**Lawrence Livermore National Laboratory**

**Fission Energy and Systems Safety Program**

SFPO-0001

December 26, 1996
NTFS96-516

Dr. Gordon English
682 Milford Drive
Kingston, Ontario
Canada K7M 6B4

Dear Dr. English:

Last summer during a phone conversation, I provided verbal responses to your questions on the Modal Study Report. Enclosed are the written responses (Attachment 1) to your questions (Attachment 2). I have also provided information regarding criticality safety and basket deformation, which was also mentioned.

As I told you, the IMPASC computer code used in the Modal Study has been superseded by the SCANS code. A copy of SCANS 2a and its user's manual are enclosed. We are finishing version 3a, which will be available next year. We will likely conduct a 2 - 3 day workshop on version 3a after its release and will notify you of the time and the location. We also have 6 volumes of theory manuals on SCANS available at your request.

I plan to attend, with the Nuclear Regulatory Commission, the Association of American Railroads presentation of "Railroad Transport of Spent Nuclear Fuel (A Risk Review) on January 8, 1997 in Washington, DC. I look forward to meeting you and discussing the risks in transporting nuclear spent fuel.

Sincerely,

Larry E Fischer

240007

Larry E. Fischer
Associate Program Leader
Fission Energy and Systems Safety Program

Attachment(s): as stated

| | | |
|---|---|---|
| cc: | C. Haughney | w/o attachments |
| | S. Shankman | w/o attachments |
| | E. Easton | with attachments |
| | M. Holt | with attachments |

m-3-4

NM07

**Attachment 1**

## Responses to Priority Questions for LLNL

A. Your interpretation of Figure 5.1 is correct.

B. Your conclusions based on the interpretation are correct. We suggest that for truck accidents you use Figures 2-3 and 2-4 with Table 5.9 to obtain probabilities and damage state information where the interpretations and conclusions have already been made and tabulated. For rail accidents use Figure 2-5 in conjunction with Table 5.11.

C. Please see response B.

D. Your interpretation is correct.

E. Please see response B.

## Responses to Longer Time Frame Questions for LLNL

Use of data

1. The LLNL study primarily uses the BMCS statistical data base for truck accidents (p. 2-10 and 2-11) and the FRA statistical data base for train accidents (p. 2-28). The Eggers data are for specific severe accidents rather than for a statistical data base. The Eggers data basically showed that most severe accidents are within the loading conditions of the regulatory "hypothetical accident conditions." Four specific particularly severe accidents from the Eggers report were discussed in the Modal Study report (p. 9-15 through 9-19), where it was concluded that even for these extreme events they were appropriately included in the study and the study's results. There are no problems with the Eggers findings. Their findings were used to establish Table 2.1, which tabulates accident loads and loading parameters. The Eggers report was also used to select a high speed beam impacting the cask as being one of the most severe loading conditions (p. E-14), and also crush (p. E-17) Table 26 from the Eggers report was used to establish loading conditions for bounding accident evaluations contained in Appendices E and F.

2. Please see response to question 1.

3. As used in the Modal Study Report, the meanings for certified and licensed casks are the same and were used interchangeably. The cask designs were based on LLNL staff's experience in reviewing casks that had been certified and by using analysis to confirm the certifiably. The cask designs reviewed were the NAC-1, TN 8/9, NAC 10/24 and IF-300.

Validation of the Models Used

1. Mesh convergence studies were performed (p. E-28). They are no longer available because the old computer system (Octopus) no longer exists. The mesh plots are shown for the truck cask in Figures E-11 and E-25 and for the rail cask in Figure E-15. The mesh plots were not shown in the other figures for clarity. DYNA2D and NIKE2D were benchmarked against each other. DYNA was used primarily for dynamic analysis whereas NIKE was used primarily for static analysis.

2. The sensitivities studies and fuel basket representation are discussed on p. E-28.

3. Currently, before a cask is certified, the applicant must demonstrate that the system remains subcritical (k ≤ 0.95) under hypothetical accident conditions, including optimum water intrusion, with fresh fuel in the basket. The basket must be shown not to deform permanently. This approach is very conservative and does not require the applicant to verify burnup credit or analyze all possible deformed configurations. (In addition, recovery of the fuel is easier if the basket is not deformed.) In reality, all spent fuel has a low fissile content (~1.5% compared with ~4%) and numerous fission products that are significant neutron poisons—which is why the fuel is removed from the reactor. Furthermore, fuel assemblies are designed to be slightly undermoderated in a reactor to provide stable operation. Any distortion which moves the rods closer together will further reduce the moderation and hence the reactivity of the fuel assembly. Large distortions of the cask, fuel basket, and fuel rods are not of concern for highly unlikely accident conditions, particularly when it is highly probable that the fuel will have significant burnup and will deform in a manner to reduce reactivity.

