ENCLOSURE 4

TN Calculation NUH32PHB-0408, Thermal Analysis of NUHOMS 32PHB DSC for Vacuum Drying Operations

AREVA TRANSNUCLEAR INC.	**Form 3.2-1** **Calculation Cover Sheet** **TIP 3.2 (Revision 4)**	**Calculation No.:** NUH32PHB-0408 **Revision No.:** 1 Page: 1 of 29

DCR NO (if applicable) : NUH32PHB-010	**PROJECT NAME:** NUHOMS® 32PHB System
PROJECT NO: 10955	**CLIENT:** CENG-Calvert Cliff Nuclear Power Plant Inc. (CCNPP)

CALCULATION TITLE:

Thermal Analysis of NUHOMS 32PHB DSC for Vacuum Drying Operations

SUMMARY DESCRIPTION:

1) Calculation Summary

This calculation evaluates vacuum drying operations for 32PHB DSC with heat loads of 29.6 kW, 25.6 kW and 23.04 kW and with blowdown gases of helium or nitrogen.

2) Storage Media Description

Secure network server initially, then redundant tape backup

If original issue, is licensing review per TIP 3.5 required?

Yes ☐ **No** ☒ **(explain below)** **Licensing Review No.:**__________

This calculation is performed to support a site specific license application by CCNPP that will be reviewed and approved by the NRC. Therefore, a 10CFR72.48 licensing review per TIP 3.5 is not applicable.

Software Utilized (subject to test requirements of TIP 3.3):	**Version:**
ANSYS	10.0
Calculation is complete: Originator Name and Signature: Venkata Venigalla *Venkat*	Date: 08/09/11
Calculation has been checked for consistency, completeness and correctness: Checker Name and Signature: Davy Qi [signature]	Date: 8/9/2011
Calculation is approved for use: *Kamran Tavassoli* Project Engineer Name and Signature: [signature]	Date: 8/17/11 [signature]

REVISION SUMMARY

REV.	DESCRIPTION	AFFECTED PAGES	AFFECTED Computational I/O
0	Initial Issue	All	All
1	To provide additional time limits for vacuum drying using nitrogen at which the fuel cladding temperature remains below the maximum temperature attained during steady-state transfer operations with helium and water in the TC/DSC annulus.	1-5, 7, 11-13, 15, 16, 24-26, 28 and 29	See Section 8.0

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1.0 PURPOSE

This calculation presents the thermal analysis of the 32PHB DSC with heat loads of 29.6 kW, 25.6 kW and 23.04 kW during vacuum drying operations. These heat loads are determined based on the transfer cask analysis for various transfer time limits in [4, 8].

Helium or nitrogen gas can be used for removal of water from 32PHB DSC cavity (blowdown) before the start of vacuum drying. Subsequent vacuum drying occurs with a helium or nitrogen environment in the DSC cavity.

If helium is used for drainage of water from DSC and water is maintained in the annulus between the DSC and TC, there is no time limit for completion of the vacuum drying process. This is because the DSC shell temperature is maintained at temperatures lower than the values calculated for the storage conditions [3]. The maximum fuel cladding temperatures with helium gas during vacuum drying operations (includes helium gas for water blowdown, vacuum drying and helium backfill) are determined using steady-state runs with boundary conditions discussed in Section 3.0. This calculation demonstrates that the steady-state, maximum fuel cladding temperatures remain below the allowable limit of 752°F established in ISG-11, Rev.3 [1].

If nitrogen is used for drainage of water during blowdown, time limits are imposed to ensure that the requirements described in ISG-11, Rev.3 [1] are satisfied. The time limits for vacuum drying operations using nitrogen for blowdown are determined for different heat loads using transient analyses.

2.0 REFERENCES

1. NRC Spent Fuel Project Office, Interim Staff Guidance, ISG-11, Rev 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel".

2. Design Criteria Document, "Design Criteria Document (DCD) for the NUHOMS® 32PHB System for Storage", Transnuclear, Inc., Document No. NUH32PHB.0101, Rev. 2.

3. Calculation, "Thermal Evaluation of NUHOMS® 32PHB DSC for Storage and Transfer Conditions", Transnuclear, Inc., Calculation No. NUH32PHB-0403, Rev. 0.

4. Calculation, "Thermal Evaluation of NUHOMS 32PHB Transfer Cask for Normal, Off-Normal, and Accident Conditions", Transnuclear, Inc., Calculation No. NUH32PHB-0402, Rev. 0.

5. Calculation, "Fuel Effective Thermal Properties for 32PHB DSC Design", Transnuclear, Inc., Calculation No. NUH32PHB-0407, Rev. 0.

6. Rohsenow, Hartnett, Cho, "Handbook of Heat Transfer", 3rd Edition, 1998.

7. ANSYS computer code and On-Line User's Manuals, Version 10.0.

8. Calculation, "Thermal Evaluation of NUHOMS 32PHB Transfer Cask for Normal, Off Normal, and Accident Conditions (Transient with <29.6 kW)", Transnuclear, Inc., Calculation No. NUH32PHB-0406, Rev. 1.

9. Calculation, "Effective Fuel Properties for Vacuum Drying", Transnuclear, Inc., Calculation No. 1095-38, Rev. 0.

10. UFSAR, "Updated Final Safety Analysis Report for the NUHOMS HD Horizontal Modular Storage System for Irradiated Nuclear Fuel", Transnuclear, Inc., NRC Docket No. 72-1030, Revision 2.

11. Calvert Cliffs Independent Spent Fuel Storage Installation Updated Safety Analysis Report, Rev.17.

3.0 ASSUMPTIONS AND CONSERVATISM

The assumptions and conservatism considered for 32PHB DSC model are the same as listed in [3] with additional assumptions noted below.

During vacuum drying operations the annulus is open to atmospheric pressure and the water in the transfer cask/DSC annulus is monitored and replenished. Therefore, no water boiling occurs within the transfer cask/DSC annulus. The DSC shell temperature is assumed to be the boiling temperature of water (212°F) for vacuum drying thermal analyses. This assumption is justified in [4], Appendix C.

The vacuum drying of the DSC is assumed not to reduce the pressure sufficiently to decrease the thermal conductivity of the gases within the DSC cavity. This assumption is justified in [9] for air at low pressures, which remains valid for nitrogen and helium.

Vacuum drying operations are assumed to start with blowdown of water from DSC cavity. It is also assumed that the active fuel length is covered with water before the start of vacuum drying operations.

An average initial temperature of 212°F is considered for the 32PHB DSC components at the start of vacuum drying operation. Based on analysis of heat up rate for a DSC and basket type similar to 32PHB design in [10], Section 4.5.1, a heat up rate of 3.2°F per hour is expected for a decay heat load of 34.8 kW. Assuming a conservative heat up rate of 4.0°F per hour for 32PHB DSC with 29.6 kW heat load and 12 hour period for operations (such as lifting and welding) prior to vacuum drying, the average temperature of the 32PHB DSC before starting of the vacuum drying operation is:

Initial average temperature = maximum pool temperature + average heat up rate x duration of operations prior to vacuum drying

Where

Maximum pool temperature = 140°F [2],

Average heat up rate = 4.0°F/hr,

Duration of operations prior to vacuum drying = 12 hours (assumed).

Initial average temperature = 140 + 4.0 x 12 =188°F.

Based on the above evaluation, assuming an initial temperature of 212°F for DSC prior to vacuum drying operation is conservative.

4.0 DESIGN INPUT

The design inputs considered for 32PHB DSC thermal model in [3] are applicable for this calculation.

4.1 Design Criteria

Maximum fuel cladding temperature limit is in accordance with ISG-11, Rev.3 [1], listed in [2] and shown in Table 4-1.

Table 4-1 Maximum Fuel Cladding Temperature Limit for Vacuum Drying Thermal Analysis

Operating Condition		Ambient Temperature (°F)	Fuel Cladding Limit (°F)
Vacuum Drying (1)	DSC in Vertical TC (with water in DSC/TC annulus)	100 (2)	752 [1]

Notes: (1) Vacuum drying operations within fuel building including water blowdown and helium backfill with the DSC located in the TC in vertical orientation are considered normal conditions.
(2) Average ambient temperature within the fuel building [2].

