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MEMORANDUM FOR: The Files

FROM: R. C. Shieh, Transportation Branch, FCMS, NMSS

SUBJECT: STRUCTURAL REVIEW OF TN-12 CASK DESIGN

By the letter of February 4, 1980, Transnuclear, Inc. withdrew the license application of the TN-12 cask design due to its inability to demonstrate that the cask design is adequate against nonductile fracture; use of the existing fracture toughness design criteria (e.g., ASME Code III-Class 2 component rules) for nuclear components shows that the design cannot meet the criteria by a wide margin. The present memo briefly summarizes the initial structural review of the cask design and subsequent reviews of TN-12 fracture-safe design analyses/proposals.

The initial review of the TN-12 cask design was completed in the mid-August of 1978. The material used in this review was the applicant's initial safety analysis report submitted with the applicant's letter of March 22, 1978. The comments arising from this review are those contained in the enclosure of NRC to Transnuclear letter of September 7, 1978.

The review time used, except for that spent in resolving the fracture toughness design issue, was well within the initial estimated time. Also, the review could have been completed earlier had it not been inhibited by the following factors:

1. The design represents a new type of cask design, i.e., first of its kind for all steel, heavy, thick (12 inches) section cask design.

2. First time use of relatively unfamilar design criteria and standards contained in the Subsection NE of the ASME Boiler and Pressure Vessel Code, Section III for Class MC Nuclear Power Plant components.

3. Use of metric (SI) units.

4. Lack of adequate design standards against nonductile fracture failure.

5. Interruption caused by reviewing the DOE's Division of Naval Reactors' S2W cask design.

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On October 5, 1978, a meeting was held between NRC and the applicant. During the meeting the comments contained in the aforementioned NRC letter were discussed. In particular, the following points, in conjunction with the comments on fastener design and impact stress analysis, were emphasized:

1. Fastener Design--Due to major differences in loading conditions between Class MC components and shipping casks, i.e., the latter are subjected to severe overall impact loading while the former are not, the appropriate cask design standards on the containment vessel fasteners (bolts and weldments) to be used should consider those contained in the Subsection NB of ASME Boiler and Pressure Vessel Code III for Class 1 components.

2. Fractures-Safe Design

   a. Impact stress evaluations should include the case at low service temperature environments in order to demonstrate that the cask design is adequate against nonductile fracture failure; nonductile fracture is a realistic and severe failure mode/safety problem for carbon steel casks under the regulatory hypothetical accident drop landings.

   b. Application of the Class MC component fracture toughness design rules of the ASME Code III to spent fuel shipping cask design is, in general, not justifiable because among others, the loading condition between shipping casks and MC components is fundamentally different as commented above. Furthermore, the TN-12 vessel wall is much thicker than that of the MC component vessels. A thicker section, for a given stress condition, has a lower fracture resistance capability than that of a thinner one.

   c. In view of lacking of appropriate fracture-safe design criteria for shipping casks, the pertinent design criteria for Class 1 components of the ASME Boiler and Pressure Vessel Code, Section III may be used in TN-12 fracture-safe design evaluation.

3. The impact stress analysis should consider transient dynamic response effects.

Appropriateness of these comments, as was expected, was supported by Dr. W. F. Anderson, Chief; Structures and Components Standards Branch (SCSB), and his staff in the subsequent meetings (8 in all), which were held primarily to resolve the fracture toughness problem of TN-12 (see Enclosures 1-8).

