario is included in Appendix 1. The temperature time-history data of the secondary lid seals for the damaged upper impact limiter skin scenario is included in Appendix 2.

All the data files used in the analyses presented in this document are included on a media disk in Appendix 3.

## 6. RESULTS AND CONCLUSIONS

Figure 2 shows the temperature profile in the cask under the conditions addressed in the SAR at the time when the secondary lid seals attain the maximum temperature. Figure 3 is the maximum temperature attained by the seals under this scenario. The maximum temperature attained by the secondary lid seals is less than 210°F.

With the assumption that the bottom end impact limiter skin is ruptured during the puncture drop, the temperature profile in the cask, at the end of the 30 minute fire is shown in Figure 4. Figure 5 shows the temperature time-history plot of the inside and outside surfaces of the baseplate. The bulk air temperature is volume-averaged for every load step. The maximum average temperature of the bulk air is calculated to be 266°F (see Appendix 2).

With the assumption that the top end impact limiter skin is ruptured during the puncture drop, the temperature profile in the cask at the time when the seal's temperature reaches a peak value is shown in Figure 6. Figure 7 shows the time-history plot of the seal's temperature during the HAC fire event. The maximum temperature attained by the secondary lid seals during this test is 581.2°F (see Figure 7 and Appendix 2).

The secondary lid seal's temperature predicted by the analyses in this document 581.2°F exceeds the 450°F specified in the currently approved SAR (Reference 1) and 235°F specified in the CofC application renewal (Reference 2).

The maximum cask cavity temperature is calculated to be 495°F (see Figure 5).

## 7. ELECTRONIC FILES

Below is the directory of the files used in the analyses presented in this document. The electronic files are included on a media disk in Appendix 3.

Volume in drive E is TH-0001 Rev.1  
Volume Serial Number is A8E9-334E

Directory of E:\

05/23/2012 01:26 PM <DIR>  
Damaged

Bottom End Impact Limiter Skin



0 File(s)

0 bytes

Directory of E:\Bottom End Impact Limiter Skin Damaged

```
05/23/2012 01:26 PM <DIR> .
05/23/2012 01:39 PM <DIR> ..
04/27/2012 06:24 PM <DIR> TH-0001
0 File(s) 0 bytes
```

Directory of E:\Bottom End Impact Limiter Skin Damaged\TH-0001

```
04/27/2012 06:24 PM <DIR> .
05/23/2012 01:26 PM <DIR> ..
05/23/2012 01:26 PM <DIR> Bottom End Impact Limiter Skin
Damaged
04/27/2012 06:24 PM <DIR> Top End Impact Limiter Skin
Damaged
04/27/2012 06:25 PM <DIR> Undamaged Impact Limiter
0 File(s) 0 bytes
```

Directory of E:\Bottom End Impact Limiter Skin Damaged\TH-0001\Bottom End Impact Limiter Skin Damaged

```
05/23/2012 01:26 PM <DIR> .
04/27/2012 06:24 PM <DIR> ..
05/23/2012 11:12 AM 1,211 AirTemp.in
05/23/2012 01:26 PM 6,633 AirTemp.out
10/31/2011 01:16 PM 65,536 annulus-sub.sub
10/31/2011 04:06 PM 131,072 cavity-sub.sub
04/24/2012 11:49 AM 5,308,416 file.db
03/14/2012 03:06 PM 24,586 file000.png
04/25/2012 01:49 PM 179,481 model.out
7 File(s) 5,716,935 bytes
```

Directory of E:\Bottom End Impact Limiter Skin Damaged\TH-0001\Top End Impact Limiter Skin Damaged

```
04/27/2012 06:24 PM <DIR> .
04/27/2012 06:24 PM <DIR> ..
10/31/2011 01:16 PM 65,536 annulus-sub.sub
04/24/2012 12:05 PM 4,325,376 file.db
03/19/2012 09:15 AM 106,692,608 file.rth
03/20/2012 05:17 PM 21,488 file000.png
04/24/2012 12:04 PM 26,944 file002.png
04/25/2012 01:50 PM 130,380 model.out
03/19/2012 09:20 AM 12,451 Seal Temp.lis
7 File(s) 111,274,783 bytes
```

Directory of E:\Bottom End Impact Limiter Skin Damaged\TH-0001\Undamaged Impact Limiter

```
04/27/2012 06:25 PM <DIR> .
04/27/2012 06:24 PM <DIR> ..
10/31/2011 01:16 PM 65,536 annulus-sub.sub
10/31/2011 01:16 PM 59,964 ansb.out
```



10/31/2011	04:06 PM	131,072	cavity-sub.sub
10/31/2011	04:06 PM	337,229	cavsub.out
04/25/2012	01:19 PM	4,390,912	file.db
03/16/2012	11:59 AM	98,631,680	file.rth
03/14/2012	03:37 PM	22,566	file000.png
03/14/2012	03:47 PM	27,818	file002.png
04/25/2012	01:18 PM	149,534	model.out
	9 File(s)	103,816,311	bytes

Total Files Listed:

23 File(s)

220,808,029 bytes

15 Dir(s)

0 bytes free

## **8. REFERENCES**

1. Safety Analysis Report for Model 8-120B Type B Shipping Packaging, Revision 7, January 2010.
2. *EnergySolutions* Document TH-028, Revision 2, Fire Transient Analyses of the 8-120B Cask Using Finite Element Models.
3. ANSYS Version 13.0, ANSYS Inc., Canonsburg, PA, 2010.

Figures

(7 pages)