Based on [1], repeated thermal cycling (repeated heatup/cooldown cycles) shall be limited to less than 10 cycles during loading operations, with cladding temperature variations that are less than 65°C (117°F) each. Backfilling the DSC with helium gas causes a one time temperature drop, which is not considered as a repeated thermal cycling. Re-evacuation of the DSC under helium atmosphere does not reduce the pressure sufficiently to decrease the thermal conductivity of helium. Therefore, re-evacuation and re-pressurizing the DSC under helium atmosphere proceed on a descending curve to the minimum steady state temperatures, and does not include any thermal cycling. It is concluded that the limit of 65°C (117°F) considered for thermal cycling during loading operations is not applicable for NUHOMS®-32PHB system.

4.2 Thermal Properties of Materials

Material properties used in 32PHB DSC thermal model for vacuum drying operations are the same as those used in [3] except for nitrogen used during water blowdown and vacuum drying processes. If nitrogen is used for water blowdown and vacuum drying processes the thermal properties for the homogenized fuel assembly in nitrogen, calculated in [5] are used and are listed in Table 4-2.

Table 4-2 Thermal Properties of Homogenized Fuel Assembly in Nitrogen [5]

Temperature (°F)	Transverse Conductivity (Btu/hr-in-°F)	Axial Conductivity (Btu/hr-in-°F)	Density (lbm/in^3)	Specific Heat (Btu/lbm-°F)
189	0.0083	0.0601	0.1308	0.0576
271	0.0104			
356	0.0131			
445	0.0164			
536	0.0205			
629	0.0253			
724	0.0310			
820	0.0375			
916	0.0448			
1014	0.0530			

4.3 Vacuum Drying Operations

This section presents a brief description of the various steps and defines the time limit applicable for each step based on the operations described in Section 5.1.1.3 and 5.1.1.4 of the CCNPP ISFSI UFSAR [11]. A flow chart of the various operations during the DSC loading is shown in [11], Figure 5.1-1. The steps described below are applicable for vacuum drying with both helium and nitrogen blowdown. However, the time limits presented in this calculation are applicable only for vacuum drying with nitrogen blowdown.

The following are the steps of the vacuum drying process for which a time limit is defined. These steps occur after the top shield plug of the DSC is seal welded and a nondestructive examination (NDE) is performed. It is assumed that active fuel length remains covered with water during welding and NDE.

a. Remaining water from the DSC cavity is removed by engaging the compressed helium or compressed nitrogen gas source.

b. When water stops flowing from the DSC, the vacuum pump is started and a vacuum of 3 torr or less is drawn in the DSC cavity.

c. The DSC internal pressure is stabilized at 3 torr or less.

d. The valve in the helium inlet is opened to allow helium to flow into the DSC.

e. The DSC is pressurized with helium to 22 psia and the shield plug seal weld tested for leakage. After the seal welds' integrity is confirmed, the DSC is re-evacuated to 3 torr and backfilled with helium to a cavity pressure of 17.2 psia.

f. The vacuum drying system (VDS) is disconnected from the DSC and the prefabricated plugs are seal welded over the DSC vent and siphon port openings. The top cover plate is placed over the shield plug. After proper fit-up between the plate and the DSC shell is verified, the top cover plate is tack welded to the shell using the automatic welding machine. The cover plate final closure weld is placed. The automatic welding machine is removed from the DSC.

g. The cask drain port valve is opened and the remaining water is removed from the cask/DSC annulus.

For vacuum drying operations with nitrogen blowdown three time limits are specified below:

1) Time limit "T1" is defined as the ***maximum allowed*** time from the initiation of Step "a" to initiation of Step "d".

2) Time limit "T2" is defined as the ***minimum allowed*** time from the initiation of Step "d" to initiation of Step "g".

3) Time limit "T3" is defined as the ***maximum allowed*** time from the initiation of Step "a" to initiation of Step "d" within which if the vacuum drying operations i.e. initiation of Step "a" to initiation of Step "d" are completed, the time limit "T2" is not applicable.
If the vacuum drying operations i.e. initiation of Step "a" to initiation of Step "d" cannot be completed within the time limit "T3", time limits "T1" and "T2" remain applicable.

The first time limit "T1" is the ***maximum allowed*** time limit for the DSC using nitrogen blowdown to ensure that the maximum fuel cladding temperature is within the acceptable limits of 752°F during vacuum drying.

The second time limit "T2" is the ***minimum required*** time limit for the DSC with helium backfill to ensure that the maximum fuel cladding and DSC components temperatures cool down sufficiently to the initial conditions used in the transfer cask thermal analysis presented in [4, 8].

The third time limit "T3" is the ***maximum allowed*** time limit for the DSC using nitrogen blowdown to ensure that the maximum fuel cladding temperature and DSC component temperatures remain below the initial conditions used in the transfer cask thermal analysis presented in [4, 8].

5.0 METHODOLOGY

The ANSYS finite element model and thermal analysis methodology for the 32PHB DSC are described in [3], and are used in this calculation for the thermal analysis of the 32PHB DSC for vacuum drying operations.

For the maximum decay heat load of 29.6 kW per 32PHB DSC, the heat load zone configuration is the same as that shown in [3], Figure 5-5.

For decay heat loads of 25.6 kW and 23.04 kW per 32PHB DSC [8], a uniform heat load of 0.8 kW and 0.72 kW per fuel assembly (FA), respectively is considered for the 32 FAs in the DSC.

The peaking factors (PFs) for 32PHB FAs as listed in [3], Table 5-10 are considered in this calculation.

The heat generation rates are calculated using Equation (5.1) from [3], and are listed in Table 5-1.

Table 5-1 Heat Generation Rates for 32PHB DSC

Decay Heat Load per DSC (kW)	Heat Load per Assembly (kW)	Heat Generation Rate (Btu/hr-in^3)	
		PF=1.0 (Base)	PF=1.101 (Maximum)
29.6	1.0	0.345	0.380
	0.8	0.276	0.304
25.6	0.8	0.276	0.304
23.04	0.72	0.249	0.274

The boundary conditions are uniform temperature of 212°F at the DSC shell as discussed in Section 3.0 and volumetric heat generation load in fuel region. Figure 5-1 shows typical boundary condition and heat generation load.

A transient run for the vacuum drying operations includes two steps:

1) To determine the maximum time limit "T1" for vacuum drying operations in nitrogen such that the maximum fuel cladding temperature is below fuel cladding limit of 752°F specified in Section 4.3.

2) Helium is used to backfill the DSC cavity after the end of vacuum drying operations in nitrogen. This transient run determines the minimum time limit "T2" with helium in the DSC cavity to allow the DSC/Basket component temperatures to cool down sufficiently to the initial conditions used in the transfer cask thermal analysis presented in [4, 8].

The maximum time limit "T3" i.e, the time limit at which the maximum fuel cladding temperature remains below the initial conditions used in the transfer cask thermal analysis presented in [4, 8] is determined via interpolation of the maximum fuel cladding temperature response during the heat up phase in nitrogen atmosphere. The time limit “T3” calculations are captured in excel spreadsheet “32PHB_VDY_R-1.xls” listed in Table 8-3.

As noted in Section 1.0, the time limit “T1” is not applicable when using helium for water blowdown during vacuum drying operations.

