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September 11, 1979

Mr. Charles E. MacDonald, Chief
Transportation Branch
Division of Fuel Cycle and Material Safety
Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: Docket No. 71-9120
Fracture Toughness for TN-12 Steels

REFERENCE: Transnuclear Letter, Kurt Goldmann to Charles E. MacDonald, NRC. E-1598, dated April 6, 1979.

Dear Mr. MacDonald:

This letter is to revise and supplement the approach contained in the referenced letter for demonstrating the suitability of TN-12 containment vessel steels from a fracture toughness point of view.

1. Material Acceptance Criteria

The containment vessel of the TN-12 is basically a cylinder made of 12 inch thick ferritic steel forgings. The material should have sufficient fracture toughness to preclude brittle failure at low temperature.

During normal conditions of transport at low ambient temperatures, stresses in the containment vessel are low and brittle failure is not likely. The hypothetical accident condition which is considered to be the most adverse for brittle failure is a free drop or puncture of an empty cask at -20F. Material acceptance criteria must be selected to assure that under these conditions the material has sufficient fracture toughness to prevent brittle failure. In particular, during the impact a crack should not propagate through the thickness of the containment vessel and thereby violate the containment function of the vessel.

In the absence of specific regulations or industry standards on fracture toughness criteria for spent fuel shipping casks, Transnuclear, Inc. proposes the following acceptance criteria

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for fracture toughness of the material for the TN-12 containment vessel:

a. Charpy V-notch test: $C_V \geq$ 20 ft-lb at -50F. (ASME B&PV Code Section III, Class MC)

b. Charpy V-notch test: $C_V \geq$ 50 ft-lb and LE $\geq$ 35 mil at the lowest service temperature of -20F. (ASME B&PV Code, Section III, Class 1).

c. Drop weight test: NDT $\leq$ -40F (ASTM E 208).

d. Acceptable flaw size:

Interior: $\leq$ 1/4 in. round (UT)
Surface: $\not<$ 1/4 in. (PT or MT)

e. Maximum crack growth: $\leq$ 0.1 in.

f. Assumed undetected surface flaw size:

Within 15 in. of trunnion centerline: 1/2 in. x 3 in. semi-elliptical.
All other locations: 1 in. x 6 in. semi-elliptical

Criterion (a) is taken from ASME Code, Section III, Class MC. The rules for Class MC components have been developed for vessels whose function is to contain radioactive materials in case of an accident and which normally operate at a pressure which is less than atmospheric pressure. The TN-12 serves a similar function and its cavity is also under negative pressure during normal transport. In the absence of high pressure, there is no large strain energy stored in the vessel material or in the internal fluid to assist the propagation of a crack through the vessel wall.

For the TN-12 there will also be no extensive residual stresses which could act as crack drivers since the vessel will be stress relieved. In the further absence of thermal stresses under the postulated accident conditions, the propagation of a flaw would be driven only by the transient forces generated by the impact. These forces are applied only during a period of approximately 30 msec.

Criterion (b) has been selected to assure a material toughness as measured by Charpy impact energy absorbing capability and ductility (lateral expansion), which is the same as required for ASME, Section III Class 1 components.

The rules of Class MC do not require drop weight NDT determinations if Charpy V-notch test requirements (a) are met. Nevertheless, criterion (c) is proposed to assure that the material drop weight NDT is lower than the lowest service temperature (LST) of -20F.

Criterion (d) is proposed to assure that there are no flaws larger than specified at the end of fabrication. Standard ASME Code, Section V, Ultrasonic Testing (UT), Dye Penetrant Testing (PT) or Magnetic Particle Testing (MT) methods will be utilized for these non-destructive examinations.

No significant crack growth is expected during the life of the TN-12, because of the low stress levels during normal operations. Transnuclear will perform a linear elastic fracture mechanics, fatigue analysis for normal operating conditions to confirm that the crack growth will be less than 0.1 in. during the lifetime of the cask, as stated in criterion (e).

It is proposed to demonstrate the acceptability of criteria (a) through (d) by model tests, as described below. For conservatism, it will be assumed for the model tests, that flaw sizes as given in (f) will go undetected during fabrication of the TN-12. The conservatism lies in three areas: (1) The assumed flaw sizes are much larger than detectable, (2) surface flaws are more critical than interior flaws and (3) the flaw location and orientation in the model will be selected to be in the areas of highest stress under the most severe hypothetical accident conditions.

2. Toughness Demonstration Tests

Drop tests with a 1/3 scale model have been used to demonstrate that the TN-12 will meet the requirements for free drop and puncture hypothetical accident conditions of 10 CFR 71. A combined total of ten tests have been performed at normal ambient temperature.

Without refurbishing, this same model was recently subjected to another free drop from a 30 ft. height and two puncture tests from 40 in. heights while the model was at a temperature of approximately -40F. No evidence of brittle failure was noted from visual observations and dye penetrant, ultrasonic, and leakage examinations after the tests.

As a further demonstration that the materials criteria of (1) above are acceptable, it is proposed to perform additional drop tests with the same 1/3 scale model at a temperature of -40F ± 10F as follows:

a) Free drop through a distance of 30 ft. on an essentially unyielding surface with the model impacting in a horizontal position on two welded trunnions. The trunnions will be refurbished prior to this test.

b) A free drop through a distance of 40 in. onto a 2 in. diameter mild steel bar mounted on an essentially unyielding surface, with the model in a horizontal position and an impact area adjacent to the front trunnion located above the center of the bar.

Prior to actual testing an evaluation will be performed to assure that the model orientations and points of impact selected above are the most severe for brittle failure of the model containment vessel.

Surface flaws will be introduced into the model prior to the tests at the most critical locations. The locations and orientation of the flaws will be based on the results of a stress analysis using a three dimensional finite element computer program. The dynamic loads will be applied statically to the model to obtain stress distributions, particularly at the attachment of the front trunnion to the shell.

Another analysis will be made to show that the crack depths selected for the model are properly scaled to produce stress intensity factors equivalent to the stress intensity factors for the reference flaws in the prototype. This analysis will be based on the approach of the Welding Research Council Bulletin No. 175, Appendix 3. The nominal stresses used in this analysis will be those obtained from the three dimensional computer analysis of the model.

The flaws in the model will be prepared by utilizing a procedure described in ASTM E 604, Standard Test Method for Dynamic Tear Energy of Metallic Materials. This procedure consists of machining a notch into the material followed by pressing a knife into the notch to sharpen its tip. The radius of the notch tip of the model flaws shall be less than 0.003 in.

Visual observations, photographs, dye penetrant, ultrasonic and crack depth examinations and leakage tests prior to and after the tests shall be utilized to confirm the absence of brittle failure. The acceptance criteria for a successful test are as follows:

a) The leakage rate shall be below an acceptable specified value to be established prior to the tests.

b) The final crack depth is less than 3/4 thickness or alternately the model will be dropped a second time from 30 ft. at the worst orientation with no leakage.

Charpy V-notch and NDT drop weight tests shall be performed to confirm the expectation that the low temperature fracture toughness properties of the model material (at the same temperatures as for the prototype) are no better than the criteria established in la, b, and c above. In addition it shall be established that the yield stress of the model trunnion material is higher than the prototype trunnion material yield stress.

We would appreciate receiving an early reply as to whether the basic approach outlined in this letter is acceptable to you. If it is acceptable, we shall submit for your review and comment our stress analyses in support of the selection of the flaw location and orientation prior to introducing the flaws into the model.

Please contact us, if you have any questions.

Very truly yours,

Kurt Goldmann

Kurt Goldmann
Chief Engineer

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