Structural Analysis Approach for the Examination of a Jetliner Impact into the NUHOMS-32, VSC-24, and TN-68 casks

The remaining casks that are to be examined for the jetliner impact scenario are the NUHOMS, VSC-24, and the TN-68. The following is an overview of how Sandia National Laboratories (SNL) will approach examining an intentional large jetliner impact into these cask systems. Each cask system will be approached in a similar manner to that used for the HI-STORM and NAC-UMS casks. A global examination will be conducted to examine global damage to the cask, the pressure loading on the cask, and to find an exit velocity for impacts on other casks or surfaces. The global analysis will likely be conducted using CTH, a Eulerian shock physics code. This is the same code that was used for the examination of the HI-STORM cask. However, other options for the global analysis are being considered. The local analyses will all be examined using finite element analysis. More detail on the individual approach for each cask system is described below.

The Threat

The threat will be the same as was used for the field of HI-STORM casks and the NAC-UMS rail cask. The same jetliner will be used as the impacting aircraft. The velocity will be

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Given this threat each cask system will be examined under a variety of scenarios. Due to variations in the cask systems, different analyses might be used for each cask system. Any restrictions on the possible scenarios that are being applied will be discussed specifically for each cask system. If it is possible to determine a "more likely" scenario, that scenario will be explored in depth.

NUHOMS-32

The NUHOMS-32 horizontal cask system for the dry storage of spent nuclear fuel assemblies provides numerous challenges for the analysis of its performance under these types of loadings. The system consists of the dry shielded canister (DSC) that is placed in a concrete horizontal storage module (HSM). The DSC rests on a steel support structure when it is inside of the HSM. The HSM is constructed of reinforced concrete slabs. The roof of the HSM is attached to the system with steel brackets. There is also a steel heat shield mounted to the inside of the concrete HSM. The NUHOMS-32 cask modules are placed in numerous configurations, some of which are outlined in the portion of the SAR that was provided by Mahendra Shah. When placed in the field the modules are attached to one another using steel brackets. All of this provides for a very complex structural system. Based on discussions with the NRC at the end of January 2003, it is

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SNL's understanding that the NRC has specified that SNL is to examine a system of 2 X 3 (total of 6) modules.

CTH will be used to develop pressure loads that can be transferred to a finite element code to examine the integrity of the systems. Finite element analyses will be conducted to examine the integrity of the NUHOMS-32 when subjected to the pressure loads found from the CTH analysis and hard component impacts from the jetliner engine and landing gear. It may be necessary to decouple the analyses of the HSM and the DSC.

SNL will conduct the CTH analyses and the finite element analyses (LS-DYNA) will be conducted at Applied Research Associates in San Antonio.

VSC-24

The Ventilated Storage Cask (VSC-24) system is a dry storage system using a Ventilated Concrete Cask (VCC) overpack constructed of a reinforced concrete exterior with a 44.5 (1.75 in) steel liner. Inside the VCC a Multi-Assembly Sealed Basket (MSB) is placed. Although the concrete is reinforced, it is not confined within steel layers as with the HI-STORM cask. It is possible that the concrete will sustain damage during the impact and no longer provide protection to the MSB. Therefore, in addition to the hard component and cask-on-cask type impacts that were conducted for the HI-STORM cask, a detailed analysis of the VCC to the pressure load from the jetliner will be required.

As stated in the Safety Analysis Report (SAR) (a portion of this report was provided to SNL my Mahendra Shah) the casks are in arrays of 20 to 200 total casks. From Figure 1.4-1 of the SAR, a typical layout has the casks spaced at 4.6 m (15 ft). The SAR does state that that these spacings are "heavily dependent on the general site layout, access roads, site boundaries and transfer equipment selection." As was found during the HI-STORM study, Unless, specified by the NRC otherwise, SNL will analyze the system with the 4.6 m (15 ft) spacing. Any variation of this spacing could substantially impact the results.

Three options for determining the pressure load and/or exit velocity of the VSC-24 during the jetliner impact are being considered:

1) CTH analysis.

One possible method is for the global analysis to be conducted using CTH in a similar manner to what was finalized for the HI-STORM cask. The possibility of must be examined. The use of CTH would allow the determination of the pressure load that should be applied to the cask in a finite element analysis. The CTH analysis also would be used to determine the cask exit velocity.

