TRANSNUCLEAR

E-22387
May 24,2005

Mr. Joseph M. Sebrosky
Spent Fuel Project Office, NMSS
U. S. Nuclear Regulatory Commission
11555 Rockville Pike M/S 0-6-F-18
Rockville, MD 20852

Subject: RAI Response for the NUHOMS® HD Storage System Docket No. 72-01030.
(TAC No. L23738)

Reference: Additional Information, TN letter E-22051 (3/7/2005)

Dear Mr. Sebrosky:

A CFD calculation was performed and referenced in our response, (E-21995), to question 4-4 of RAI1, dated 12/13/2004. Subsequent to the staff's review of this response, you requested a copy of the referenced CFD calculation and this was provided to you in the referenced submittal. After the staff's review of the calculation, additional questions were provided to us and discussed in a telecom on 4/7/2005. During this discussion, several issues were identified with the use of the FLUENT code and the data input and modeling that was utilized in the analysis. We agreed to review the analysis and talk to the FLUENT code providers in order to provide additional information/clarification requested by the staff.

After Transnuclear contacted the FLUENT providers and reviewed the analysis, another telecom was held on 5/3/2005 to provide feedback to your staff. At the conclusion of the telecom, it was decided that Transnuclear should submit answers to the additional questions provided by the staff on 4/6/2005. The attachment to this letter provides Transnuclear's response to the staff's additional questions. The previously submitted calculation (10494-87) has been revised (rev 1) and is attached along with four (4) CDs. This information is considered proprietary and the affidavit is also attached.

The analysis was performed to justify the heat transfer methodology utilized in the liquid neutron shield region of the transfer cask. As in most any computer analysis, limitations on computer "power" and modeling constraints force one to choose a region of interest to be modeled in rigorous detail, while regions of less interest are modeled in less detail. In this analysis, the region inside the neutron shield jacket is the region of interest and was modeled accordingly. Heat transfer for regions of the transfer cask surrounding the neutron shield region have been evaluated in other analyses and are ancillary to and not the subject of this analysis.

If you have any questions, please contact me.

Sincerely,

Michael Mason
Chief Engineer
Attachments: as stated above

NMSS01

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Responses to Additional Questions (4/6/2005)

NUHOMS-HD
Transnuclear

Staff Issues

A) Confirmation of the Effective Thermal Conductivity Within the Neutron Shield of the OS187H Transfer Cask Using a CFD Method.

FLUENT CFD model of the OS187H Transfer Cask - Boundary Condition #2: Variable neutron shield shell temperature.

Material Properties

1 Justify the use of Boussinesq Approximation to obtain air density vs using ideal gas or incompressible ideal gas approximation.

RESPONSE: As the attached view foil from the FLUENT tutorial series shows, the Boussinesq Approximation must be used for natural convection problems inside closed domains when the steady-state solver is used. Further, per the Icepak user guide (see below), the Boussinesq Approximation yields appropriate results if $\beta(T - T_0) \ll 1$

This is certainly true for the water jacket and the value for the airside is on the order of 0.10 to 0.13.

Finally, as the calculation states, the analysis was conducted using the Icepak pre- and post-processor. This package limits the user's choice to either all domains solved using the ideal gas relationship or all domains solved using the Boussinesq Approximation. Attempting to use the ideal gas relationship option with the steady-state solver will result in erroneously high velocities on the airside due to numerical errors introduced into the solution by the inappropriate application of the ideal gas relationship to the water side.

To verify the level of solution difference achieved using the ideal gas relationship vs. the Boussinesq Approximation, the FLUENT office which supports the Icepak module was contacted and they provided a method for accessing the full code during the solution process. Via this direct access to the full code it was possible to separate the fluid domains, applying the Boussinesq Approximation to the water side only and the ideal gas relationship to the airside only. Comparing the solutions between the use of the ideal gas relationship and the Boussinesq Approximation for the same model setup showed that the use of the Boussinesq Approximation would result in approximately a 14°F increase in the model peak temperatures in comparison with those predicted using the ideal gas relationship. This result is attributed the fact that application of the Boussinesq Approximation over predicts the reduction in density that occurs as the air is heated, thus reducing the computed heat transfer from the shell. The ΔT between the average structural shell and outer skin temperatures (across the neutron shield jacket) remained at 12°F for either solution approach.