4. The sensitivity studies primarily consisted in a series of meetings and discussions amongst LLNL and NRC staff members. It was concluded that it would be extremely difficult to calculate the strain in all components and their failure for all accident conditions; therefore the inner containment shell was selected as a single conservative parameter. The result of this conservative approach is that failure of containment and radioactive releases are significantly over predicted, but doesn't make sure the need to identify the exact location of the impact is eliminated and the exact cause of failure does not have to be identified with a high level of certainty. The strains in the cask were also related to the "g" loads to the cask, fuel and components to assess their capability to resist failure, and this was included in the selection of strain levels for the radiological hazards estimated in Figure 8-7. The lead slump was also estimated and included by analysis to the strain levels.

5. The IMPASC model and code have been replaced with the SCANS code, which has been extensively benchmarked with NIKE and limited test data.

Attachment 2



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**TranSys Research Ltd.**
Transportation Systems Specialists

# FAX TRANSMITTAL

| | |
|---|---|
| Attention: | Earl Easton |
| Title: | Section Leader - Transportation Safety |
| Company: | NRC |
| Date: | 02/05/96 |
| cc: | Bob Fronczak, AAR |
| From: | Gordon English phone: 613 389 5632 Fax: 613 389 5499 |
| Subject: | Spent Fuel Transport by Rail 6 Pages (including this cover page) |

This is further to your discussions with Bob Fronczak at the AAR and relates to our review of their recommended practices for the transport of spent nuclear fuel.

We have a number of questions about the NRC licensing test procedures and about the NRC sponsored report **Shipping Container Response to Severe Highway and Railway Accident Conditions** by Lawrence Livermore National Laboratory (LLNL). Some questions may be addressed by anyone knowledgeable of cask testing and design; while LLNL may have to clarify others.

We have identified a subset of questions that we believe are fairly straight forward and can be answered (or discussed) quite quickly. In general, this subset of questions asks for clarification of NRC test methods (item I) and confirmation from LLNL of the content of two of their Figures (item II).

The other questions (item III) may require LLNL to review their files from the time of the study. We would like answers to as many of these as can be addressed in a short time frame; but where answers are not available, we can discuss the general implications for our report and whether distribution of the draft should be delayed until further details are available.

If you require any clarification of the questions, please do not hesitate to contact me.

Regards,
[signature]

## I. Regulation Interpretation and Test Conditions

**(all questions in this category are priority ones)**

1. Are there any design directives or licensing tests conducted with respect to end-cap style impact limiters?

2. More specifically, is there a known force magnitude below which impact limiters will not become dislodged: a) if exerted in tension; and b) if exerted in lateral shear? If so please provide details; if not, could design details, illustrations or technical descriptions be provided on typical methods of attachment of end-cap style impact limiter used on licensed casks.

3. Where end cap style impact limiters limiters are employed in a cask design, does NRC require any tests to be conducted on the cask without the impact limiters attached? If so please describe them.

4. The pin drop test calls for the pin to be long enough to cause maximum damage. Could you provide a test description and test results for this test when conducted on a cask similar to LLNL's candidate rail cask (i.e. with end cap impact limiters of at least 40" end depth and 20" side depth)?

5. Is buckling of the pin interpreted as a "pass"; and if so, is there any limitation posed on either the depth of an impact limiter, or the test configuration such that the pin length is constrained to a certain buckling threshold.? Please provide details of relevant past tests.

6. Does NRC know how the pin drop test would scale up to other bodies; particularly for larger: areas, strengths, and impact energies? If so please provide details?

7. Similarly, has NRC (or others) ever scaled the energy absorption capacity of the impact limiters from flat surfaces to varying degrees of non-flat surfaces? If so please provide details.

8. Drop test number 3 (dynamic crush) is not applicable to rail transport casks. It is included for smaller casks on the rationale they are shipped in multiple quantities and with other packages and are susceptible to impacts from these bodies. We believe that in train derailments a rail car is also very susceptible to pile ups and/or constrained impacts by other vehicles in the train. This type of loading is more prevalent with North American trains than with European trains. Has the NRC ever investigated the costs/benefits of including a scaled up version of drop test # 3 for rail casks? If so please provide the details.