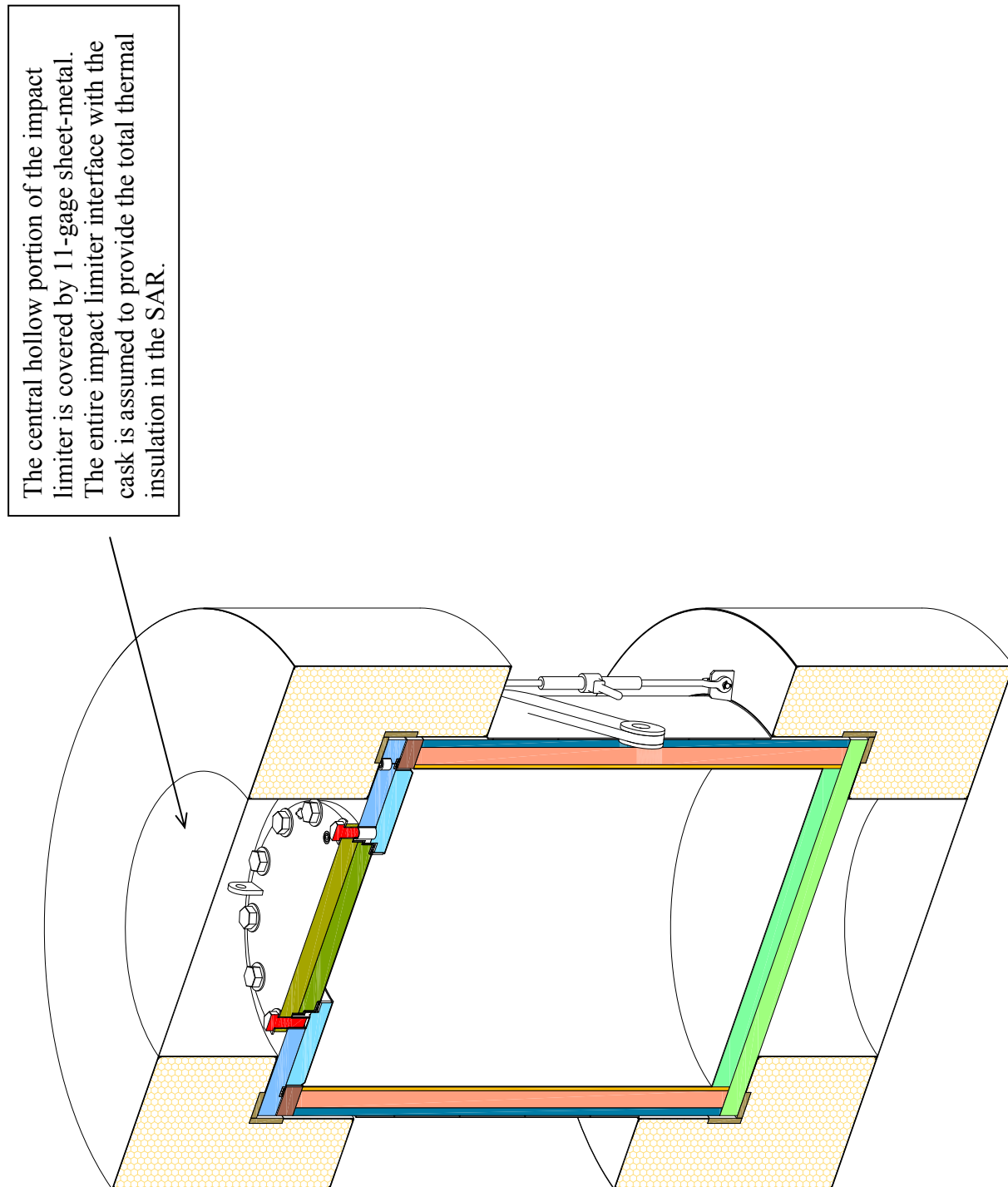


Figure 1 – 8-120B Cask with the Impact Limiter

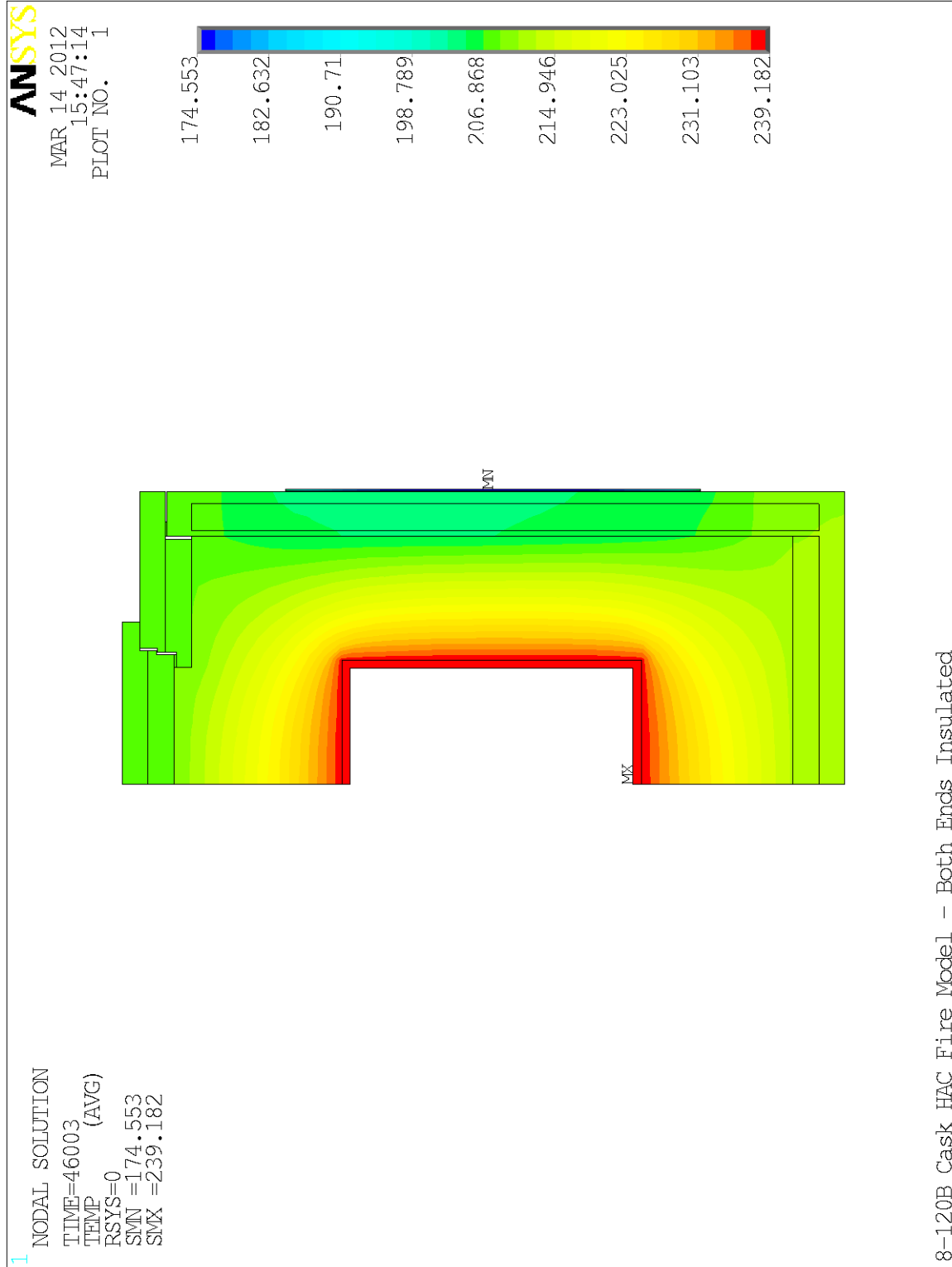


Figure 2 – 8-120B Cask Temperature Profile at the Time When the Secondary Lid Seals Attain the Peak Temperature

(SAR Analysis)

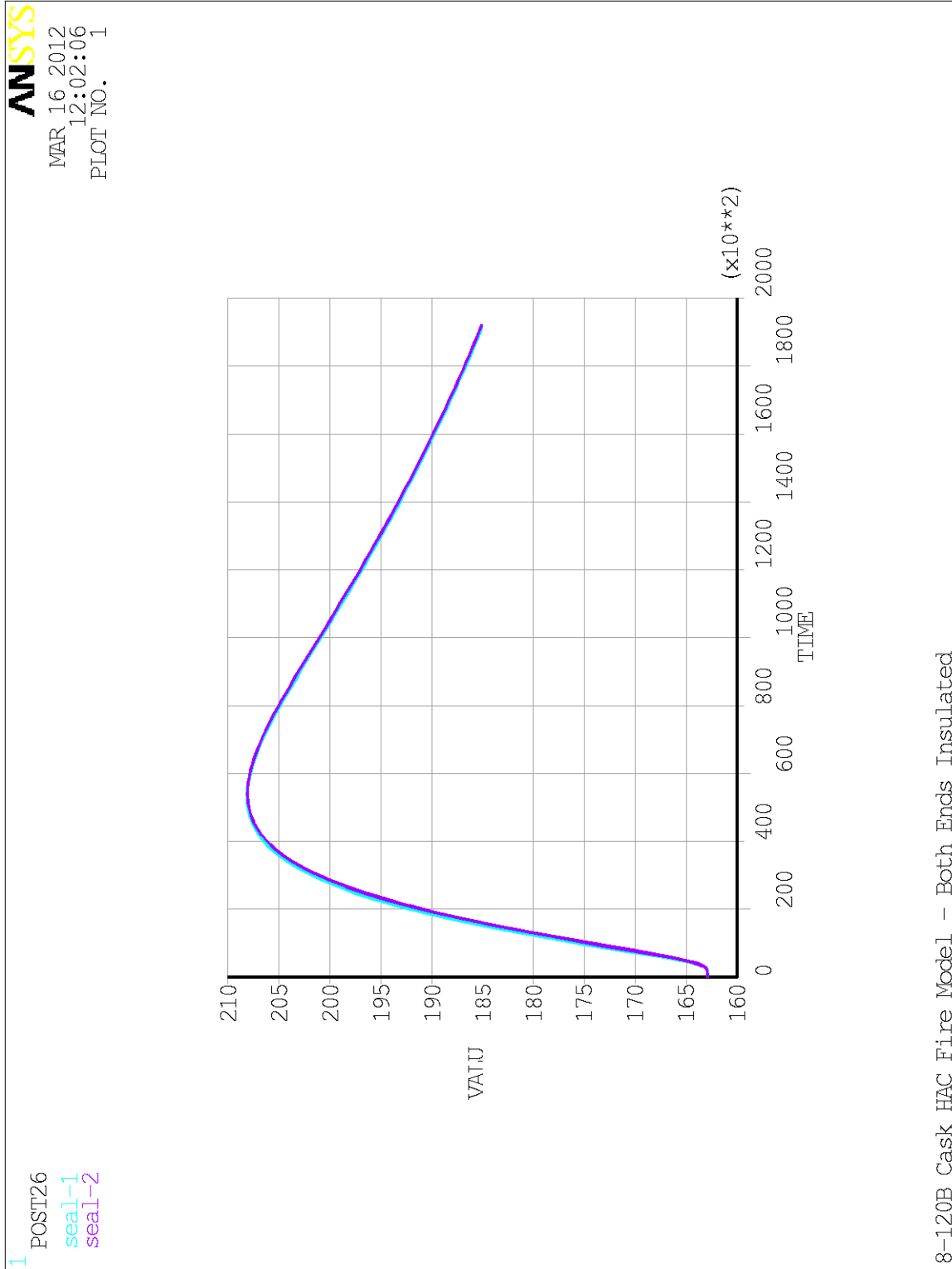


Figure 3 – 8-120B Cask Secondary Lid Seal's Temperature Time-History Plot

(SAR Analysis)