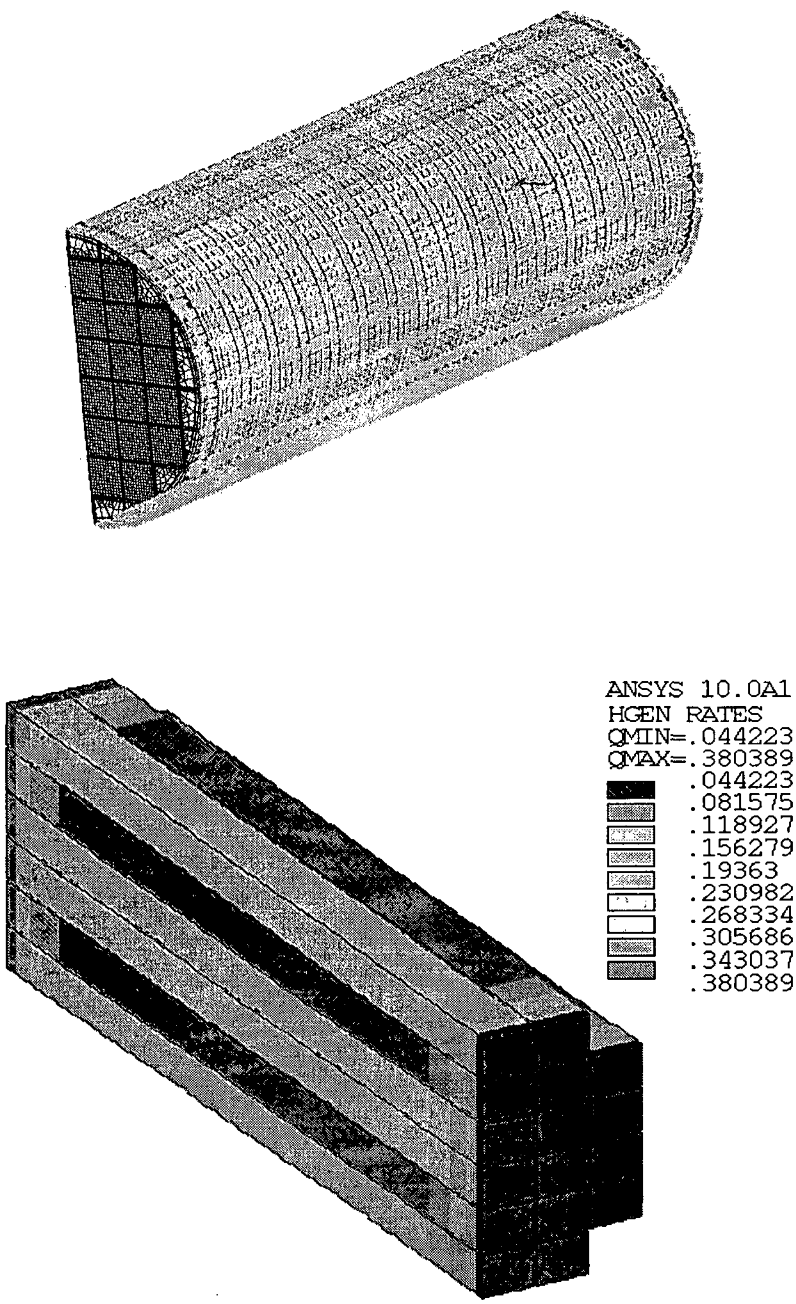


Figure 5-1 Typical Boundary Condition and Heat Generation for Vacuum Drying Operations (Shown for 29.6 kW / DSC)

6.0 RESULTS

The maximum temperature histories of fuel cladding for 32PHB DSC vacuum drying operations are listed in Table 6-1.

Table 6-1 Maximum Temperature Histories of Fuel Cladding for 32PHB DSC Vacuum Drying Operations

Operating Condition	29.6 kW			25.6 kW		23.04 kW	
	Time (Hr)	Fuel Cladding T_{max} (°F)		Time (Hr)	Fuel Cladding T_{max} (°F)	Time (Hr)	Fuel Cladding T_{max} (°F)
Blowdown Gas		**Helium**	**Nitrogen**	**Nitrogen**			
Water Blowdown & Vacuum Drying	8	279	299	8	262 8 239		
	16	437	490	16	447	16	412
	24	521	621	24	573	24	530
	32	560	**711**	32	656	32	610
				40	**709**	40	662
						48	696
						56	**718**
Helium Backfill	40	578	667	48	646	60	670
	48	586	630	56	601	64	626
	56	589	610	64	577	72	564
	64	591	**600**	**72**	**562**	80	538
	72	591	595	90	556	**86**	**530**
	80	591	593			90	528
Steady-State with Helium Backfill		**592**	**592**		**555**		**524**
Maximum Time Limit in Nitrogen (For water blowdown and vacuum drying), "T1" (Hrs)		N/A	**32**		**40**		**56**
Minimum Time Limit in Helium Backfill, "T2" (Hrs)		N/A	**32**		**32**		**30**
Maximum Time Limit in Nitrogen Backfill, "T3" (Hrs)		N/A	**22**		**23**		**24**

Table 6-1 lists the maximum time limit, "T1" for water blowdown and vacuum drying in nitrogen and the minimum time limit, "T2" with helium in the DSC cavity to allow the DSC/Basket component temperatures to cool down sufficiently to the initial conditions used in the transfer cask thermal analysis presented in [4, 8].

The third time limit "T3" which is the maximum allowed time limit for the DSC using nitrogen blowdown to ensure that the maximum fuel cladding temperature and DSC component temperatures remain below the initial conditions used in the transfer cask thermal analysis presented in [4, 8] are also listed in Table 6-1.

If the vacuum drying operations i.e. initiation of Step "a" to initiation of Step "d" described in Section 4.3

- are completed within the time limit "T3", the time limit "T2" is not applicable or
- cannot be completed within the time limit "T3", the time limits "T1" and "T2" remain applicable.

For comparison, Table 6-1 and Figure 6-7 also show transient temperature history when helium is used for water blowdown, vacuum drying and helium backfill. As noted in Section 1.0, the time limit "T1" is not applicable when using helium for water blowdown during vacuum drying operations.

The maximum 32PHB DSC component temperatures are listed in Table 6-2 for vacuum drying operations.

Table 6-2 Maximum 32PHB DSC Component Temperatures

Operating Condition		Fuel Cladding	Basket (Guide Sleeve)	DSC (Shell[(2)])	Neutron Absorber Plate	Basket Rails	Top Shield Plug	Bottom Shield Plug
Water blowdown, vacuum drying with Nitrogen and helium backfill.		T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)
29.6 kW	Nitrogen @ 32 hrs [(1)]	711	682	212	680	429	212	229
	Helium @ Steady-State	592	567	212	567	298	224	252
25.6 kW	Nitrogen @ 40 hrs [(1)]	709	676	212	674	425	215	233
	Helium @ Steady State	555	528	212	528	286	222	247
23.04 kW	Nitrogen @ 56 hrs [(1)]	718	685	212	683	436	217	237
	Helium @ Steady-State	524	499	212	498	279	221	243

Notes: (1) The end of water blowdown and vacuum drying operations in nitrogen.

(2) The maximum DSC shell temperature is the temperature along the shell and does not include the top and bottom end plates.

Table 6-3 shows 32PHB DSC component average temperatures (including hottest & whole DSC sections) for vacuum drying operations.

Table 6-3 32PHB DSC Component Average Temperatures (Hottest/Whole DSC Section)

Heat Load	Hottest Section (°F)							Whole DSC (°F)				
	R0 (1)	R45 (1)	R90 (1)	R135 (1)	R180 (1)	Bask. Comp.	Shell (4)	Bask. Comp	Rail (2)	Shell (4)	Cavity Gas (3)	Fuel
End of Water Blowdown and Vacuum Drying Operations in Nitrogen												
29.6 kW @ 32 hrs	374	425	374	425	374	561	212	513	405	212	495	560
25.6 kW @ 40 hrs	378	421	378	421	378	553	212	509	404	212	491	553
23.04 kW @ 56 hrs	389	432	389	432	389	562	212	519	415	212	501	562
Steady-State Vacuum Drying Operations in Helium												
29.6 kW	269	290	269	290	269	426	212	386	278	212	372	425
25.6 kW	262	279	262	279	262	399	212	364	268	212	352	399
23.04 kW	257	273	257	273	257	381	212	350	263	212	339	382

Notes: (1) The locations of the rails are shown in [3], Figure 6-1.

(2) Maximum average rail temperatures.

(3) Based on all components in the DSC cavity.

(4) The maximum DSC shell temperature is the temperature along the shell and does not include the top and bottom end plates.

Typical temperature plots for 32PHB DSC components for vacuum drying in nitrogen are shown in Figure 6-1 to Figure 6-3.