## II. Priority Questions for LLNL (Interpretation of Figures 5.1 and 4.1)

We have data interpretation questions related to Figure 5.1 of LLNL's report. There is quite a bit of information presented in the cask orientation curves drawn there. Others have made a different interpretation of the data than we have and we would like to have our logic reviewed. We would like to have LLNL either confirm that our interpretation of the Figure is correct or provide the proper interpretation. We have provided a copy of the original figures for easy reference.

A. Please indicate whether the following interpretation of the Figure content is correct:

1. The solid curves present a fit of data points such that each solid line locates a conservative estimate of the strain levels experienced for the specified cask orientation under a range of impact speeds.
2. The dashed lines are there simply to highlight the speeds associated with the two identified strain thresholds (i.e. .02% and 2.0%).
3. Impact velocity refers to the cask's speed-vector component that is perpendicular to the impacted surface.

B. Using this interpretation, please confirm that a 0.2% strain level is achieved at (roughly):

31 mph impact speed for a cask with a 0° (side) orientation;
34 mph impact speed if at a 45° orientation; and;
38 mph impact speed if at a 90° (end) orientation.

Similarly, a 2.0% strain threshold, is reached at:

52 mph impact speed for a cask with a 0° (side) orientation;
49 mph impact speed if at a 45° orientation; and;
47 mph impact speed if at a 90° (end) orientation.

C. Further, if one wished to determine the speed magnitude necessary to reach the 2% strain threshold for a cask at 90 degree orientation, impacting the unyielding surface with a velocity vector angle of 45°, one would select the 47 mph impact speed from the plot and divide by .707 (sin 45°) to derive the cask speed = 66.5 mph.

D. There was a third threshold level used in the study (30% strain). Please confirm that the Figure offers no basis to estimate the impact speeds necessary to reach that threshold for casks at 45° and 0° orientations; other than that the speeds would be unreasonably high ones.

E. If one wished to estimate the influence of surface hardness, one could use Figure 4.2. Please confirm our interpretation of this Figure indicating that: going from an unyielding to medium surface hardness leads to a 1.8 (~ 82 / 45 mph) increase in impact speed to attain the S2 response level (i.e. 0.02 strain). Thus, the impact described in III above would have to occur at 1.8 * 47 = 85 mph which in turn is associated with a cask speed of 84.6 / sin45 = 120 mph.

## III. Longer Time Frame Questions for LLNL

### Use of data

1. The LLNL study references a report by Eggers as one of its data sources but appears to use very little of the information presented in it. There is no documentation concerning the use and non-use of data from the Eggers study (NUREG/CR 3499). Are there known problems with the Eggers findings?; or have other studies assessed the types of loads and related severity data derived by Eggers?
2. It is not clear how loading scenarios were derived from the reviews of accident reports (in either the Eggers study or the LLNL study). Could someone explain what specific criteria were applied in reviewing the accident reports to draw conclusions about the types of load that particular cars had experienced in the course of the accident.
3. On page 3-23 of NUREG/CR-4829 Vol. 1 it is indicated that the representative cask design is based on currently licensed cask designs which are not yet certified. Could you please define the meanings of, and differences between, a licensed and a certified cask for transporting radioactive waste in the U.S.? Also, could you please identify these casks and provide information regarding their design and any analyses and testing which they have undergone. (Note: The specific questions presented previously under "NRC testing" could idealy be answered with respect to these casks).

### Validation of the models used

1. Were mesh convergence studies undertaken in the finite element analyses; and are they available? Related to this, only the component outlines (not meshes) are plotted for the side impact DYNA2D/NIKE2D calculations (Figs E-21,22). Can we see the mesh plots for these models. Also, the authors are not clear as to which analyses were based on NIKE and which on DYNA — can this be clarified?
2. Can we get details of the sensitivity analyses performed to evaluate the influence of including a fuel baskets representation on the response of the representative cask model?
3. Given the large amount of deformation (ovaling) predicted for side impact (e.g. Fig E-22), one would expect considerable damage to fuel rod / support basket assemblies and the potential for fuel rods to be pushed together. Similarly for the end impacts (as stated in the report), the rods are expected to buckle, which could lead to large lateral displacements. Could these conditions affect the sub-criticality assumptions? Is there a clear definition of what degree of fuel rod deformation leads to susceptibility to criticality?
4. The discussion on pp. 4-3 of NUREG/CR-4829 Vol. 1 talks about variations in strain in shells, bolts and enclosures and implies that sensitivity studies were conducted which determined the "relationship between strains at different locations or on different components inside the cask". Can we get the details of these sensitivity analyses?
5. A one dimensional beam model (IMPASC) was used for much of the rail cask analysis. Neither the model or its validation were well documented. Could we get background information on both the model and its validation within the scope of the study.