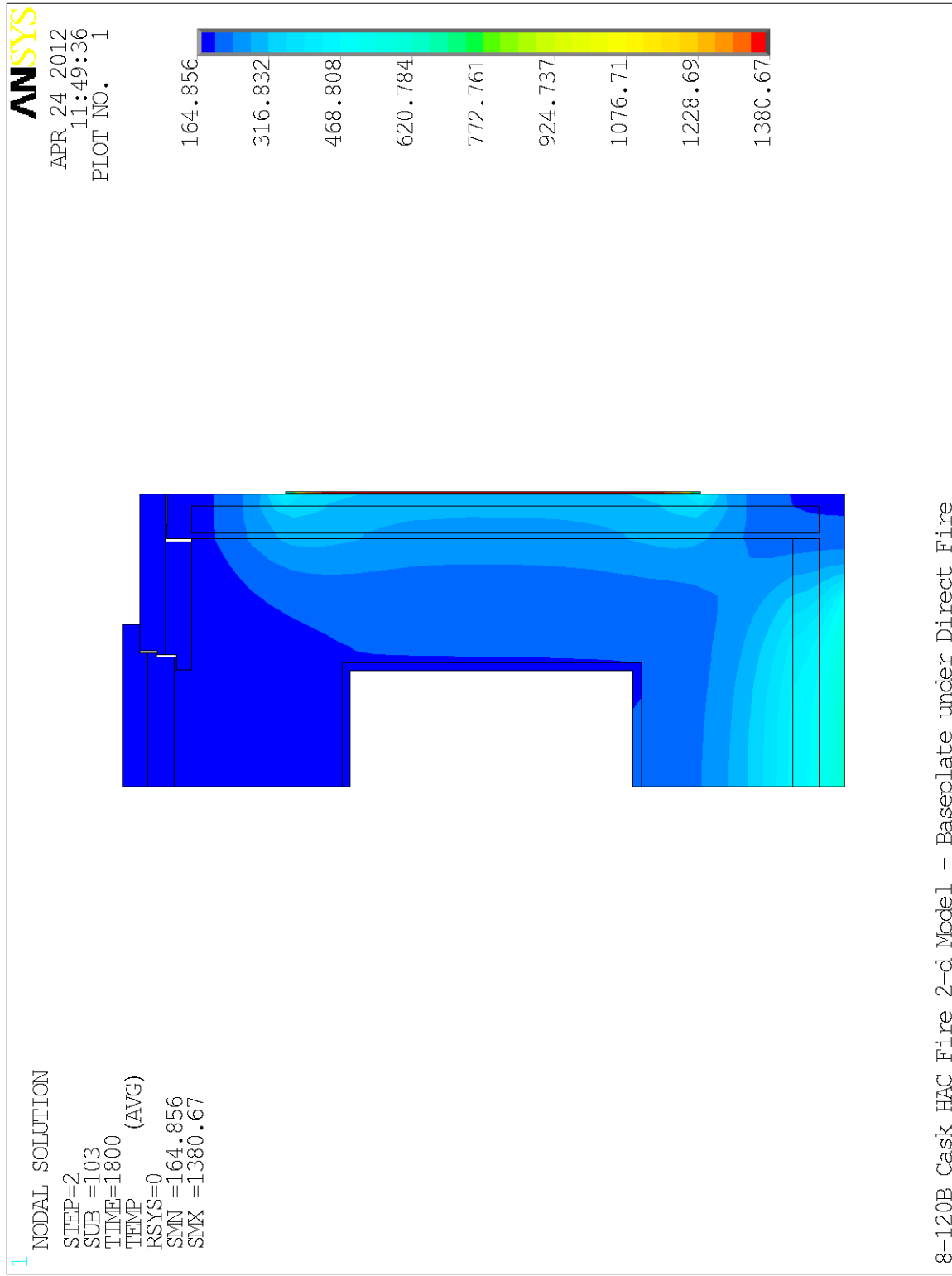


Figure 4 – 8-120B Cask with Damaged Bottom Impact Limiter Cover – Temperature Profile at the End of the Fire



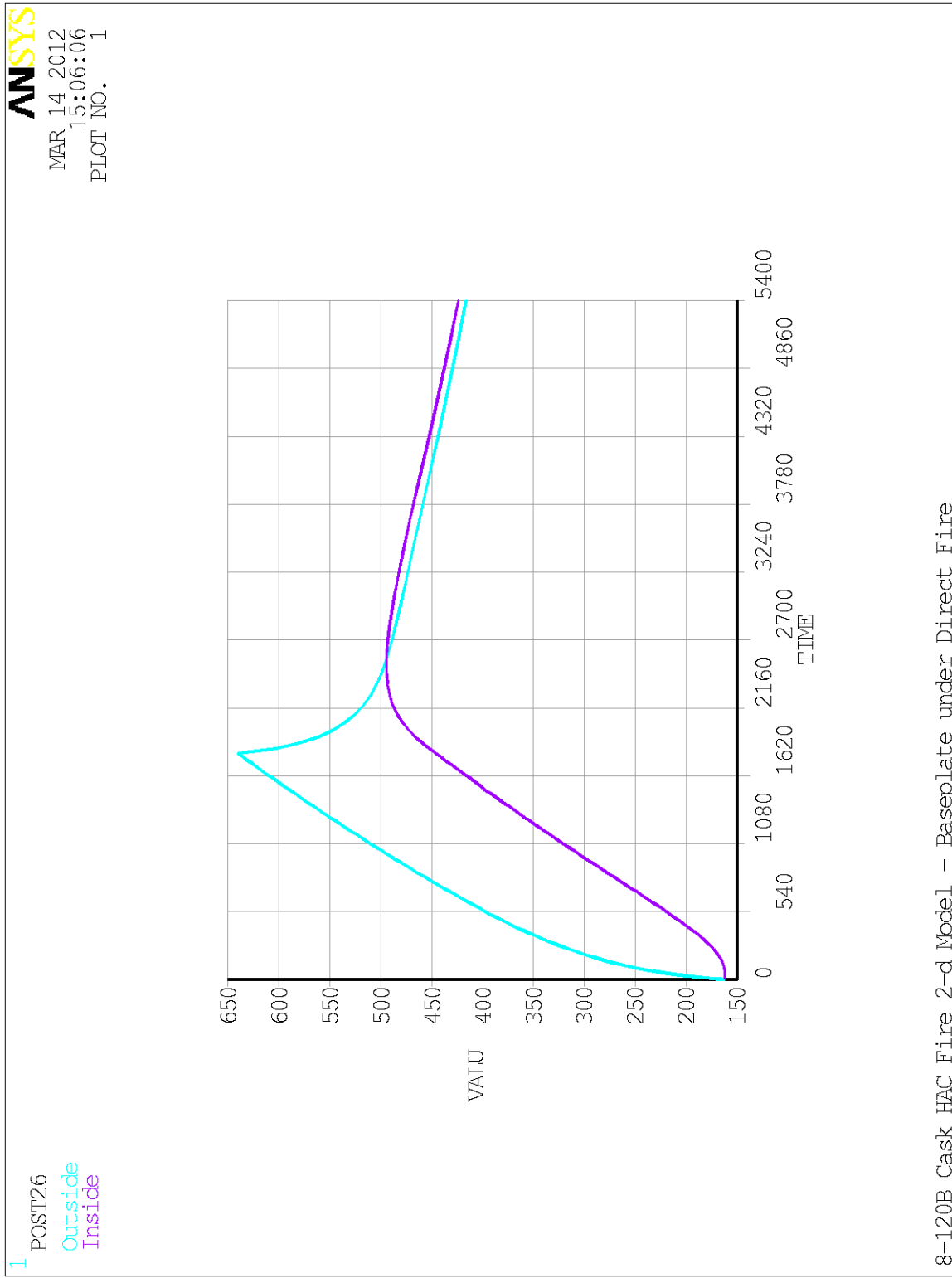


Figure 5 – 8-120B Cask Baseplate Inside and Outside Temperature Time-History Plot

