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MEMORANDUM FOR: The Files

FROM: D. J. Guzy, Transportation Branch, FCMS

SUBJECT: MEETING ON THE TN-12 BRITTLE FRACTURE CRITERIA HELD NOVEMBER 30, 1978

The proposed design of the TN-12 spent fuel cask uses welded forgings of A508 Class 1 steel with radial thicknesses of up to 12 inches. These large thickness are required for radiation shielding. Brittle fracture is a realistic failure mode when the impact of the 30 foot drop test at -20°F (the minimum environmental temperature specified by R.G. 7.8) is considered. The use of thick sectioned carbon steel is new for spent fuel cask design and there is not currently a definitive position on fracture criteria for FCTR license review. A meeting to discuss this problem was held on November 30, 1978 and was attended by R. H. Odegaarden, R. C. Shieh, C. R. Chappell, R. G. Clary, J. O Mayor and myself of FCTR and W. F. Anderson of SCSB. C. E. MacDonald of FCTR and P. N. Randall of SCSB attended parts of the meeting.

The discussion dealt primarily with existing brittle fracture standards and their appropriateness to fuel cask design. ASME Nuclear Class 1 and MC components requirements were considered along with the Navy's requirements for submarine hulls.

In a previous discussion with Rong Shieh and myself, Neil Randall noted that the ASME Code pertains mainly to pressure vessels and that it would be useful to look at fracture criteria developed for components where the loading is primarily dynamic. Neil contacted Jim Goode of NRL and found that the Navy's requirements for submarine hull materials was a minimum of 50 ft-lbs absorbed energy for a Charpy-V notch test (with specimen longitudinal in plate) at -120°F or an absorbed energy of 400 ft-lbs for a dynamic tear test (per ASTM E604-77, specimen transverse to plate rolling direction) at 0°F. The minimum service temperature for submarines was thought to be about 0°F and hull thickness ranged up to 5 or 6 inches. The steel used in submarine hulls is HY-80 which is similar to A543 Class 1 and has a slightly higher nickel alloy content

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(and thus more toughness) than A508 Class 1. The requirements given above were discussed during the November 30th meeting and it was concluded that this approach would put the material toughness at the upper shelf of the fracture toughness diagram and thus avoid low energy fracture. While adjustments may be needed to account for the differences in thickness and materials between the TN-12 and submarine hulls, the group seemed to feel that NRL's values for absorbed energy and temperature differential would have sufficient conservatism for our use.

Treatment of spent fuel cask containment vessels as Class 1 nuclear components has generally been considered acceptable by FCTR and thus the fracture criteria of Subsection NB of Section III of the Code was discussed at the meeting. This criteria requires fracture mechanics analyses which begin by assuming a given crack size and then use a sophisticated stress analysis to determine a maximum stress intensity factor. The value of this is then compared with the Code's value of K_{IR}. K_{IR} is a function of the lowest service temperature and a reference temperature, RT_{NDT}, which is set by drop weight and Charpy-V notch testing. It was emphasized at the meeting that this approach is valid only for brittle behavior where linear fracture mechanics applies. Also, implicit in the use of this method was that the component meet other Class 1 requirements for materials, fabrication, and inspection. It was also emphasized that it would be hard to predict the cask's structural response to impact loading with enough accuracy to perform an adequate fracture analysis. Some rough evaluation were made at the meeting using the impact test results of finless TN-12 scale models. It was estimated that some parts of the TN-12, particularly around the trunnions, would experience high local stresses during impact and thus invalidate linear elastic fracture mechanics. Also, it was felt that for A508 Class 1 steel at -20°F and with stresses near yield, the allowable cracks would be a fraction of an inch and it would be difficult to meet Class 1 inspection requirements. The feeling of the group seemed to be that the use of Class 1 fracture criteria would be acceptable for fuel casks, but a "materials approach" criteria such as the Navy's would be far simpler and thus favorable.

Transnuclear, Inc. has used ASME Class MC (metallic containment vessel) fracture criteria in their proposal. This uses a "materials approach" but the values involved are significantly less than those given by NRL. Although class MC components must withstand faulted (accident) conditions, the loading would be primarily static pressure loads. Earthquake dynamic loads would be far less than the "g" loads produced in fuel cask impact. Metallic containment vessels are usually less than 2-1/2" in thickness.[1] The group felt that because of these differences, Class MC fracture criteria is unacceptable for spent fuel cask review.

It was stated at the meeting that the A508 Class 1 steel proposed for use in the TN-12 would have a nil ductility temperature (NDT) of somewhere between -40°F and +40°F. Rough evaluations using the upper limit indicated that this material would probably be determined to be unacceptable.

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[1]In conversations with Bill Anderson and Neil Randall subsequent to this meeting, I have learned that the current fracture requirements for ASME Class 2 components increase the allowable temperature difference between the NDT and lowest service temperature for thicknesses greater than 2-1/2". For a 12" thickness, the allowable temperature difference is about 90°F. Early versions of the ASME Code considered metallic containment vessels to be Class 2 components.