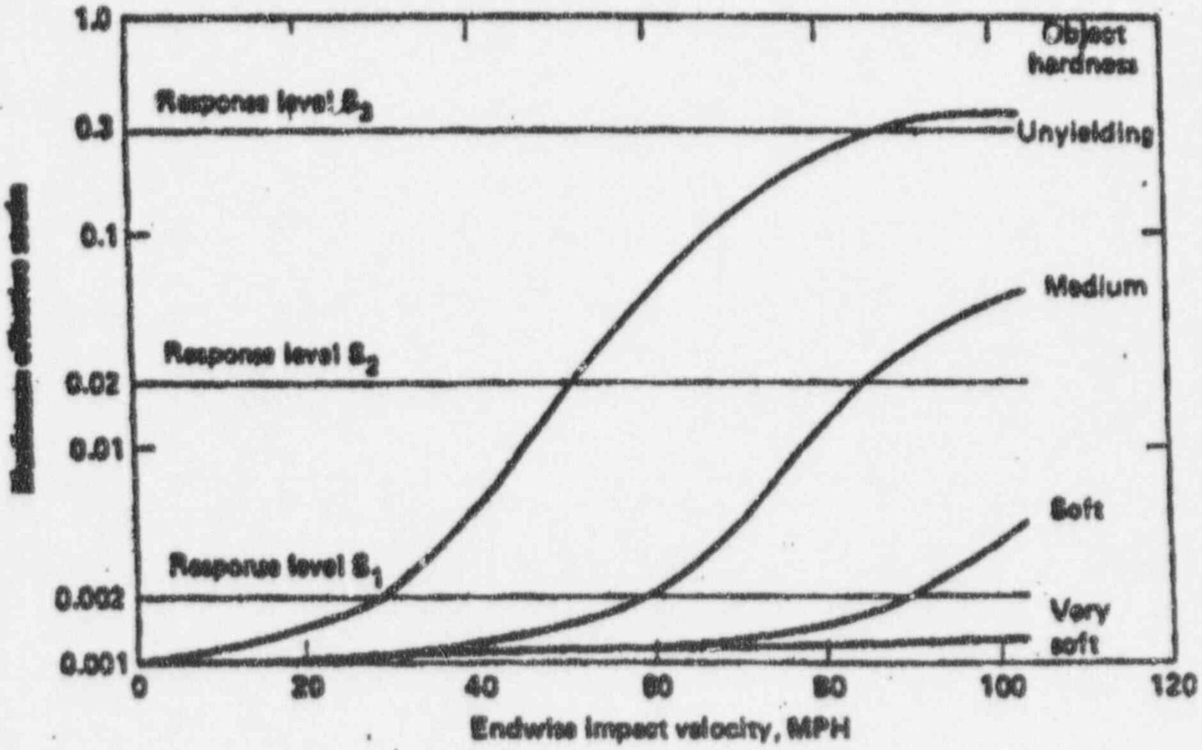


Figure 4-2 Schematic representation of cask structural response for various surface hardness and impact velocities.