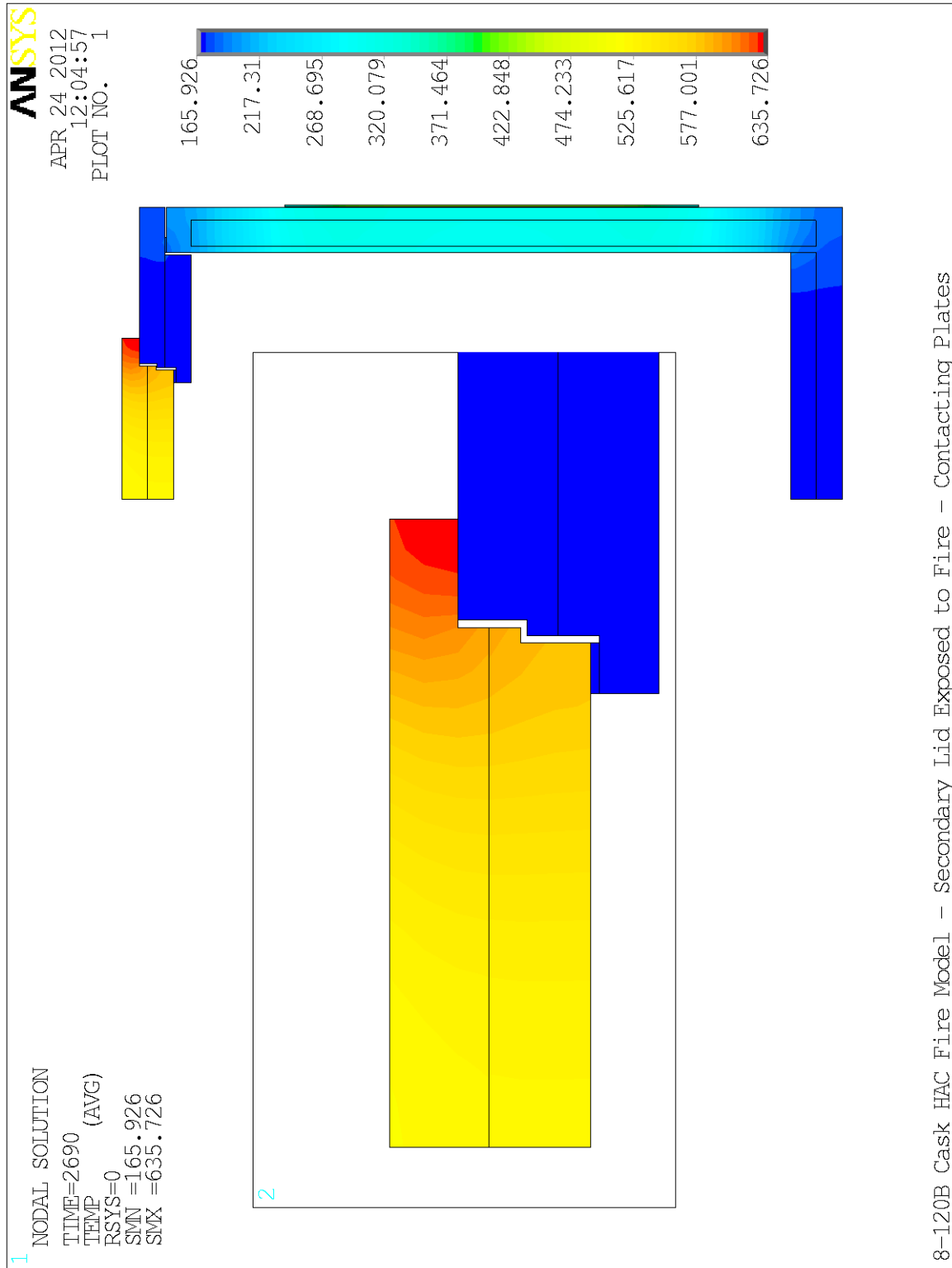
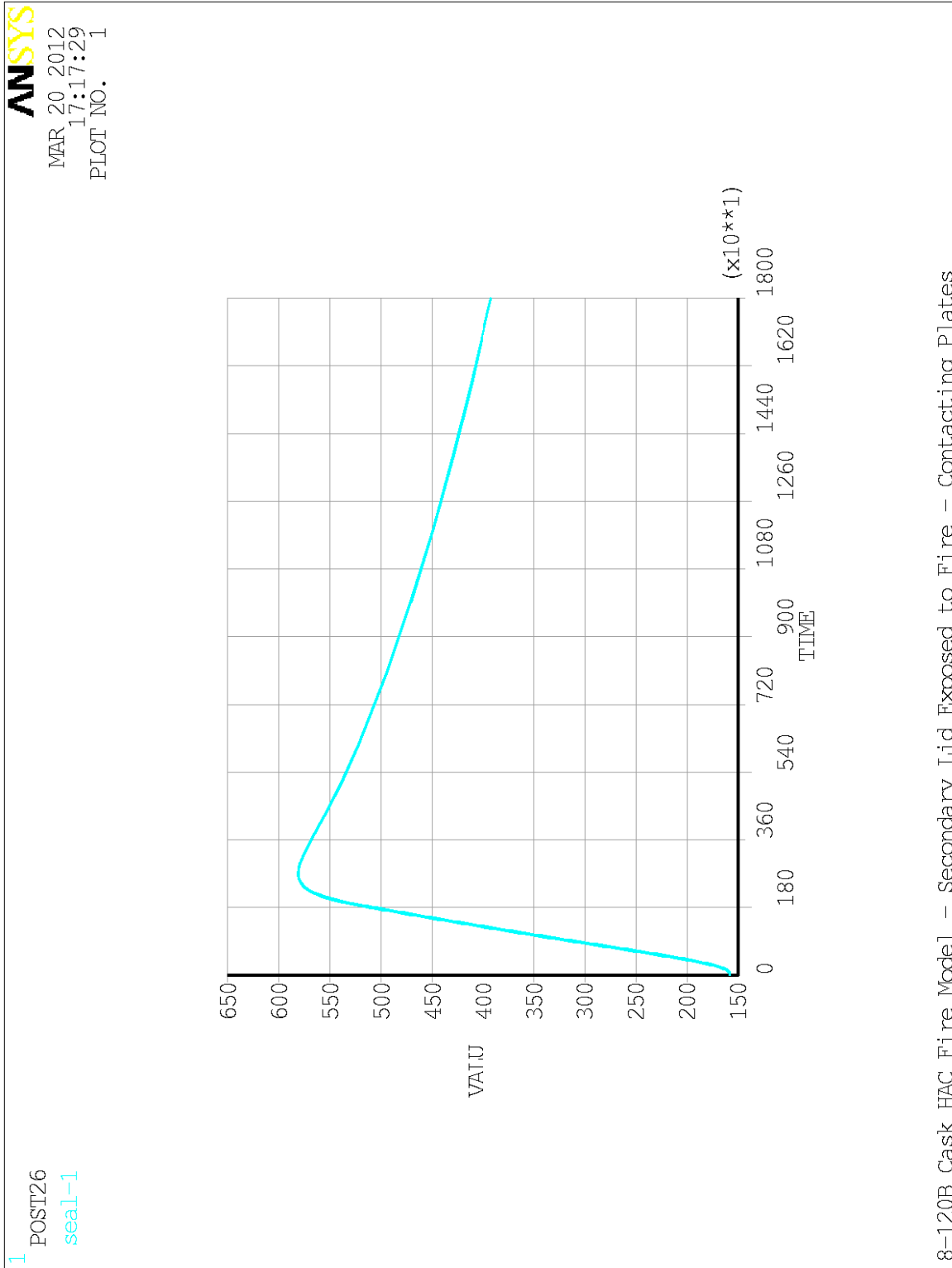


Figure 6 – 8-120B Cask Temperature Profile at the Time When the Secondary Lid Seals Attain the Peak Temperature

Damaged Upper Impact Limiter Skin



**Figure 7 – 8-120B Cask Secondary Lid Seal’s Temperature Time-History Plot**

Damaged Upper Impact Limiter Skin

Appendix 1  
FEM Data Print-Out  
(18 Pages)

ANSYS Finite Element Model Print-Out

## G L O B A L   S T A T U S

ANSYS - Engineering Analysis System      Apr 25, 2012      13:18  
Release 13.0      00222442      WINDOWS x64    Version

Current working directory: D:\ANSYS Analyses\8-120B Fire After Puncture Drop\Both  
Ends Insulated

MENULIST File: C:\Program Files\ANSYS Inc\v130\ANSYS\gui\en-us\UIDL\menulist130.ans

Product(s) enabled: ANSYS Mechanical

Total connect time. . . . . 0 hours 1 minutes  
Total CP usage. . . . . 0 hours 0 minutes 2.1 seconds

## J O B   I N F O R M A T I O N -----

8-120B Cask HAC Fire Model - Both Ends Insulated

Current jobname . . . . . .file  
Initial jobname . . . . . .file

Units . . . . . .unknown

	Available	Used
Scratch Memory Space. . . . .	9600.000 mb	517.787 mb ( 5.4%)
Database space . . . . .	65535.750 mb	2.173 mb ( 0.0%)

User menu file in use . . .%ANSYS130\_DIR%\gui\en-us\UIDL\UIMENU.GRN  
User menu file in use . . .%ANSYS130\_DIR%\gui\en-us\UIDL\UIFUNC1.GRN  
User menu file in use . . .%ANSYS130\_DIR%\gui\en-us\UIDL\UIFUNC2.GRN  
User menu file in use . . .%ANSYS130\_DIR%\gui\en-us\UIDL\MECHTOOL.AUI  
Beta features . . . . .are not shown in the user interface

## M O D E L   I N F O R M A T I O N -----

Solid model summary:

	Largest Number	Number Defined	Number Selected
Keypoints . . . . .	85	83	0
Lines . . . . .	115	113	0
Areas . . . . .	37	37	0
Volumes . . . . .	0	0	0

Finite element model summary:

	Largest Number	Number Defined	Number Selected
Nodes . . . . .	2002	633	633
Elements. . . . .	1465	696	696
Element types . . . . .	69	48	n.a.
Real constant sets. . . . .	61	25	n.a.
Material property sets. . .	14	10	n.a.

Coupling. . . . .	2	2	n.a.
Constraint equations. . . .	0	0	n.a.
Master DOFs . . . . .	0	0	n.a.
Dynamic gap conditions. . .	0	0	n.a.