Currently two CTH analyses are being considered

These two analyses would provide information on cask exit velocity and pressure loads for two likely impact positions. They would provide guidance on how the exit velocity and pressure load vary with impact location. Ex 2

2) Scaling based on the exit velocity and the force vs. time curve from CTH analysis of HI-STORM Cask.

From the CTH analysis of the jetliner impacting the HI-STORM cask, the velocity as a function of time was determined. This data was differentiated to determine the force applied to the cask by the jetliner:

$$F = d\,(m^* v_x) / dt$$

It is possible that this data could be used to determine a forcing function for the VSC-24 cask. However, this force is developed using the velocity from the HI-STORM cask analysis, which would not be the same for this cask.

3) Calculating cask exit velocity assuming a perfectly plastic collision.

A perfectly plastic collision can be assumed and the exit velocity of the cask can be calculated from the following conservation of momentum equation:

$$m_a v_o = (m_a + m_c) v_f$$

For the analysis in consideration,

m_a = the effective mass of the airplane striking the cask
m_c = the mass of the cask
v_o = the initial velocity of the airplane =
v_f = the exit velocity of the cask

Ex 2

The force applied to the cask would have to be determined from method 1 or 2 above.

Each of these methods has merits and present difficulties. It is not certain which method provides the most accurate measure of exit velocity. Determining exit velocity from CTH provides the most flexibility in understanding how the exit velocity varies with impact location of the jetliner. Method 3 can only provide an exit velocity for a Method 2 might save some calculation costs, but does require some rationalizing for its justification. Ex 2

Determination of the damage of the cask due to the overall pressure of the jetliner impact is difficult. The CTH calculation alone does not have enough resolution with the jetliner and cask to provide an accurate measure of the damage. Decoupling the force, determined from either a CTH calculation on the specific cask or using the force

Ex 2 portions

determined from the HI-STORM analysis, also presents difficulties. The pressure on the cask and the displacement of the cask are coupled events. The force determined as shown in 2) above is an average force on the whole cask. However, when the force is applied in CTH it is not uniform. When the events are decoupled, the force applied to the cask in the finite element analysis will be applied as an average force over an area. This will result in different kinematic behavior of the cask that will make the load applied to the cask incorrect.

The merits of each of these methods are being considered to determine which method will be applied.

After determining the cask exit velocity and the load to apply to the cask, finite element calculations will be conducted to examine cask integrity. The pressure load will be applied to the cask system. The system will also be examined for hard component impacts from the jetliner (the nose landing gear and engine will be used). Cask-on-cask impacts will also be evaluated. The integrity of the MSB during the event will be examined.

The CTH and finite element (PRONTO) calculations will be conducted at SNL.

TN-68

The TN-68 is a steel, lead, steel transportation/storage cask that does not have an internal canister that contains the fuel. If the lid or seal of the lid is breached there can be a release of radioactive material. The typical array of casks as stated in the SAR is 2 by X arrays of cask on 4.9 m (16 ft) cask spacing. Just as with the HI-STORM and VSC-24 casks, the spacing of the casks could be critical. The 4.9 m (16 ft) spacing will be used unless the NRC specifies another.

Since the TN-68 does not have an internal canister to prevent the release of radioactive material when the seal of the lid is breached, a detailed analysis of the lid will have to be conducted. The most likely threat to the integrity of the lid is the Ex 2

However, the pressure load from the jetliner must also be examined. Therefore, just as with the VSC-24 cask discussed above, a global analysis using one or a combination of the any of the three methods presented above for the VSC-24 will be conducted for the TN-68 to determine the pressure load on the cask due to the jetliner impact and the cask exit velocity. The pressure load and exit velocity will be used in detailed finite element analyses to examine the cask integrity. In addition, hard component and cask-on-cask analyses will be performed. These analyses will examine the cask integrity due to nose landing gear impacts, engine impacts, and collisions of casks with other casks or sudden deceleration of the cask due to impacts with the ground (soil, pad, or roadways).

The CTH analyses will be conducted at SNL and the finite element analyses will be performed at ORNL.