<u>Excerpt from Icepak User Guide:</u> *Section 33.3.1 The Boussinesq Model*

By default, Icepak uses the Boussinesq model for natural-convection flows. This model treats density as a constant value in all solved equations, except for the buoyancy term in the momentum equation:

$$(\rho - \rho_0)g \approx -\rho_0\beta(T - T_0)g$$

where ρ_0 is the (constant) density of the flow T_0, is the operating temperature, and β is the thermal expansion coefficient. The above equation is obtained by using the Boussinesq approximation $\rho = \rho_0(1 - \beta\Delta T)$ to eliminate ρ from the buoyancy term. This approximation is accurate as long as changes in actual density are small; specifically, the Boussinesq approximation is valid when $\beta(T - T_0) \ll 1$

2 Justify the use of a constant air viscosity equal to 1 kg/m-s. Table 3 of Transnuclear Calculation No. 10494-87 provides a table for thermal properties of air, including viscosity. From this Table viscosity of air at 100°F appears to be about 1.9045E-5 kg/m-sec. The value used by the applicant appears to be much higher than the value of air at the cask operating conditions for environment.

RESPONSE: The use of a constant air viscosity was not intended. The problem has been re-run with the Table 3 values of viscosity and the results showed an increased level of heat transfer from the neutron shield skin to the air, but with essentially the same ΔT on the water side.

3 Justify the applied FLUENT turbulence option and make sure the near-wall treatment is properly resolved (i.e., is the standard k-epsilon model with standard wall functions being applied adequately and in accordance with the FLUENT guidelines?).

RESPONSE: The use of the Icepak module for this work severely limits the ability of the applicant to do detailed analysis of the boundary layer meshing (i.e., the y+ values can not be computed nor displayed). The FLUENT guidelines suggest a y+ value of 30 to 60 for the application of the k-epsilon models with wall functions. As such, the meshing scheme used for the original calculation was revised to move the first mesh point out from the surface of the neutron shield surface. Sensitivity to the meshing scheme was evaluated via the use of 3 different mesh schemes. While the variations in the meshing scheme was seen to have an impact on the overall temperature levels achieved in the model, the computed effective heat transfer rate within the water jacket remained essentially constant for the given heat load and geometry conditions. This result is expected since the heat transfer rate from the exterior of the neutron shield shell does not directly affect the heat transfer process within the water jacket – instead, it is important to this specific analysis only in how it generates a given temperature level on the neutron shield skin.

4 Justify the use of the Boussinesq approximation to obtain the water density vs a temperature dependent piece-wise linear or polynomial representation.

RESPONSE: As explained in the response to Question #1 above, the FLUENT code requires that the Boussinesq Approximation must be used for natural convection problems inside closed domains when the steady-state solver is used.

As seen from the sensitivity results presented in the revised calculation for the application of the ideal gas vs. the Boussinesq Approximation for the air side showed that the two modeling approaches produce similar results. Given this and the fact that the parameter $B(T-T_o)$ is << 1 for the 12°F average ΔT seen for the water jacket is very small the use of Boussinesq Approximation is fully justified and necessary.

5 Justify a value equal to 1.0 for emissivity of neutron shield enclosing walls for steel oxidized surfaces.

RESPONSE: The applicant is unsure where the staff observed the value of 1.0 for the emisssivity. Examination of the model confirmed that the 'Steel-Oxidized' surface was assigned an emissivity value of 0.8. Further, radiation is not active within the water jacket. As such, the value of the emissivity for this surface is immaterial to the solutions presented.