# BOUNDARY CONDITION INFORMATION -----

	Number Defined		
Constraints on nodes. . . . .	4		
Constraints on keypoints. . . . .	0		
Constraints on lines. . . . .	0		
Constraints on areas. . . . .	0		
Forces on nodes . . . . .	0		
Forces on keypoints . . . . .	0		
Surface loads on elements . . . . .	126		
Number of element flagged surfaces . . .	0		
Surface loads on lines. . . . .	0		
Surface loads on areas. . . . .	0		
Body loads on elements. . . . .	0		
Body loads on areas . . . . .	0		
Body loads on lines . . . . .	0		
Body loads on nodes . . . . .	0		
Body loads on keypoints . . . . .	0		
Temperatures			
Uniform temperature. . . . .	70.000		
Offset from absolute scale . . . . .	460.000		
	X	Y	Z
Linear acceleration . . . . .	0.0000	0.0000	0.0000
Angular velocity (about global CS). . . .	0.0000	0.0000	0.0000
Angular acceleration (about global CS). .	0.0000	0.0000	0.0000
Location of reference CS. . . . .	0.0000	0.0000	0.0000
Angular velocity (about reference CS) . .	0.0000	0.0000	0.0000
Angular acceleration (about reference CS)	0.0000	0.0000	0.0000

# ROUTINE INFORMATION -----

Current routine. . . . .Preprocessing (PREP7)

Active coordinate system . . . . . 0 (Cartesian)

Display coordinate system. . . . . 0 (Cartesian)

## Current element attributes:

Type number . . . . .	69	(CONTA172)
Real number . . . . .	61	
Material number . . . . .	1	
Element coordinate system number. .	0	

Current mesher type. . . . .free mesher

Current element meshing shape 2D . . .use default element shape.

Current element meshing shape 3D . . .use default element shape.

SmrtSize Level . . . . . OFF

```

Global element size. . . . . 0 divisions per line

Active coordinate system . . . . . 0 (Cartesian)

Display coordinate system. . . . . 0 (Cartesian)

Analysis type. . . . . .Transient

Active options for this analysis type:
  Solution method . . . . .Full
  Equation solver to use. . . . .Sparse

Results file . . . . .file.rth

Load step number . . . . . 5

Number of substeps:
  Starting number of substeps . . . . 40000
  Maximum number of substeps. . . . . 40000
  Minimum number of substeps. . . . . 100
  Step change boundary conditions . .Yes

```

#### Analysis Options

```

New, Restart, or Expansion Pass: NEW ANALYSIS
Discipline (based on active DOF): THERMAL
  Analysis type: TRANSIENT
  Analysis method: FULL

```

```

      Newton-Raphson option      PROGRAM CHOOSES
Newton-Raphson adaptive descent  DO NOT USE ADAPT DESCENT

```

```
Equation solver to be used  SPARSE DIRECT SOLVER
```

```

Difference (in degrees) between absolute zero and
the temperature system being used  460.00

```

```
LIST ELEMENT TYPES FROM      1 TO      69 BY      1
```

```

ELEMENT TYPE      1 IS PLANE55      AXI. THERMAL SOLID
KEYOPT( 1- 6)=      0      0      1      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

ELEMENT TYPE      2 IS TARGE169      2-D TARGET SEGMENT
KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

ELEMENT TYPE      3 IS CONTA171      2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=      2      2      0      2      0      0
KEYOPT( 7-12)=      0      0      0      2      0      5
KEYOPT(13-18)=      0      0      0      0      0      0

ELEMENT TYPE      4 IS TARGE169      2-D TARGET SEGMENT
KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0

```

KEYOPT (13-18)=	0	0	0	0	0	0
ELEMENT TYPE	5	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		0	0	2	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	6	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	7	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		2	0	2	0
KEYOPT ( 7-12)=	0		0	0	2	0
KEYOPT (13-18)=	0		0	0	0	5
ELEMENT TYPE	8	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	9	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		2	0	2	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	5
ELEMENT TYPE	10	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	11	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		2	0	2	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	5
ELEMENT TYPE	12	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	13	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		2	0	2	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	5
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KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0
ELEMENT TYPE	15	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT ( 1- 6)=	2		2	0	2	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	5
ELEMENT TYPE	16	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT ( 1- 6)=	0		0	0	0	0
KEYOPT ( 7-12)=	0		0	0	0	0
KEYOPT (13-18)=	0		0	0	0	0



ELEMENT TYPE	17	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		0	0	2	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	18	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT( 1- 6)=	0		0	0	0	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	19	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		2	0	2	0
KEYOPT( 7-12)=	0		0	0	0	5
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	20	IS	TARGE169	2-D TARGET	SEGMENT	
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KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	21	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		2	0	2	0
KEYOPT( 7-12)=	0		0	0	0	5
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	22	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT( 1- 6)=	0		0	0	0	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	23	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		2	0	2	0
KEYOPT( 7-12)=	0		0	0	0	5
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	24	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT( 1- 6)=	0		0	0	0	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	25	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		2	0	2	0
KEYOPT( 7-12)=	0		0	0	0	5
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	26	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT( 1- 6)=	0		0	0	0	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	27	IS	CONTA171	2D 2-NODE	THERMAL	CONTACT
KEYOPT( 1- 6)=	2		2	0	2	0
KEYOPT( 7-12)=	0		0	0	0	5
KEYOPT(13-18)=	0		0	0	0	0
ELEMENT TYPE	28	IS	TARGE169	2-D TARGET	SEGMENT	
KEYOPT( 1- 6)=	0		0	0	0	0
KEYOPT( 7-12)=	0		0	0	0	0
KEYOPT(13-18)=	0		0	0	0	0

ELEMENT TYPE	29	IS	CONTA171	2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=	2		2	0 2 0 0
KEYOPT( 7-12)=	0		0	0 0 0 5
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	49	IS	LINK33	3-D CONDUCTION BAR
KEYOPT( 1- 6)=	0		0	0 0 0 0
KEYOPT( 7-12)=	0		0	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	50	IS	MATRIX50	SUPERELEMENT (SUBSTRUCTURE)
KEYOPT( 1- 6)=	1		0	0 0 0 0
KEYOPT( 7-12)=	0		0	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	51	IS	SURF151	2-D THERMAL SURFACE
KEYOPT( 1- 6)=	0		0	1 1 1 0
KEYOPT( 7-12)=	1		4	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	52	IS	SURF151	2-D THERMAL SURFACE
KEYOPT( 1- 6)=	0		0	1 1 1 0
KEYOPT( 7-12)=	0		0	1 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	53	IS	SURF151	2-D THERMAL SURFACE
KEYOPT( 1- 6)=	0		0	1 1 1 0
KEYOPT( 7-12)=	0		4	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	54	IS	SURF151	2-D THERMAL SURFACE
KEYOPT( 1- 6)=	0		0	1 1 1 0
KEYOPT( 7-12)=	0		0	1 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	55	IS	SURF151	2-D THERMAL SURFACE
KEYOPT( 1- 6)=	0		0	1 1 0 0
KEYOPT( 7-12)=	0		1	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	56	IS	TARGE169	2-D TARGET SEGMENT
KEYOPT( 1- 6)=	0		0	0 0 0 0
KEYOPT( 7-12)=	0		0	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	57	IS	CONTA171	2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=	2		0	0 2 0 0
KEYOPT( 7-12)=	0		0	0 0 0 5
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	58	IS	TARGE169	2-D TARGET SEGMENT
KEYOPT( 1- 6)=	0		0	0 0 0 0
KEYOPT( 7-12)=	0		0	0 0 0 0
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	59	IS	CONTA171	2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=	2		0	0 2 0 0
KEYOPT( 7-12)=	0		0	0 0 0 5
KEYOPT(13-18)=	0		0	0 0 0 0
ELEMENT TYPE	60	IS	TARGE169	2-D TARGET SEGMENT

```

KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      61 IS CONTA171      2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=      2      0      0      2      0      0
KEYOPT( 7-12)=      0      0      0      0      0      5
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      62 IS TARGE169      2-D TARGET SEGMENT
KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      63 IS CONTA171      2D 2-NODE THERMAL CONTACT
KEYOPT( 1- 6)=      2      0      0      2      0      0
KEYOPT( 7-12)=      0      0      0      0      0      5
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      66 IS TARGE169      2-D TARGET SEGMENT
KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      67 IS CONTA172      2D 3-NODE THERMAL CONTACT
KEYOPT( 1- 6)=      2      2      0      2      0      0
KEYOPT( 7-12)=      0      0      0      2      0      5
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      68 IS TARGE169      2-D TARGET SEGMENT
KEYOPT( 1- 6)=      0      0      0      0      0      0
KEYOPT( 7-12)=      0      0      0      0      0      0
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

ELEMENT TYPE      69 IS CONTA172      2D 3-NODE THERMAL CONTACT
KEYOPT( 1- 6)=      2      2      0      2      0      0
KEYOPT( 7-12)=      0      0      0      2      0      5
KEYOPT(13-18)=      0      0      0      0      0      0