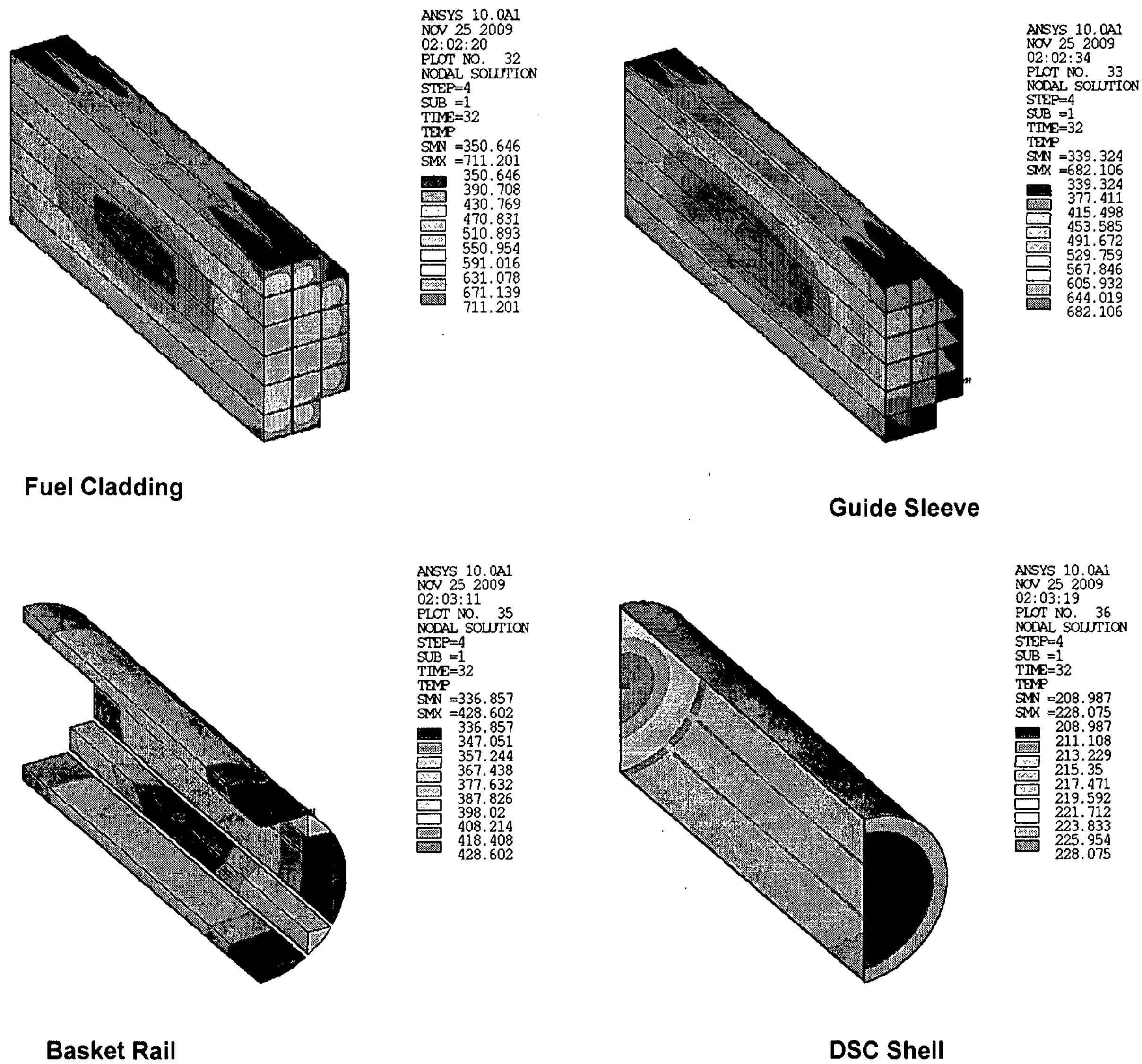


Figure 6-1 Temperature Plots for 32PHB DSC
(Vacuum Drying in Nitrogen, 29.6 kW @ 32 Hours)

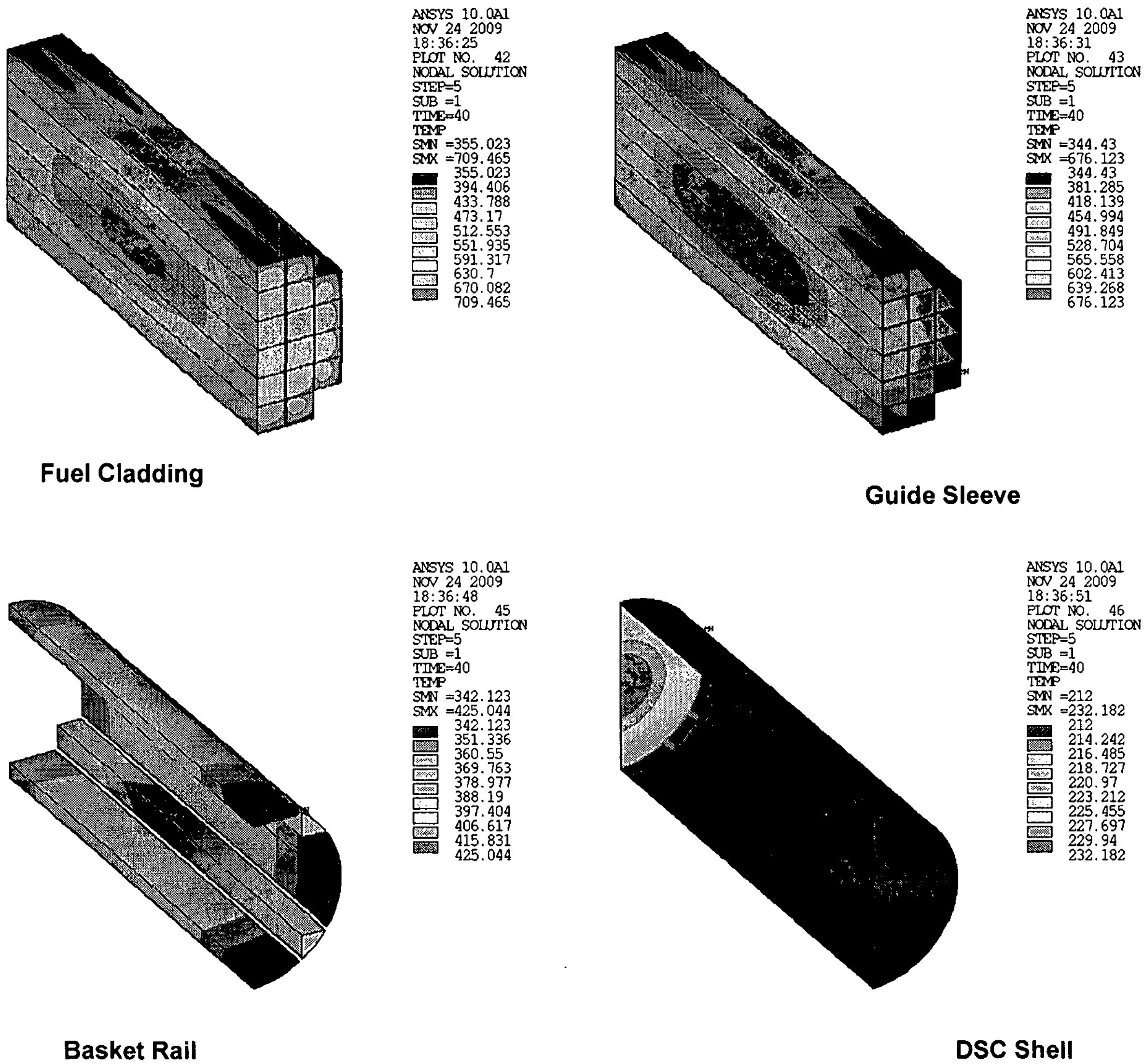
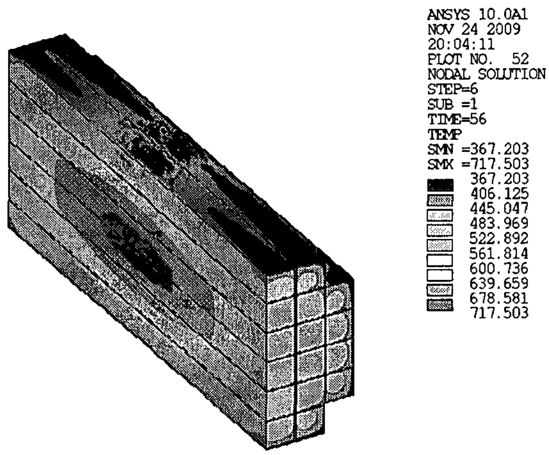
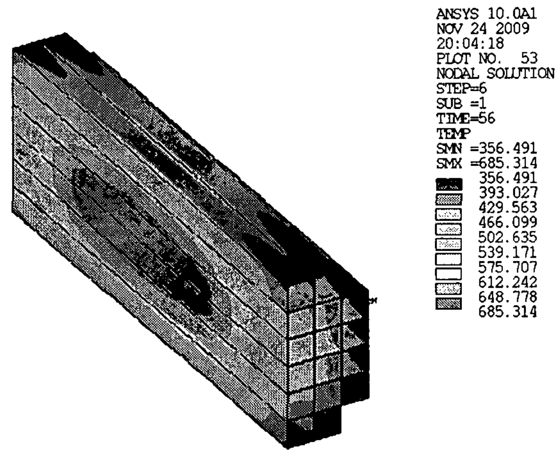