Model

6 Justify the use of source term applied to the structural shell vs applying the appropriate heat flux to the inner wall of structural shell. The applicant could use symmetry on the X-direction and reduce to one half the current CFD domain.

RESPONSE: The application of the source term to the structural shell as a volumetric heat source was chosen for simplicity within the available Icepak modeling options. A different method of applying the heat source within the limitations of the Icepak module would have adversely affected other aspects of the modeling. While the application of a heat flux to the inner wall of the structural shell would have yielded an accurate computation of the temperature drop across the radial thickness of the structural shell, this portion of the solution is immaterial to what is the ΔT across the water jacket. Given these considerations, and since the ΔT across the water jacket is the focus of the RAI, the use of a volumetric heat source was selected as the most appropriate method that would not compromise the primary objective of the solution.

The use of a symmetry condition on the X-direction was not an option for the Icepak module. Since the choice of mesh generators is limited within this module the use of a symmetry plane would not have allowed the mesher to generate an appropriate mesh within the water jacket.

7 Extend CFD domain in X and Y to 4 or 5 cask diameters in order to avoid any effect of pressure boundary on the cask walls exposed to the environment.

RESPONSE: Although the results indicated some 'pinching' of the solution, the impact was originally judged to be acceptable given the fact that the model was already using approximately 1.3 million mesh cells and the computational speed was being significantly affected. The re-analysis extends the domain out as part of the other model changes – the effects appeared to be in the direction of reduced temperature levels and not higher temperatures.

8 The bottom of the transfer cask is confined by the transportation bed. It may be more adequate to locate a wall on bottom of cask at a distance equal to the distance between bottom of the cask and the transportation bed. A pressure boundary condition for the bottom of CFD domain may not be an adequate representation of the actual physical boundary.

RESPONSE: The centerline of the trunnions supporting the OS187H transfer cask is approximately 60 inches above the bed of the transfer skid. Since the O.D. of the transfer cask is 92.2 inches, a minimum clearance of approximately 14 inches will exist between the bottom of the OS187H transfer cask and the bed of the transfer skid. Further, since the bed of both the transfer skid and the transfer trailer are fabricated of structural steel members without the use of solid decking, the presence of these components will present essentially no resistance to the flow of air upward and around the O.D. of the transfer cask. As such, it is appropriate to model the convection occurring from the exterior of the transfer cask as that occurring from an isolated, horizontal cylinder in air.

9 Justify why the effective thermal conductivity of the neutron shield is based on temperature gradients calculated using average wall temperatures. Prove that this approach is bounding or conservative.

RESPONSE: Proof that the approach is bounding or conservative is impossible from a practical point of view since it is impossible to 'assign' the heat removed from a given sub-segment of the structural shell with the heat transferred to a given sub-segment of the neutron shield due to the circulatory and somewhat random movement of the water. While it is possible to arbitrary use the temperatures of radially opposing segments of the structural and neutron shield shells, the approach would not be technically correct in that it would mis-represent the true heat transfer patterns occurring within the water jacket. The use of the average wall temperatures is appropriate for the following reasons: 1) the heat transfer in the water jacket is global to the enclosure (i.e., the circulation of the water brings all of the surfaces into the heat transfer process), and 2) the semi-empirical heat transfer correlations are all based on average temperatures. As such, the approach used is consistent with industry standards and is the only practical approach available for both the analysis of the data as well as the application of the computed heat transfer coefficients.

10 Table 4-8 of the SAR. The maximum temperature during vacuum drying Procedure B is 751°F, which is one degree below the allowable limit. TN needs to provide a sensitivity study (including calculation uncertainties of input data, modeling assumptions, and method of analysis) on the accuracy of predicting temperature to within one degree. Predicting a temperature to within one degree is very difficult. Even physical experiments can't measure temperatures with this accuracy. Justify why this value is acceptable.