```

```

CURRENT NODAL DOF SET IS TEMP
THREE-DIMENSIONAL MODEL

```

```

LIST REAL SETS      1 TO      61 BY      1

```

```

REAL CONSTANT SET      3 ITEMS      1 TO      6
0.0000      0.0000      1.0000      0.10000      0.0000      0.0000

```

```

REAL CONSTANT SET      3 ITEMS      7 TO     12
0.0000      0.0000      0.10000E+21      0.0000      1.0000      0.0000

```

```

REAL CONSTANT SET      3 ITEMS     13 TO     18
0.0000      0.0000      1.0000      0.0000      1.0000      0.50000

```

```

REAL CONSTANT SET      3 ITEMS     19 TO     24
0.0000      1.0000      1.0000      0.0000      0.0000      1.0000

```

```

REAL CONSTANT SET      4 ITEMS      1 TO      6
0.0000      0.0000      1.0000      0.10000      0.0000      0.0000

```

```

REAL CONSTANT SET      4 ITEMS      7 TO     12
0.0000      0.0000      0.10000E+21      0.0000      1.0000      0.0000

```

REAL CONSTANT SET	4	ITEMS 13 TO 18			
0.0000 0.0000		0.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	4	ITEMS 19 TO 24			
0.0000 0.0000		1.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	5	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	5	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	5	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	5	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	6	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	6	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	6	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	6	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	7	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	7	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	7	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	7	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	8	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	8	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	8	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	8	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	9	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	9	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	

REAL CONSTANT SET	9	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	9	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	10	ITEMS 1 TO 6			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	10	ITEMS 7 TO 12			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	10	ITEMS 13 TO 18			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	10	ITEMS 19 TO 24			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	11	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	11	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	11	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	11	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	12	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	12	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	12	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	12	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	13	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	13	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	13	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	13	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	14	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	14	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	14	ITEMS 13 TO 18			



0.0000	0.0000	1.0000	0.0000	1.0000	0.50000
REAL CONSTANT SET	14	ITEMS 19 TO	24		
0.0000	1.0000	1.0000	0.0000	0.0000	1.0000
REAL CONSTANT SET	15	ITEMS 1 TO	6		
0.0000	0.0000	1.0000	0.10000	0.0000	0.0000
REAL CONSTANT SET	15	ITEMS 7 TO	12		
0.0000	0.0000	0.10000E+21	0.0000	1.0000	0.0000
REAL CONSTANT SET	15	ITEMS 13 TO	18		
0.0000	0.0000	1.0000	0.0000	1.0000	0.50000
REAL CONSTANT SET	15	ITEMS 19 TO	24		
0.0000	1.0000	1.0000	0.0000	0.0000	1.0000
REAL CONSTANT SET	16	ITEMS 1 TO	6		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	16	ITEMS 7 TO	12		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	16	ITEMS 13 TO	18		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	16	ITEMS 19 TO	24		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	51	ITEMS 1 TO	6		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	51	ITEMS 7 TO	12		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	51	ITEMS 13 TO	18		
0.33330	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	52	ITEMS 1 TO	6		
1.0000	0.33056E-14	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	52	ITEMS 7 TO	12		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	52	ITEMS 13 TO	18		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	53	ITEMS 1 TO	6		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	53	ITEMS 7 TO	12		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	53	ITEMS 13 TO	18		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	54	ITEMS 1 TO	6		
1.0000	0.33056E-14	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	54	ITEMS 7 TO	12		
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

REAL CONSTANT SET	54	ITEMS 13 TO 18	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	55	ITEMS 1 TO 6	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	55	ITEMS 7 TO 12	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	55	ITEMS 13 TO 18	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	55	ITEMS 19 TO 24	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	56	ITEMS 1 TO 6	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	56	ITEMS 7 TO 12	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	56	ITEMS 13 TO 18	0.0000	0.0000	0.0000	0.0000
0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	56	ITEMS 19 TO 24	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	57	ITEMS 1 TO 6	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	57	ITEMS 7 TO 12	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	57	ITEMS 13 TO 18	0.0000	0.0000	0.0000	0.0000
0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	57	ITEMS 19 TO 24	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	58	ITEMS 1 TO 6	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	58	ITEMS 7 TO 12	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	58	ITEMS 13 TO 18	0.0000	0.0000	0.0000	0.0000
0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	58	ITEMS 19 TO 24	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
REAL CONSTANT SET	59	ITEMS 1 TO 6	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	1.0000	0.10000	0.0000	0.0000	0.0000
REAL CONSTANT SET	59	ITEMS 7 TO 12	0.0000	0.0000	0.0000	1.0000
0.0000	0.0000	0.10000E+21	0.0000	0.0000	1.0000	0.0000
REAL CONSTANT SET	59	ITEMS 13 TO 18	0.0000	0.0000	0.0000	1.0000
0.0000	0.0000	1.0000	0.0000	0.0000	1.0000	0.50000



REAL CONSTANT SET	59	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	
REAL CONSTANT SET	60	ITEMS 1 TO 6			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	60	ITEMS 7 TO 12			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	60	ITEMS 13 TO 18			
0.0000 1.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	60	ITEMS 19 TO 24			
0.0000 0.0000		0.0000 0.0000	0.0000	0.0000	
REAL CONSTANT SET	61	ITEMS 1 TO 6			
0.0000 0.0000		1.0000 0.10000	0.0000	0.0000	
REAL CONSTANT SET	61	ITEMS 7 TO 12			
0.0000 0.0000		0.10000E+21 0.0000	1.0000	0.0000	
REAL CONSTANT SET	61	ITEMS 13 TO 18			
0.0000 0.0000		1.0000 0.0000	1.0000	0.50000	
REAL CONSTANT SET	61	ITEMS 19 TO 24			
0.0000 1.0000		1.0000 0.0000	0.0000	1.0000	

LIST MATERIALS 1 TO 14 BY 1  
PROPERTY= ALL

MATERIAL NUMBER 1

TEMP	DENS
70.000	0.28180
100.00	0.28180
150.00	0.28180
200.00	0.28180
250.00	0.28180
300.00	0.28180
350.00	0.28180
400.00	0.28180
450.00	0.28180
500.00	0.28180
550.00	0.28180
600.00	0.28180
650.00	0.28180
700.00	0.28180
750.00	0.28180
800.00	0.28180
900.00	0.28180
1000.0	0.28180
1100.0	0.28180
1200.0	0.28180
1300.0	0.28180
1400.0	0.28180
1500.0	0.28180

TEMP	MU
	0.000000

TEMP	KXX
------	-----



70.000	0.81300E-03
100.00	0.80300E-03
150.00	0.78900E-03
200.00	0.77800E-03
250.00	0.76200E-03
300.00	0.74800E-03
350.00	0.73100E-03
400.00	0.71500E-03
450.00	0.70100E-03
500.00	0.68300E-03
550.00	0.66700E-03
600.00	0.64800E-03
650.00	0.63200E-03
700.00	0.61600E-03
750.00	0.60000E-03
800.00	0.58300E-03
900.00	0.55100E-03
1000.0	0.51900E-03
1100.0	0.48400E-03
1200.0	0.45100E-03
1300.0	0.41700E-03
1400.0	0.38000E-03
1500.0	0.36300E-03

TEMP	C
70.000	0.10400
100.00	0.10600
150.00	0.10900
200.00	0.11300
250.00	0.11500
300.00	0.11800
350.00	0.12200
400.00	0.12400
450.00	0.12600
500.00	0.12800
550.00	0.13100
600.00	0.13300
650.00	0.13500
700.00	0.13900
750.00	0.14200
800.00	0.14600
900.00	0.15400
1000.0	0.16300
1100.0	0.17200
1200.0	0.18400
1300.0	0.20500
1400.0	0.41100
1500.0	0.19900

TEMP	EMIS
	0.000000

MATERIAL NUMBER	
	2

TEMP	DENS
70.000	0.28240
100.00	0.28240
150.00	0.28240
200.00	0.28240
250.00	0.28240
300.00	0.28240



350.00	0.28240
400.00	0.28240
450.00	0.28240
500.00	0.28240
550.00	0.28240
600.00	0.28240
650.00	0.28240
700.00	0.28240
750.00	0.28240
800.00	0.28240
900.00	0.28240
1000.0	0.28240
1100.0	0.28240
1200.0	0.28240
1300.0	0.28240
1400.0	0.28240
1500.0	0.28240

TEMP	MU
	0.000000

TEMP	KXX
70.000	0.19900E-03
100.00	0.20100E-03
150.00	0.20800E-03
200.00	0.21500E-03
250.00	0.22200E-03
300.00	0.22700E-03
350.00	0.23400E-03
400.00	0.24100E-03
450.00	0.24500E-03
500.00	0.25200E-03
550.00	0.25700E-03
600.00	0.26200E-03
650.00	0.26900E-03
700.00	0.27300E-03
750.00	0.27800E-03
800.00	0.28200E-03
900.00	0.29400E-03
1000.0	0.30600E-03
1100.0	0.31500E-03
1200.0	0.32400E-03
1300.0	0.33600E-03
1400.0	0.34500E-03
1500.0	0.35400E-03