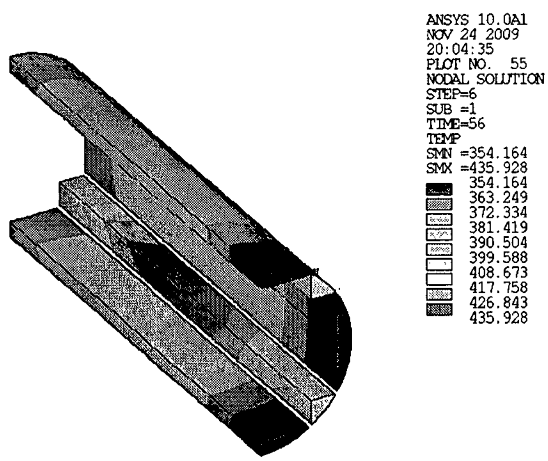
Figure 6-2 Temperature Plots for 32PHB DSC (Vacuum Drying in Nitrogen, 25.6 kW @ 40 Hours)



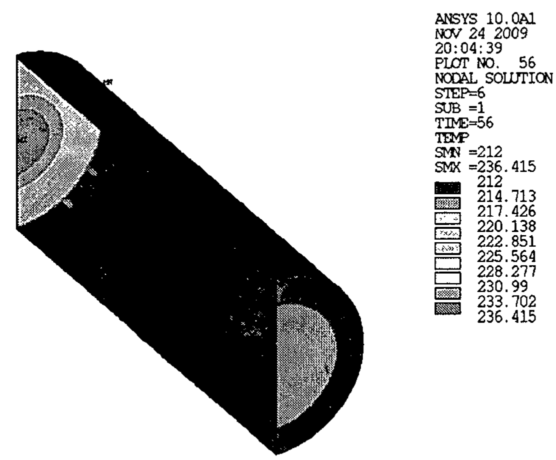
Fuel Cladding



Guide Sleeve



Basket Rail



DSC Shell

Figure 6-3 Temperature Plots for 32PHB DSC (Vacuum Drying in Nitrogen, 23.04 kW @ 56 Hours)

Typical temperature plots for 32PHB DSC components for steady-state vacuum drying in helium are shown in Figure 6-4 to Figure 6-6.

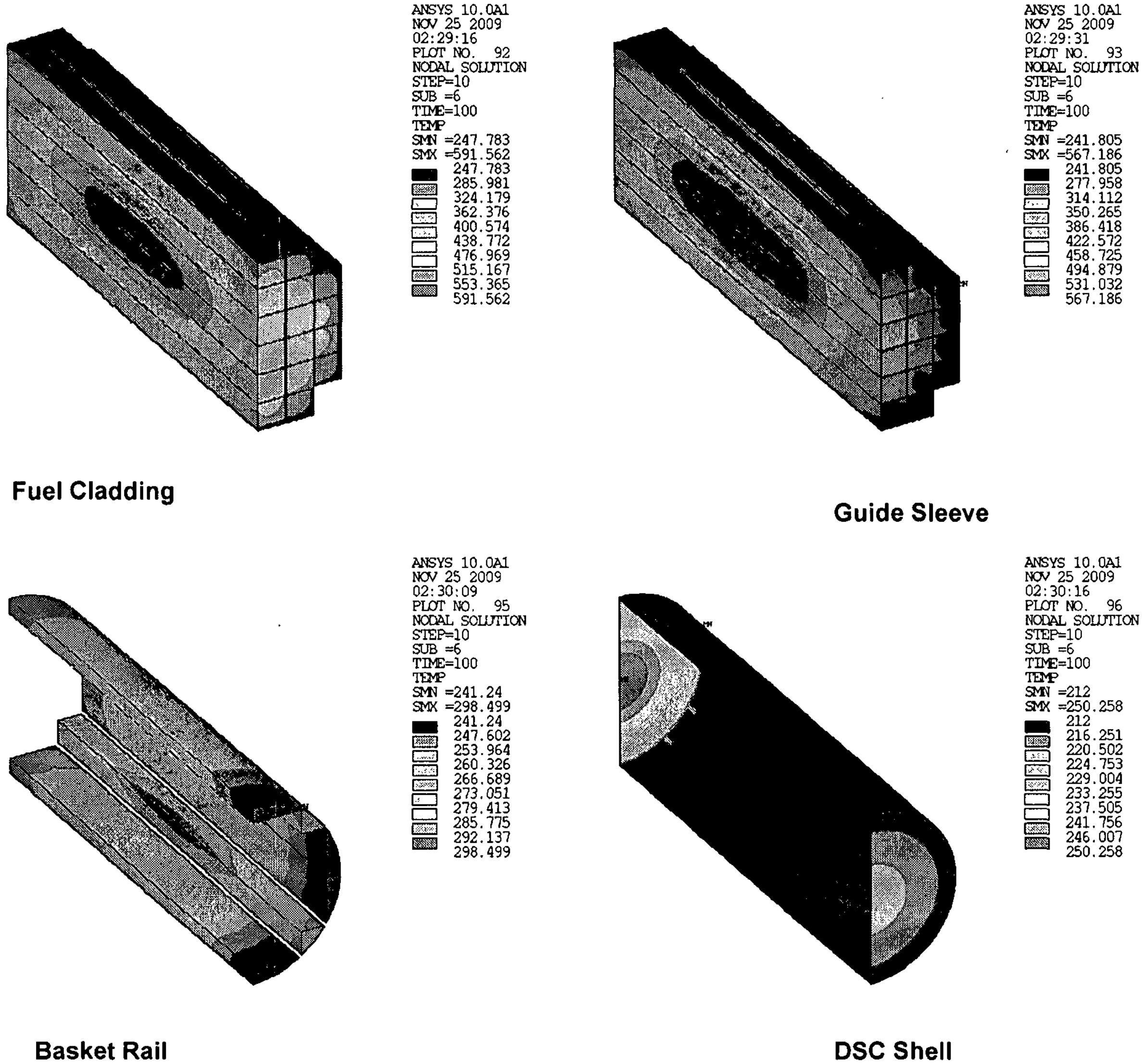


Figure 6-4 Temperature Plots for 32PHB DSC (Steady-State Vacuum Drying in Helium @ 29.6 kW)

