TRANSNUCLEAR

Form 3.1-1
Calculation Approval Sheet

Project Name: NUHOMS-32P **Project #:** 10950

Calculation Title: Effective Fuel Properties for Vacuum Drying

Calculation #: 1095-38 **Draft/Revision #:** 0 **DCR #:** ---

Number of pages: 4

Number of CDs attached: 1

If original issue, 10CFR72.48 review required?
[X] No (explain) **[ ] Yes, SR No.** ______
This calculation is performed in support of the licensee, CCNPP

1. **This calculation is complete and ready for independent review**

   Originator's Signature ______ Date: 7/1/03

2. **This calculation has been checked for consistency, completeness, and arithmetic correctness.**

   Checker Signature ______ Date: 7/1/03

3. **Calculation preparation and check complies with procedure - package is complete**

   PE's Signature Glenn Guerra Date: 8/25/03

1.0 Purpose

To determine the effective fuel conductivity during vacuum drawing for use in the NUHOMS-32P thermal analyses.

2.0 References

1) Calc No. 1095-2, Rev 0, "NUHOMS-32P, Effective Fuel Properties"
2) W. M. Rohsenow, J. P. Hartnett, "Handbook of Heat Transfer Fundamentals", 2nd Edition, 1985.
3) ANSYS Computer Code and User's Manuals, Volumes 1-4, Rev. 5.7. See Test Reports E-18762 through E-18768 for validation of computer code.
4) ANSYS files : /calc1095-38/ fuel.db, fuel.rth, fuel.sub
5) Calvert Cliffs Independent Spent Fuel Storage Installation, Volume 1, USAR, Rev. 11.
6) Roth, A., Vacuum Technology, 2nd Edition, 1982
7) Diament, R.M.E., Thermal and Acoustic Insulation, 1986
8) Perry & Chilton, Chemical Engineers Handbook, 5th Edition, 5th Edition, 1973

3.0 Assumptions

1) Convection heat transfer is conservatively neglected.
2) The assembly is assumed to be centered within a fuel compartment.
3) Radiation heat transfer between the fuel pellets and the fuel cladding is neglected.
4) The decay heat load of each assembly is assumed to be 0.660 kW.
5) The fuel compartment is 8.5 inches square.
6) Conductivity for air at 0.1 bar, which is assumed to be the same at low pressures.
7) Other material properties and dimensions are identical to reference 1.

4.0 Discussion

The radial effective conductivity is determined by using the same finite element model of the fuel assembly used in Reference 1. The material representing helium in the model was replaced by anther material with the identical properties of air.

According to Reference 5 for the vacuum drying procedure, the DSC air space will be purged with filtered plant air, before the welding of the top shield plug begins. Engaging compressed helium or compressed air then removes the remaining water from the DSC cavity. The conductivity of air is lower than helium. Air properties at 0.1 bar are considered for the back fill gas during the vacuum drying procedure. Since the air during vacuum drying stays in the viscous state, its thermal conductivity is independent of pressure (see Appendix A for justification). In addition existence of water vapor within the basket during vacuum drying procedure increases the gas conductivity, which is conservatively not considered in this analysis.

4.1 Material Properties

Air

Temperature(2) (K)	Conductivity(2) (W/m-k)	Temperature (°F)	Conductivity (Btu/hr-in-°F)
300	0.0263	80	0.00127
400	0.0336	260	0.00163
500	0.0403	440	0.00195
600	0.0466	620	0.00226
800	0.0577	980	0.00279
1000	0.0681	1340	0.00330

(From Table 15, Chapter 3)

5.0 Results

The radial effective conductivity of the fuel assembly calculated from the results of the ANSYS model is listed below.

Fuel Compartment Wall Temperature (°F)	Maximum Fuel Temperature (°F)	Average Fuel Temperature (°F)	Effective Radial Fuel Conductivity (Btu/hr-in-°F)
100	251.455	175.728	0.0080
200	317.480	258.740	0.0103
300	391.572	345.786	0.0133
400	471.890	435.945	0.0169
500	557.003	528.502	0.0213
600	645.715	622.858	0.0265

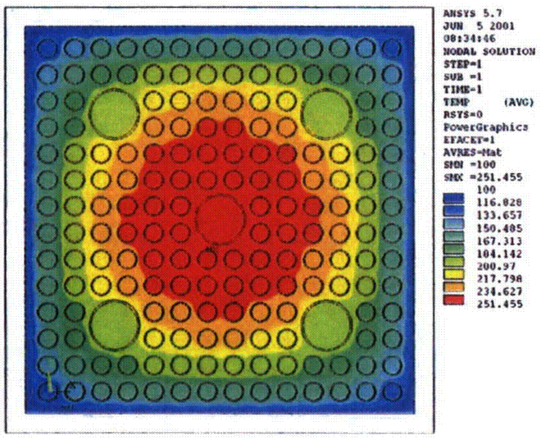
6.0 Conclusions

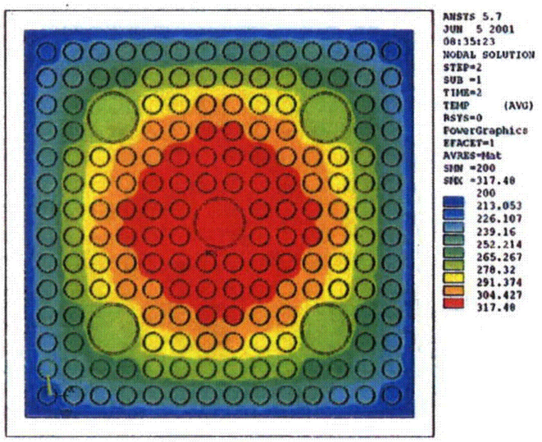
The effective radial conductivity calculated in section 5.0.