TEMP	C
70.000	0.11700
100.00	0.11700
150.00	0.12000
200.00	0.12200
250.00	0.12500
300.00	0.12600
350.00	0.12800
400.00	0.12900
450.00	0.13000
500.00	0.13100
550.00	0.13200
600.00	0.13300
650.00	0.13400
700.00	0.13500



750.00	0.13600
800.00	0.13600
900.00	0.13800
1000.0	0.13900
1100.0	0.14100
1200.0	0.14100
1300.0	0.14300
1400.0	0.14400
1500.0	0.14500

MATERIAL NUMBER 3

TEMP	DENS
70.000	0.41090
100.00	0.41090
150.00	0.41090
200.00	0.41090
250.00	0.41090
300.00	0.41090
350.00	0.41090
400.00	0.41090
450.00	0.41090
500.00	0.41090
550.00	0.41090
600.00	0.41090
650.00	0.41090
700.00	0.41090
750.00	0.41090
800.00	0.41090
900.00	0.41090
1000.0	0.41090
1100.0	0.41090
1200.0	0.41090
1300.0	0.41090
1400.0	0.41090
1500.0	0.41090

TEMP	KXX
70.000	0.46500E-03
100.00	0.46100E-03
150.00	0.45500E-03
200.00	0.44800E-03
250.00	0.44100E-03
300.00	0.43500E-03
350.00	0.42800E-03
400.00	0.42200E-03
450.00	0.41500E-03
500.00	0.40900E-03
550.00	0.40200E-03
600.00	0.39500E-03
650.00	0.38900E-03
700.00	0.38900E-03
750.00	0.38900E-03
800.00	0.38900E-03
900.00	0.38900E-03
1000.0	0.38900E-03
1100.0	0.38900E-03
1200.0	0.38900E-03
1300.0	0.38900E-03
1400.0	0.38900E-03
1500.0	0.38900E-03

TEMP	C
70.000	0.31050E-01
100.00	0.31050E-01
150.00	0.31050E-01
200.00	0.31050E-01
250.00	0.31050E-01
300.00	0.31050E-01
350.00	0.31050E-01
400.00	0.31050E-01
450.00	0.31050E-01
500.00	0.31050E-01
550.00	0.31050E-01
600.00	0.31050E-01
650.00	0.31050E-01
700.00	0.31050E-01
750.00	0.31050E-01
800.00	0.31050E-01
900.00	0.31050E-01
1000.0	0.31050E-01
1100.0	0.31050E-01
1200.0	0.31050E-01
1300.0	0.31050E-01
1400.0	0.31050E-01
1500.0	0.31050E-01

MATERIAL NUMBER 4

TEMP	DENS
70.000	0.43510E-04
100.00	0.41120E-04
150.00	0.37520E-04
200.00	0.34680E-04
250.00	0.32360E-04
300.00	0.30310E-04
350.00	0.28310E-04
400.00	0.26730E-04
450.00	0.25220E-04
500.00	0.23960E-04
550.00	0.22780E-04
600.00	0.21680E-04
650.00	0.20710E-04
700.00	0.19800E-04
750.00	0.18980E-04
800.00	0.18180E-04
900.00	0.16900E-04
1000.0	0.15710E-04
1100.0	0.14720E-04
1200.0	0.13850E-04
1300.0	0.13040E-04
1400.0	0.12350E-04
1500.0	0.11710E-04

TEMP	KXX
70.000	0.34490E-06
100.00	0.36210E-06
150.00	0.39030E-06
200.00	0.41770E-06
250.00	0.44460E-06
300.00	0.47040E-06
350.00	0.49570E-06

400.00	0.52040E-06
450.00	0.54480E-06
500.00	0.56880E-06
550.00	0.59210E-06
600.00	0.61430E-06
650.00	0.63630E-06
700.00	0.65810E-06
750.00	0.67900E-06
800.00	0.69960E-06
900.00	0.74090E-06
1000.0	0.78040E-06
1100.0	0.81750E-06
1200.0	0.85450E-06
1300.0	0.88970E-06
1400.0	0.92850E-06
1500.0	0.97070E-06

TEMP	C
70.000	0.24020
100.00	0.24040
150.00	0.24080
200.00	0.24140
250.00	0.24210
300.00	0.24290
350.00	0.24380
400.00	0.24500
450.00	0.24610
500.00	0.24740
550.00	0.24900
600.00	0.25110
650.00	0.25270
700.00	0.25380
750.00	0.25520
800.00	0.25680
900.00	0.25960
1000.0	0.26280
1100.0	0.26590
1200.0	0.26890
1300.0	0.27170
1400.0	0.27420
1500.0	0.27660

MATERIAL NUMBER 5

TEMP	EMIS
	0.1500000

MATERIAL NUMBER 6

TEMP	EMIS
	0.1500000

MATERIAL NUMBER 7

TEMP	EMIS
	0.2000000

MATERIAL NUMBER 8

TEMP	EMIS
	0.2000000

MATERIAL NUMBER        12

TEMP                    EMIS  
                         0.7347000

MATERIAL NUMBER        14

TEMP                    EMIS  
                         0.9000000

The nodal point coordinates, element connectivity, and  
boundary conditions print-out are listed in the file:

**TH-0001\Undamaged impact limiter\model.out**

This file is provided in Appendix 3.

Appendix 2

ANSYS Result Print-Out

(9 Pages)

|

# Damaged Upper Impact Limiter Skin – Seal Temperature Tim-History

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
1.0000	158.418	158.431
4.5980	158.418	158.431
8.1960	158.418	158.431
18.990	158.420	158.433
36.980	158.455	158.467
54.970	158.561	158.568
72.960	158.780	158.777
90.950	159.155	159.135
108.94	159.718	159.674
126.93	160.495	160.417
144.92	161.501	161.379
162.91	162.742	162.568
180.90	164.219	163.983
198.89	165.926	165.621
216.88	167.854	167.474
234.87	169.993	169.529
252.86	172.328	171.776
270.85	174.846	174.202
288.84	177.533	176.793
306.83	180.376	179.537

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
324.82	183.362	182.420
342.81	186.477	185.432
360.80	189.711	188.562
378.79	193.052	191.797
396.78	196.490	195.130
414.77	200.018	198.552
432.76	203.628	202.056
450.75	207.313	205.635
468.74	211.077	209.294
486.73	214.903	213.015
504.72	218.783	216.792
522.71	222.714	220.620
540.70	226.688	224.493
558.69	230.701	228.407
576.68	234.749	232.357
594.67	238.827	236.339
612.66	242.932	240.349
630.65	247.060	244.384
648.64	251.209	248.441
666.63	255.373	252.516

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
684.62	259.550	256.606
702.61	263.737	260.708
720.60	267.933	264.820
738.59	272.135	268.940
756.58	276.342	273.066
774.57	280.552	277.198
792.56	284.764	281.332
810.55	288.977	285.469
828.54	293.188	289.606



846.53	297.397	293.742
864.52	301.602	297.877
882.51	305.801	302.007
900.50	309.992	306.132
918.49	314.176	310.250
936.48	318.353	314.362
954.47	322.523	318.468
972.46	326.685	322.567
990.45	330.839	326.659
1008.4	334.986	330.744
1026.4	339.124	334.822

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
1044.4	343.255	338.893
1062.4	347.378	342.956
1080.4	351.493	347.013
1098.4	355.604	351.064
1116.4	359.710	355.111
1134.4	363.811	359.154
1152.4	367.906	363.192
1170.4	371.993	367.225
1188.3	376.073	371.252
1206.3	380.146	375.272
1224.3	384.209	379.285
1242.3	388.265	383.291
1260.3	392.311	387.290
1278.3	396.348	391.280
1296.3	400.376	395.262
1314.3	404.394	399.235
1332.3	408.403	403.200
1350.3	412.401	407.156
1368.2	416.389	411.103
1386.2	420.366	415.040

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
1404.2	424.331	418.967
1422.2	428.286	422.883
1440.2	432.229	426.789
1458.2	436.160	430.685
1476.2	440.079	434.569
1494.2	443.985	438.442
1512.2	447.879	442.303
1530.2	451.761	446.153
1548.1	455.629	449.990
1566.1	459.484	453.816
1584.1	463.326	457.629
1602.1	467.156	461.429
1620.1	470.973	465.218
1638.1	474.777	468.995
1656.1	478.569	472.760
1674.1	482.349	476.513
1692.1	486.116	480.254
1710.1	489.870	483.983
1728.0	493.611	487.701
1746.0	497.340	491.406

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
------	--------------------	--------------------