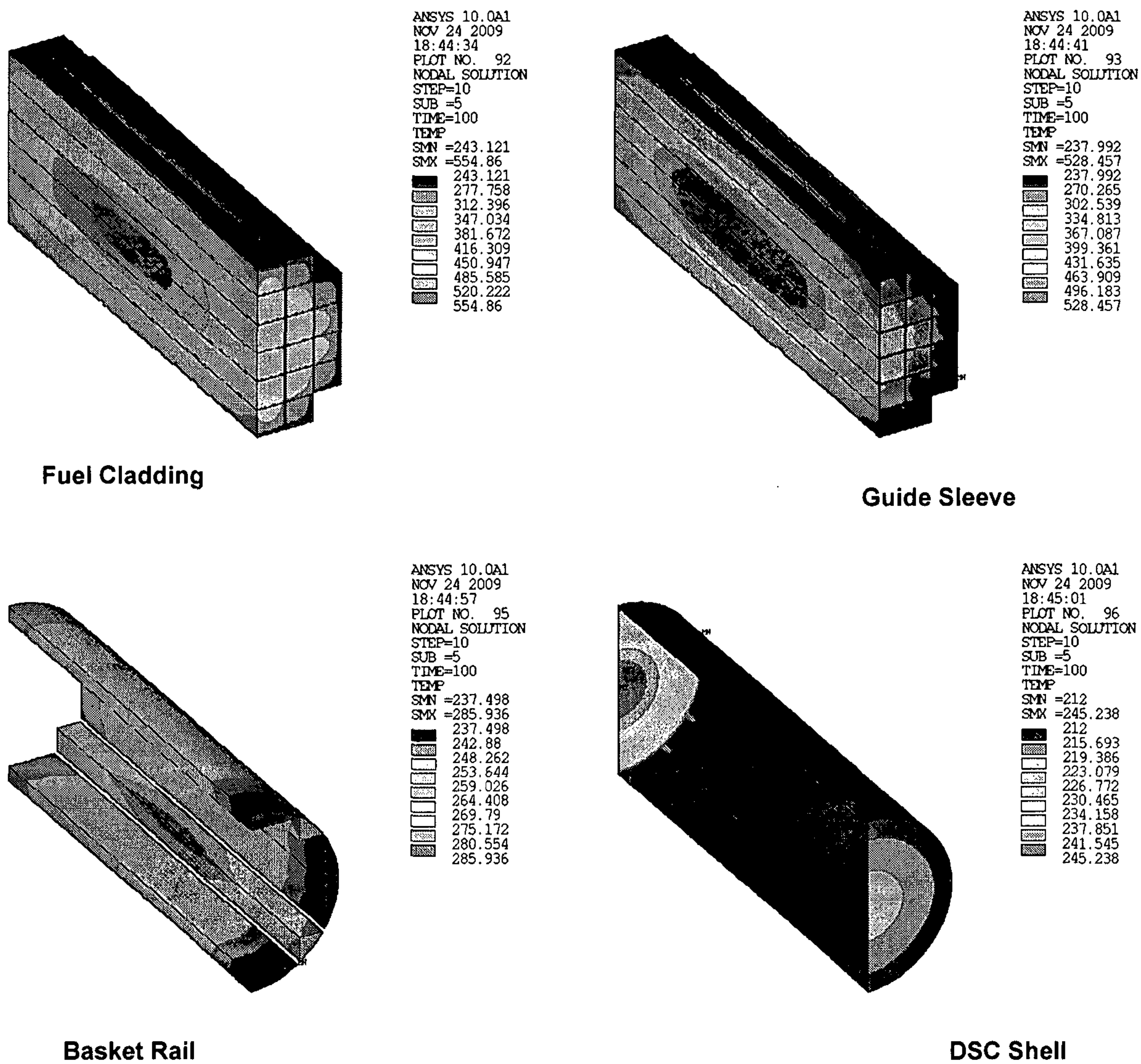


Figure 6-5 Temperature Plots for 32PHB DSC (Steady-State Vacuum Drying in Helium @ 25.6 kW)

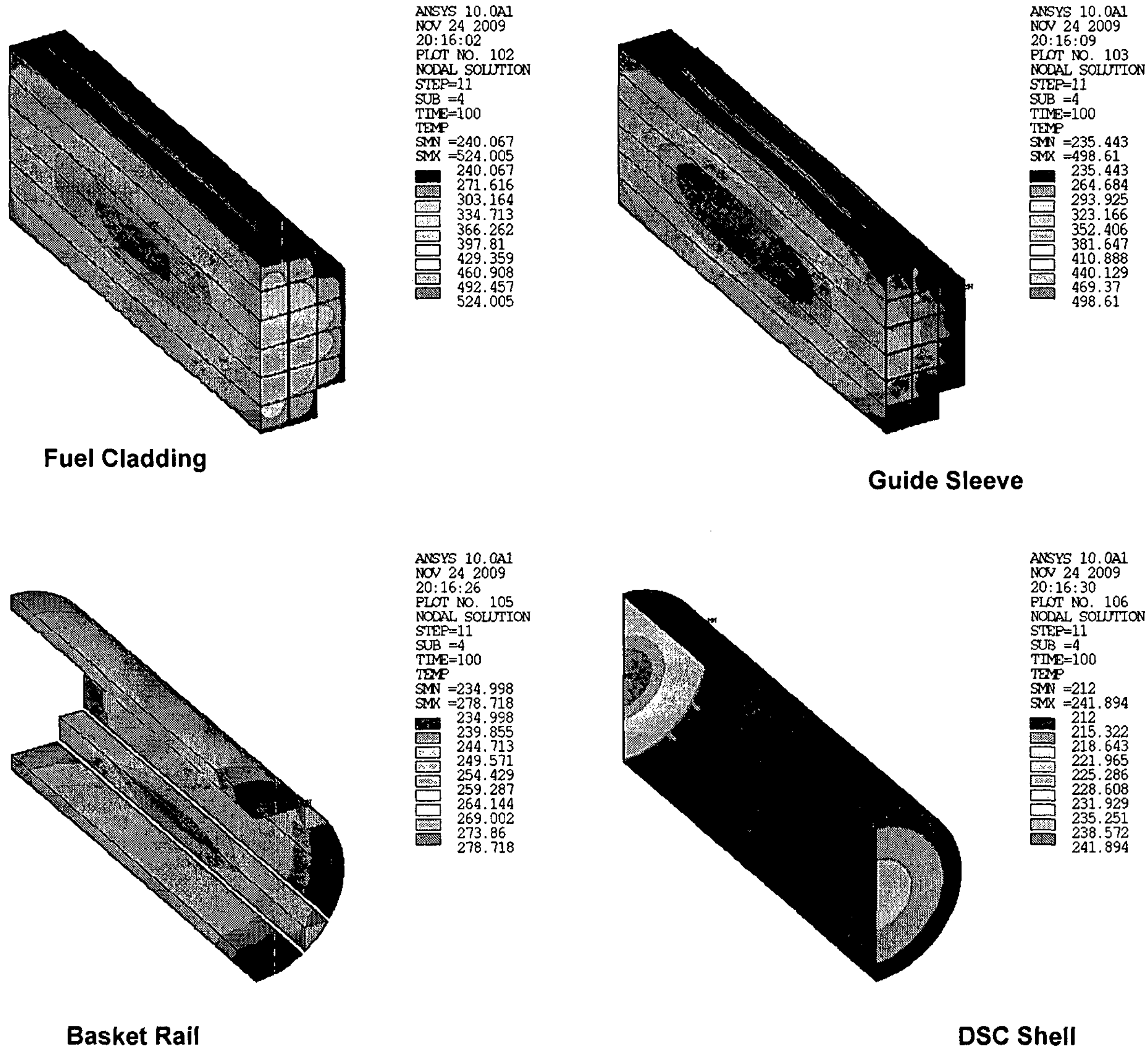


Figure 6-6 Temperature Plots for 32PHB DSC (Steady-State Vacuum Drying in Helium @ 23.04 kW)

Maximum temperature histories of fuel cladding for vacuum drying operations are shown in Figure 6-7 through Figure 6-9.