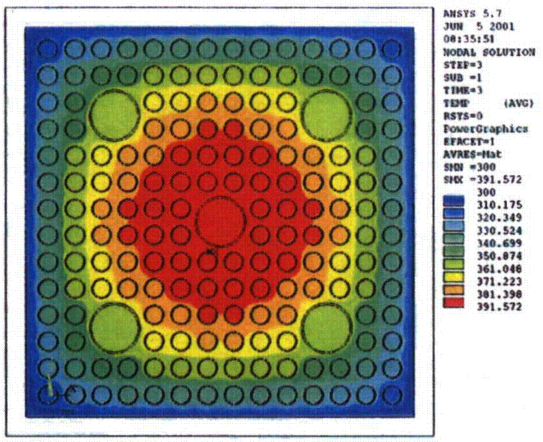
Average Fuel Temperature (°F)	Effective Radial Fuel Conductivity (Btu/hr-in-°F)
175.728	0.0080
258.740	0.0103
345.786	0.0133
435.945	0.0169
528.502	0.0213
622.858	0.0265

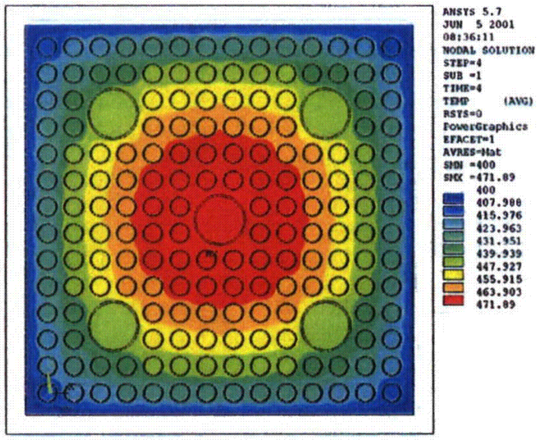
Appendix A

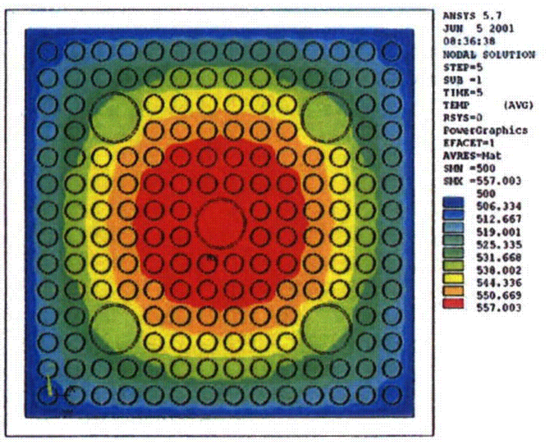
Temperature Distribution

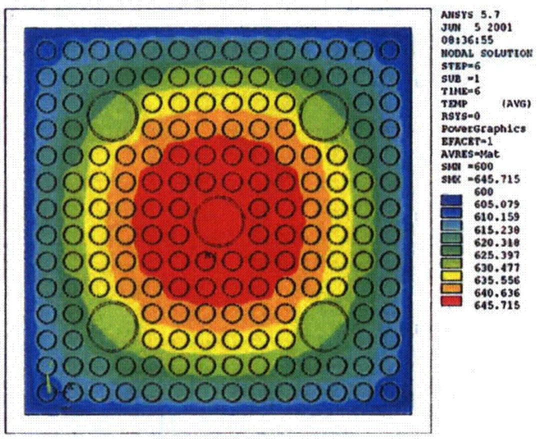












Appendix B

Effect of Pressure on Air Conductivity

Heat transfer within the cavities of the fuel can be classified into the following cases (ref. 6):

1) ***viscous state***, in which the totality of molecules is responsible for the heat transfer. The viscous state occurs as long as the pressure is higher than the range in which the molecular state occurs. Within the viscous state, the thermal conductivity of a gas is independent of pressure.

2) ***molecular state***, Heat conductivity in the molecular state is when the gas pressure is so low that the molecular mean free path is about equal or greater than the distance between the plates. The gas is no longer characterized by viscosity. The last state for conductivity is no longer valid and therefore the conductivity is found to be dependent on pressure. The process under these conditions is called free molecular conduction.

The pressure at which the molecular mean free path is equal to the minimum distance between the surfaces within the NUHOMS-32P package is determined below.

The smallest gap used in the thermal model is 0.01 inches. The smallest gap is set equal to the mean free path to determine the minimum pressure at which the molecular state occurs.

The mean free path of the molecules is determined by the following equation (ref. 7):

$$\frac{1}{L} = A * p * (1 + B * T)$$

L = mean free path (meters) = (0.010in)(1 m/39.70 in) = 2.54E-4 m
p = pressure (Pa)
T = temperature (K) = assumed to be 300 °F = 422.2 K
A = 118.76 m/N for air
B = 0.00885 1/K for air

$$p = [AL(1+BT)]^{-1}$$
$$p = [(118.76)(2.5400E\text{-}4)(1+(0.00885)(422.2))]^{-1}$$
$$p = 7.0 \text{ Pa} = 0.070 \text{ mbar}$$

For pressures above 0.070 mbar, heat transfer of the air within the cask cavity during vacuum drying can be characterized by the viscous state. The minimum vacuum drying pressure of about 4 mbar or 3 torr (ref. 8) is well above this pressure and the conductivity of the air will not be a function of the pressure.