In the first few meetings, the applicant attempted to demonstrate that TN-12 design was adequate against fracture failure on the basis of the ASME Code III, Appendix G fracture-safe design procedure. After it became apparent that TN-12 cask could not meet the Appendix G design criteria, applicant's effort shifted to that of using a somewhat improved version of the Class MC component code rules for fracture toughness, which was to be supplemented by a 1/3-scale model toughness demonstration test. Due to drastic differences in shell thickness and type and severity of loading conditions between the Class MC components and TN-12, use of the slightly improved version of MC component rules in TN-12 fracture toughness design could not be justified. Furthermore, the technical basis for scale model testing techniques involving fracture has not been sufficiently developed to permit the model testing techniques to be used as a fracture-safe design acceptance/demonstration procedure. This is particularly true for the TN-12 case, in which complex geometry, dynamic loading and inelastic deformation are involved in the trunnion area. This is why scale model testing techniques have not been accepted by engineering communities or included in the ASME Boiler and Pressure Vessel Code as a technically sound procedure for demonstrating fracture-safe design of carbon steel structures.

As a result of the applicant's inability to demonstrate that the TN-12 cask design is adequate against nonductile fracture failure, and the existing technically sound fracture toughness design criteria for nuclear components show gross inadequacy of the TN-12 design, the applicant by the letter of February 4, 1980, finally withdrew his application for the certificate of compliance for TN-12 cask design (see Enclosure A1).

From these meetings, the following positions have emerged among the technical staffs of NRC FCTC and SCS Branches and/or NRC consultants:

1. It is unquestionable that, as identified in the initial review of TN-12 cask design, nonductile fracture is a realistic failure mode for TN-12 cask design and also is a potential safety problem for carbon steel cask designs.

2. Cask fracture-safe design criteria should be at least as stringent as those of the Class 2 components of ASME Code III; however, meeting the latter criteria needs not assure fracture-safe design of shipping casks. It is questionable that the fracture toughness rules specified in subsection NE (for MC components) of ASME Code III can be applied to shipping cask designs.

3. The technical basis for use of scale model testing techniques in demonstrating the adequacy of a shipping cask or other structures against nonductile fracture failure has not been sufficiently developed; as such, scale model testing techniques should not be used as an independent acceptance procedure for fracture-safe design of shipping casks.

The question of validity of using the scale model testing techniques in demonstrating adequacy of fracture-safe design of shipping casks was raised by myself in the meetings of January 10, February 23, and March 20, 1979 (see Enclosure 2-4). This was evident from nonexistance of fracture-safe design acceptance criteria in the ASME code or other existing structural design codes based on the model testing techniques, or of well-developed, experimentally verified fracture scaling laws. This opinion had been strongly supported by the SCSB staff during these and subsequent meetings.

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The SCSB staff provided expert opinions and detailed information on this and other fracture-related matters. A similar opinion was expressed by virtually all knowledgeable persons, including certain internationally recognized, authoritative experts in my off-record telephone conversations with these people.

The above viewpoint was strongly reiterated by me during the meeting of August 31, 1979, (see Enclosure 5), in which it was also mentioned that if the proposed 1/3-scale model testing technique in the Transnuclear letter of April 6, 1979 is to be accepted, in view of many uncertainties, the validity of the technique must be verified through a series of scale model tests. Following this meeting, Transnuclear, Inc. proposes another set of fracture toughness design/demonstration cirteria, which is a slightly improved version of the preceding one, for NRC review.

Questionable validity and/or shortcomings of the proposed criteria were expressed/pointed out by W. F. Anderson of SD, C. Z. Serpan of RES, and G. D. Whitman of ORNL in their memos of November 29, December 3 and December 3, 1979, respectively (see Enclosures B1-B3). In addition, during the meeting of January 15, 1980, the following serious problem areas in the use of the proposed scale model fracture demonstration testing technique were again pointed out by me:

1. Inadequacy of using the static, linear elastic stress intensity factor in determining the model crack size in modeling the nonlinear (inelastic), dynamic fracturing problem of TN-12 in the trunnion area.

2. Questionable validity of the proposed model testing technique in simulating the prototype cask crack propagation fracturing problem.

In conclusion, the applicant's proposed scale model testing technique for fracture-scale demonstrations were not even close to the acceptable one.

Correspondence from Transnuclear, Inc., NRC internal memos and correspondence from NRC consultants are enclosed herewith as Enclosures A1-A5, B1-B8 and C1-C3, respectively.

/s/

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