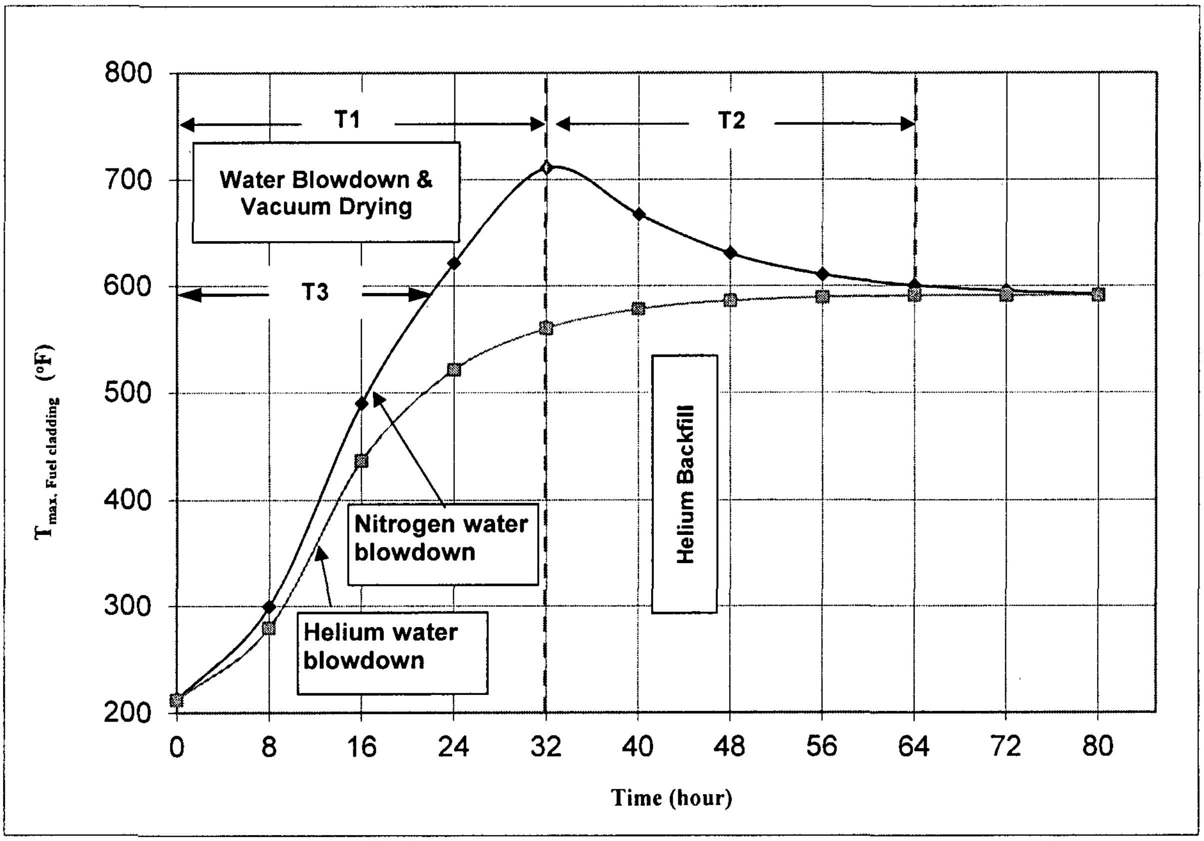


Figure 6-7 Maximum Temperature History of Fuel Cladding for Vacuum Drying Operations @ 29.6 kW

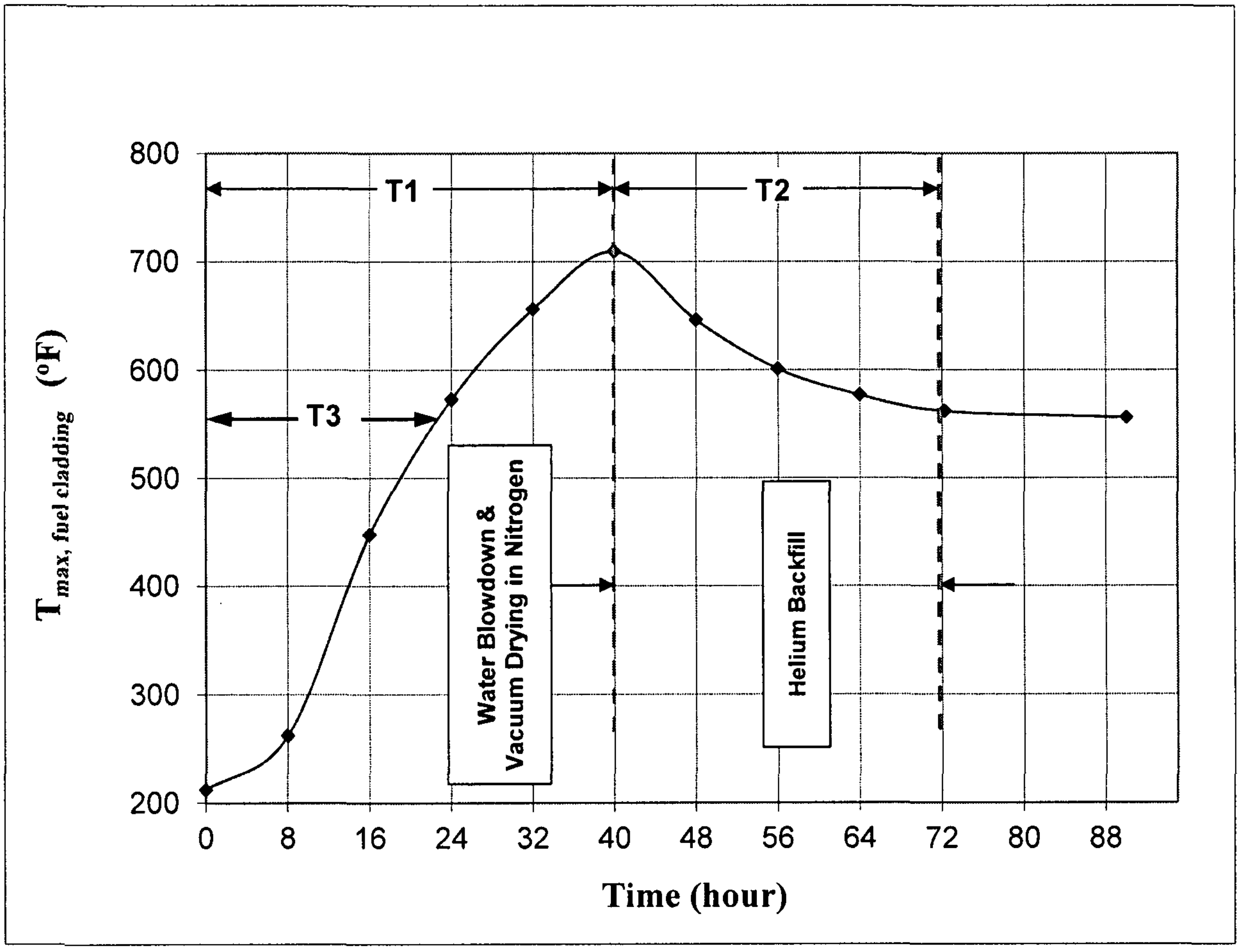


Figure 6-8 Maximum Temperature History of Fuel Cladding for Vacuum Drying Operations @ 25.6 kW