RESPONSE: The value of 751°F in Table 4-8 is not during the vacuum drying operation. Rather, it is the calculated fuel clad temperature, using vacuum drying Procedure B, at 12 hours after vacuum drying if the transfer cask annulus has not been backfilled with helium. Based on SAR Figure 4-36, the calculated fuel clad temperature at 9 hours after vacuum drying is about 730°F which allows sufficient margin to the allowable limit. We will add a Technical Specification requirement that the transfer cask must be backfilled with helium within 9 hours after completion of vacuum drying.

Natural Convection – the Boussinesq Model

- Boussinesq model assumes the fluid density is uniform
  - *Except* for the body force term in the momentum equation along the direction of gravity, we have:

    $$(\rho - \rho_0)g = -\rho_0 \beta (T - T_0) g$$

  - Valid when density variations are small (i.e., small variations in T).
- It provides faster convergence for many natural-convection flows than by using fluid density as function of temperature.
  - Constant density assumptions reduces non-linearity.
  - Suitable when density variations are small.
  - Cannot be used together with species transport or reacting flows.
- Natural convection problems inside closed domains:
  - For steady-state solver, Boussinesq model must be used.
    - The constant density, ρ_o, properly specifies the mass of the domain.
  - For unsteady solver, Boussinesq model or ideal-gas law can be used.
    - Initial conditions define mass in the domain.

AFFIDAVIT

STATE OF NEW YORK }
}
}
}
COUNTY OF WESTCHESTER }

Before me, the undersigned authority, personally appeared Alan Hanson who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Transnuclear, Inc. and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Alan S. Hanson

ALAN HANSON

Sworn to and subscribed Before me this 25 day of May, 2005.

ANNE MARIE CLEARY
Notary Public, State of New York
No. 01CL6001814
Qualified in Westchester County
Commission Expires Jan. 26, 2006

(1) I am President of Transnuclear, Inc. and my responsibilities include reviewing the proprietary information sought to be withheld from public disclosure in connection with the licensing of spent fuel transport cask systems or spent fuel storage cask systems. I am authorized to apply for its withholding on behalf of Transnuclear, Inc.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.390 of the commission's regulations and in conjunction with the Transnuclear application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Transnuclear in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) The following information is furnished pursuant to the provisions of paragraph 10CFR 2.390(b)(4) to determine whether the information sought to be withheld from public disclosure should be withheld.

   (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Transnuclear.

   (ii) The information is of a type customarily held in confidence by Transnuclear, is not customarily disclosed to the public and is transmitted to the commission in confidence.

   (iii) The information sought to be protected is not now available in public sources to the best of our knowledge and belief and the release of such information might result in a loss of competitive advantage as follows:

      (a) It reveals the distinguishing aspects of a storage system where prevention of its use by any of Transnuclear's competitors without license from Transnuclear constitutes a competitive economic advantage over other companies.

      (b) It consists of supporting data, including test data, relative to a component or material, the application of which secures a competitive economic or technical advantage.

      (c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(5) The information is being transmitted to the commission in confidence and, under the provision of 10CFR Section 2.390, it is to be received in confidence by the Commission.

(6) The information sought to be protected is not available in public sources to the best of our knowledge and belief.

(7) The proprietary information sought to be withheld is information referenced in our response to the RAI for the NUHOMS® -32PTH HD System. Specifically, Transnuclear calculation 10494-87, rev 1 with attached CDs.

(8) This information should be held in confidence because it provides details of design calculations that were developed at significant expense. This information has substantial commercial value to Transnuclear in connecting with competition with other vendors for contracts.

The subject information could only be duplicated by competitors if they were to invest time and effort equivalent to that invested by Transnuclear provided they have the requisite talent and experience.

Public disclosure of this information is likely to cause substantial harm to the competitive position of Transnuclear, because it would simplify design and evaluation tasks without requiring a commensurate investment of time and effort.