P.5

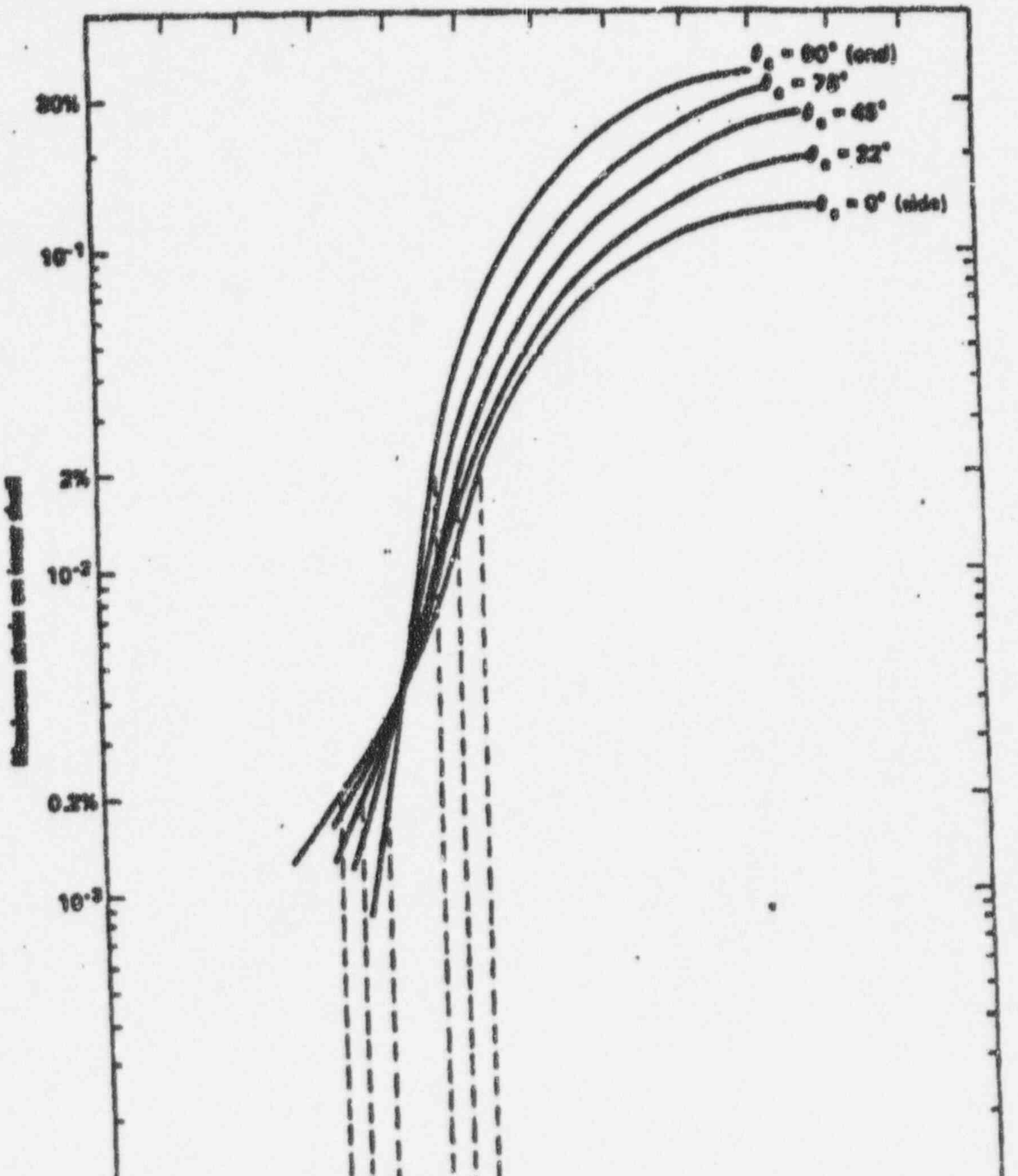


Figure 5-1 Effect of cask orientation on the strain-impact velocit relationship for a truck cask impacting an unyieldin object.

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# FAX TRANSMITTAL

Attention: Larry Fischer
Company: LLNL (510 424 6889)
Date: 04/25/96

From: Gordon English phone: 613 389 5632 Fax: 613 389 5499

Subject: Modal Study Report 1 Pages (including this cover page)

This is being sent to give you our address for the information package on "SCANS" model that is the outgrowth of IMPASC.

Further to our conversation this morning I wanted to make sure I properly interpreted the criticality issue and the discussion around our question 3 under 'Validation'. Our original impression was that deformation of the fuel basket was a concern because it could lead to concentration of the fuel pellets. This was derived from the first paragraph on page 1-5 of your report which states that the "criticality requirement is typically met by demonstrating that essentially no deformation occurs to the basket, the structure within the cask which holds the spent fuel." The deformations illustrated in Figure E-22 would appear to not meet such a criterion. From our conversation this morning I understood you to say that concentration of the fuel pellets is not a concern; that in fact they are in the most susceptible state as packaged and any concentration actually lowers the risk of criticality.

This raises the question of why deformation of the fuel basket is the criterion typically used to demonstrate avoidance of this hazard. Could you please add to the other items you will be following up on a brief explanation of:

the relationship between basket deformation and criticality, and (if not self evident from that explanation);

why the deformations of Figure E-22 do not pose a criticality concern.

Thanks, and best regards