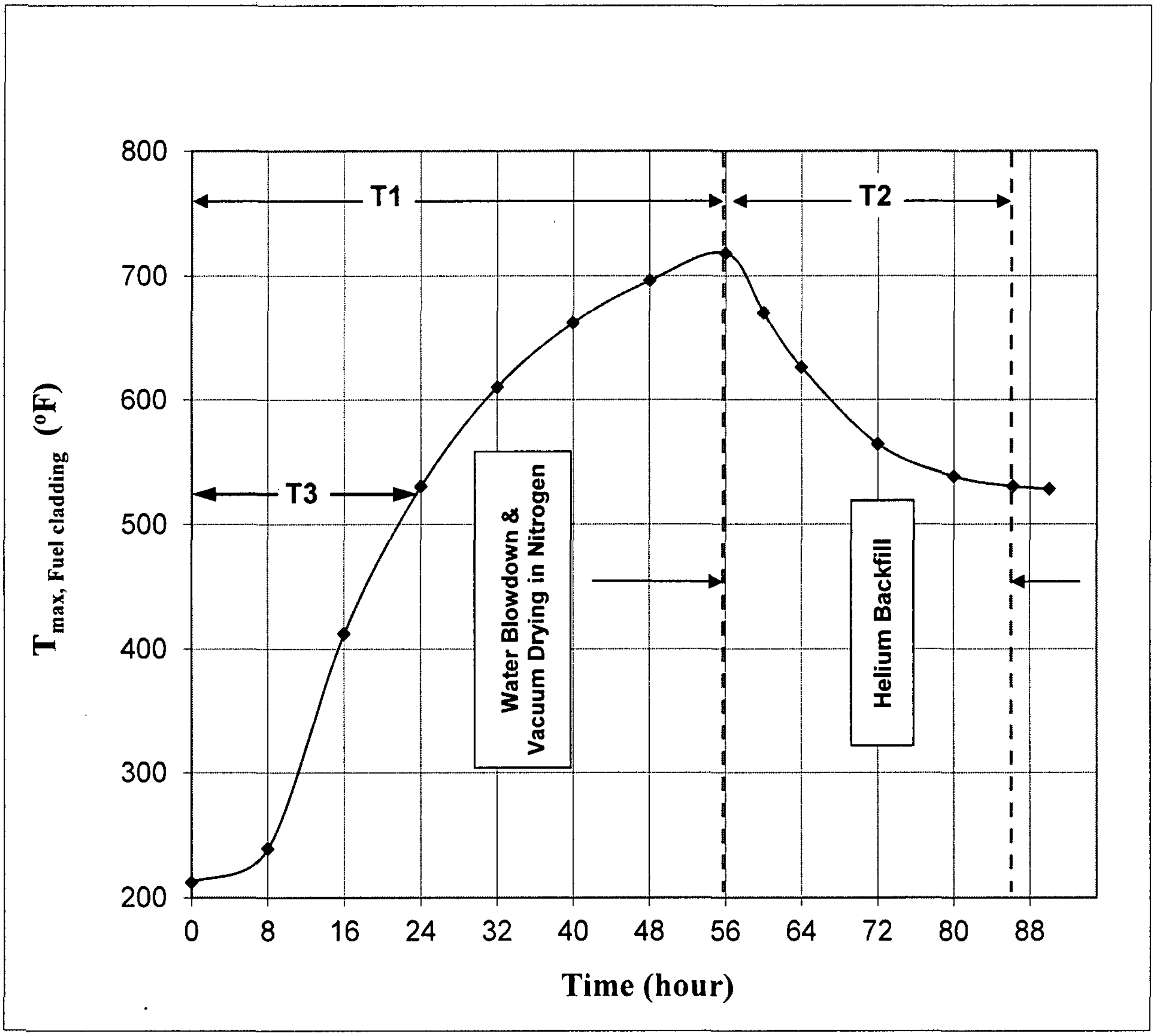


Figure 6-9 Maximum Temperature History of Fuel Cladding for Vacuum Drying Operations @ 23.04 kW

7.0 CONCLUSION

The maximum fuel cladding temperatures for 32PHB DSC for vacuum drying operations are shown in Table 7-1.

Table 7-1 Maximum Fuel Cladding Temperatures for Vacuum Drying

Operating Condition		Fuel Cladding	Limit
Water blowdown and Vacuum Drying, Helium Backfill		T_{max} (°F)	T_{max} (°F)
29.6 kW	Nitrogen @ 32 hrs (1)	**711**	752 [1]
	Helium @ Steady State (2)	**592**	
25.6 kW	Nitrogen @ 40 hrs (1)	**709**	
	Helium @ Steady State (2)	**555**	
23.04 kW	Nitrogen @ 56 hrs (1)	**718**	
	Helium @ Steady State (2)	**524**	

Notes: (1) The end of vacuum drying operations in nitrogen.
(2) Steady-state vacuum drying operations in helium.

The maximum component temperatures of 32PHB DSC for vacuum drying operations are summarized in Table 7-2.

Table 7-2 Maximum Basket Component Temperatures

Operating Condition		Fuel Cladding	Basket (Guide Sleeve)	DSC (Shell(3))	NA Plate	Basket Rails	Top Shield Plug	Bottom Shield Plug
Water blowdown and Vacuum Drying, Helium Backfill		T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)	T_{max} (°F)
29.6 kW	Nitrogen @ 32 hrs (1)	711	682	212	680	429	212	229
	Helium @ Steady-State(2)	592	567	212	567	298	224	252
25.6 kW	Nitrogen @ 40 hrs (1)	709	676	212	674	425	215	233
	Helium @ Steady State(2)	555	528	212	528	286	222	247
23.04 kW	Nitrogen @ 56 hrs (1)	718	685	212	683	436	217	237
	Helium @ Steady-State(2)	524	499	212	498	279	221	243

Notes: (1) The end of vacuum drying operations in nitrogen.
(2) Steady-state vacuum drying operations in helium.
(3) The maximum DSC shell temperature is the temperature along the shell and does not include the top and bottom end plates.

The maximum time limits for vacuum drying operations in nitrogen and the minimum time limits for reaching steady-state vacuum drying condition in helium after end of vacuum drying operations in nitrogen are listed in Table 7-3, respectively.

Table 7-3 Time Limits for Vacuum Drying Operations

Heat Load (kW)	29.6	25.6	23.04
Maximum Time Limit in Nitrogen, T1 (Hrs)	32	40	56
Minimum Time Limit in Helium Backfill, T2 (Hrs)	32	32	30
Maximum Time Limit in Nitrogen, T3 (Hrs)	22	23	24

As seen from Table 7-1, the maximum fuel cladding temperatures calculated for vacuum drying operations are below the allowable limits. As seen from Table 7-2, the maximum temperatures for top and bottom shield plugs are below lead melting temperature limit of 662°F [2]. All design criteria specified in Section 4.1 are herein satisfied.

8.0 LISTING OF COMPUTER FILES

A summary of ANSYS runs is listed in Table 8-1. All the runs are performed using ANSYS version 10.0 [7] with operating system "Linux RedHat ES 5.1", and CPU "Opteron 275 DC 2.2 GHz" / "Xeon 5160 DC 3.0 GHz".

Table 8-1 Summary of ANSYS Runs

Run Name	Description	Blowdown Gas	Date / Time
32PHB_VDN1MH	Vacuum Drying Operations, 29.6 kW	Nitrogen	11/25/09 02:31 AM
32PHB_VDY1	Vacuum Drying Operations, 25.6 kW		11/24/09 06:45 PM
32PHB_VDY2	Vacuum Drying Operations, 23.04 kW		11/24/09 08:17 PM
32PHB_VDY4	Vacuum Drying Operations, 29.6 kW	Helium	11/25/09 07:09 PM

ANSYS macros, and associated files used in this calculation are shown in Table 8-2.

Table 8-2 Associated Files and Macros

File Name	Description	Date / Time
32PHB_Model.db [3]	32PHB DSC Model	07/10/09 07:49 PM
32PHB_Mat1H.inp	Material properties for 32PHB DSC including Helium	09/14/09 04:55 PM
32PHB_Mat1N.inp	Material properties for 32PHB DSC including Nitrogen	09/14/09 04:58 PM
32PHB_HLZC2.MAC	Heat generation for 32PHB DSC, 29.6 kW	09/03/09 09:56 AM
32PHB_HLZC2A.MAC	Heat generation for 32PHB DSC below 29.6 kW	09/29/09 02:09 PM
Macro	Maximum/Minimum temperatures	05/20/05 01:03 PM
Results.mac	Maximum and average 32PHB DSC component temperatures	07/22/09 12:52 PM

The spreadsheet used in this calculation is listed in Table 8-3.

Table 8-3 List of Spreadsheet

File Name	Description	Date / Time
32PHB_VDY.xls	Time histories of maximum fuel cladding temperatures	12/01/09 06:27 PM
32PHB_VDY_R-1.xls	Excel spreadsheet for calculating time limit "T3"	08/09/11 04:32 PM