1764.0	501.056	495.099
1782.0	504.758	498.780
1800.0	508.447	502.448
1800.0	508.451	502.452
1800.0	508.455	502.456
1800.1	508.467	502.468
1800.2	508.488	502.489
1800.3	508.508	502.509
1800.4	508.529	502.529
1800.5	508.549	502.550
1800.6	508.569	502.570
1800.7	508.590	502.590
1800.8	508.610	502.611
1800.9	508.631	502.631
1801.0	508.651	502.651
1805.8	509.621	503.616
1810.5	510.591	504.581
1824.8	513.489	507.463
1839.0	516.373	510.333
1881.2	524.620	518.543

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
1927.3	533.081	526.976
1978.9	541.648	535.537
2037.0	550.003	543.921
2102.3	557.791	551.785
2175.4	564.714	558.846
2257.5	570.552	564.891
2349.0	575.145	569.762
2451.4	578.446	573.406
2564.7	580.430	575.790
2689.7	581.162	576.966
2826.9	580.744	577.021
2977.2	579.299	576.061
3142.1	576.947	574.194
3323.4	573.796	571.518
3526.3	569.880	568.062
3761.6	565.110	563.736
4049.9	559.209	558.268
4435.6	551.506	550.993
5029.4	540.382	540.290
6132.1	521.993	522.272

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
8034.1	494.830	495.300
9936.1	470.896	471.399
11838.	449.423	449.904
13740.	429.960	430.404
15642.	412.203	412.609
17544.	395.936	396.306
19446.	380.987	381.325
21348.	367.214	367.524
23250.	354.495	354.779
25152.	342.695	342.957
27054.	331.723	331.965
28956.	321.508	321.731
30858.	311.986	312.193
32760.	303.101	303.293
34662.	294.797	294.977
36564.	287.027	287.195
38466.	279.762	279.919

40368.	272.964	273.111
42270.	266.597	266.735
44172.	260.628	260.758

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
46074.	255.029	255.150
47976.	249.772	249.886
49878.	244.833	244.940
51780.	240.193	240.294
53682.	235.830	235.926
55584.	231.726	231.817
57486.	227.863	227.949
59388.	224.223	224.305
61290.	220.793	220.870
63192.	217.557	217.631
65094.	214.505	214.575
66996.	211.623	211.689
68898.	208.901	208.964
70800.	206.329	206.389
72702.	203.897	203.955
74604.	201.597	201.653
76506.	199.422	199.475
78408.	197.362	197.413
80310.	195.411	195.460
82212.	193.562	193.609

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
84114.	191.809	191.854
86016.	190.147	190.190
87918.	188.571	188.613
89820.	187.076	187.116
91722.	185.658	185.696
93624.	184.312	184.349
95526.	183.034	183.071
97428.	181.822	181.857
99330.	180.671	180.704
0.10123E+06	179.577	179.610
0.10313E+06	178.539	178.571
0.10504E+06	177.553	177.584
0.10694E+06	176.616	176.646
0.10884E+06	175.726	175.754
0.11074E+06	174.879	174.908
0.11264E+06	174.075	174.103
0.11455E+06	173.311	173.338
0.11645E+06	172.585	172.611
0.11835E+06	171.894	171.919
0.12025E+06	171.237	171.262

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
0.12215E+06	170.613	170.637
0.12406E+06	170.019	170.042
0.12596E+06	169.454	169.477
0.12786E+06	168.916	168.939
0.12976E+06	168.405	168.427
0.13166E+06	167.919	167.941
0.13357E+06	167.456	167.477
0.13547E+06	167.016	167.037

0.13737E+06	166.597	166.618
0.13927E+06	166.199	166.219
0.14117E+06	165.819	165.839
0.14308E+06	165.458	165.478
0.14498E+06	165.115	165.134
0.14688E+06	164.788	164.807
0.14878E+06	164.476	164.495
0.15068E+06	164.180	164.198
0.15259E+06	163.898	163.916
0.15449E+06	163.629	163.647
0.15639E+06	163.374	163.391
0.15829E+06	163.130	163.148

\*\*\*\*\* ANSYS POST26 VARIABLE LISTING \*\*\*\*\*

TIME	214 TEMP seal-1	221 TEMP seal-2
0.16019E+06	162.899	162.916
0.16210E+06	162.678	162.695
0.16400E+06	162.468	162.484
0.16590E+06	162.268	162.284
0.16780E+06	162.077	162.093
0.16970E+06	161.896	161.912
0.17161E+06	161.723	161.739
0.17351E+06	161.558	161.574
0.17541E+06	161.402	161.417
0.17731E+06	161.252	161.268
0.17921E+06	161.110	161.126
0.18112E+06	160.975	160.990
0.18302E+06	160.846	160.861
0.18492E+06	160.723	160.738
0.18682E+06	160.606	160.621
0.18872E+06	160.495	160.509
0.19063E+06	160.388	160.403
0.19200E+06	160.314	160.329

### 8-120B cask Bulk Air Average Temperature with the Damaged Lower Impact Limiter

The input file for post processing of the data (AirTemp.in) is listed in the data disk included in Appendix 3. The output file (AirTemp.out) is listed below.

Cavity Air Bulk Average Temperature Time-History

Time	Avrg.Temp.
1.	174.
5.	174.
8.	174.
19.	174.
30.	174.
48.	174.
66.	174.
84.	174.
102.	174.
120.	174.
138.	174.
156.	174.
174.	174.
192.	174.
210.	174.
228.	174.
246.	174.
264.	174.
282.	174.
300.	175.

318.	175.
336.	175.
354.	175.
372.	176.
390.	176.
408.	176.
426.	176.
444.	177.
462.	177.
480.	177.
498.	178.
516.	178.
534.	178.
551.	179.
569.	179.
587.	180.
605.	180.
623.	181.
641.	181.
659.	182.
677.	182.
695.	183.
713.	183.
731.	184.
749.	184.
767.	185.
785.	186.
803.	186.
821.	187.
839.	187.
857.	188.
875.	189.
893.	189.
911.	190.
929.	191.
947.	191.
965.	192.
983.	193.
1001.	193.
1019.	194.
1037.	195.
1055.	196.
1073.	196.
1091.	197.
1109.	198.
1127.	199.
1145.	199.
1163.	200.
1181.	201.
1199.	202.
1217.	202.
1235.	203.
1253.	204.
1271.	205.
1289.	206.
1307.	206.
1325.	207.
1343.	208.
1361.	209.
1379.	210.
1397.	211.
1415.	211.
1433.	212.
1451.	213.
1469.	214.
1487.	215.
1505.	216.
1523.	216.
1541.	217.



1559.	218.
1577.	219.
1595.	220.
1613.	221.
1631.	222.
1649.	223.
1667.	223.
1685.	224.
1703.	225.
1721.	226.
1739.	227.
1757.	228.
1775.	229.
1793.	230.
1800.	230.
1800.	230.
1800.	230.
1800.	230.
1800.	230.
1800.	230.
1800.	230.
1800.	230.
1801.	230.
1801.	230.
1801.	230.
1801.	230.
1801.	230.
1806.	230.
1811.	230.
1825.	231.
1839.	232.
1882.	234.
1928.	236.
1980.	239.
2038.	241.
2104.	244.
2177.	247.
2259.	250.
2352.	252.
2455.	255.
2570.	257.
2699.	260.
2842.	261.
3003.	263.
3186.	264.
3396.	265.
3648.	266.
3967.	266.
4405.	265.
5070.	264.
6137.	263.
7750.	261.
9652.	259.
11554.	258.
13456.	256.
15358.	255.
17260.	254.
19162.	253.
21064.	252.
22966.	250.
24868.	249.
26770.	248.
28672.	247.
30574.	246.
32476.	245.
34378.	244.
36280.	242.
38182.	241.
40084.	240.

41986.	239.
43888.	238.
45790.	237.
47692.	236.
49594.	235.
51496.	234.
53398.	233.
55300.	232.
57202.	231.
59104.	230.
61006.	229.
62908.	228.
64810.	227.
66712.	226.
68614.	225.
70516.	224.
72418.	223.
74320.	223.
76222.	222.
78123.	221.
80025.	220.
81927.	219.
83829.	219.
85731.	218.
87633.	217.
89535.	216.
91437.	216.
93339.	215.
95241.	214.
97143.	214.
99045.	213.
100947.	212.
102849.	212.
104751.	211.
106653.	210.
108555.	210.
110457.	209.
112359.	209.
114261.	208.
116163.	207.
118065.	207.
119967.	206.
121869.	206.
123771.	205.
125673.	205.
127575.	204.
129477.	204.
131379.	203.
133281.	203.
135183.	202.
137085.	202.
138987.	201.
140889.	201.
142791.	201.
144693.	200.
146595.	200.
148497.	199.
150399.	199.
152301.	198.
154203.	198.
156105.	198.
158007.	197.
159909.	197.
161811.	197.
163713.	196.
165615.	196.
167517.	195.
169419.	195.
171321.	195.



173223.	194.
175125.	194.
177027.	194.
178929.	194.
180831.	193.
182733.	193.
184635.	193.
186537.	192.
188439.	192.
190341.	192.
192000.	192.

Maximum Average Temperature      265.64   at Time      3966.89



Appendix 3

Media Disk (CD-ROM)

(1 Disk)