Entergy

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F. G. Burford
Acting Director
Nuclear Safety & Licensing

RBG-46495

November 15, 2005

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: River Bend Station
Docket Nos. 50-458 and 72-49
License No. NPF-47
Supplement to Revised License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations"

Reference:

1. License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations," dated March 8, 2005
2. Supplement to License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations," dated April 19, 2005
3. Supplement to License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations," dated July 12, 2005
4. Revised License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations," dated September 21, 2005
5. Supplement to License Amendment Request (LAR) 2004-26, "Use of the Fuel Building Cask Handling Crane for Dry Spent Fuel Cask Loading Operations," dated November 14, 2005

Dear Sir or Madam:

In Reference 1, Entergy Operations Incorporated (Entergy) requested an operating license amendment for River Bend Station (RBS). The proposed license amendment requested approval for the use of the Fuel Building Cask Handling Crane (FBCHC) for dry spent fuel cask handling operations. Specifically, consistent with the requirements of 10 CFR 50.59 and the guidance in NUREG-0612 and Bulletin 96-02, Entergy had determined that certain heavy load drop events required NRC review and approval prior to implementing dry storage cask operations at RBS. The original request was also supplemented in References 2, 3, 4, and 5. This submittal contains additional information as requested by the NRC Staff.

NMSS01
A001

Add: B. Vaidya

Attachment 1 contains responses to comments from two teleconferences on October 7 and November 14, 2005. Attachment 2 contains information requested on the teleconference of November 14, 2005 to clarify the discussion of the true stress-strain curve provided in response to item 3.1 of Attachment 4 to Reference 4. Although the pages of Attachment 2 are marked proprietary, the proprietary information was in attachments to that paper which are not relevant to RBS and have not been included.

The proposed amendment was evaluated in accordance with 10 CFR 50.90(a)(1) using criteria in 10 CFR 50.92(c) and it was determined to involve no significant hazards considerations. The bases for these determinations are included in the Reference 1. The No Significant Hazards Considerations are not affected by the responses to the RAIs.

Entergy requests approval of the proposed amendment as soon as practicable but no later than December 1, 2005 to allow loading casks this year. Entergy is requesting this date due to the impact on preparation activities for our refueling equipment to support our scheduled outage in April, 2006. Additionally, numerous ancillary components used for Dry Fuel Storage activities are shared with Grand Gulf Nuclear Station. These components are required to be at Grand Gulf early in 2006 to support their required demonstrations prior to cask loading later in 2006. River Bend Station is required to implement Dry Fuel Storage in order to maintain full core offload capability. Once approved, the amendment will be implemented prior to using the FBCHC for the loading of dry spent fuel casks.

If you have any questions or require additional information, please contact Mr. Bill Brice at 601-368-5076.

No new commitments are included in this response.

I declare under penalty of perjury that the foregoing is true and correct. Executed on November 15, 2005

Sincerely,

FGB/WBB/baa
Attachments: 1. Response to Additional RAIs for LAR 2004-26
2. Holtec International Position Paper DS-307

cc: (See Next Page)

cc: U.S. Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 400
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Attn: Mr. N. Kalyanam
Attn: Mr. B. Vaidya
MS O-7D1
Washington, DC 20555-0001

LA Dept. of Environmental Quality
Office of Environmental Compliance
Emergency and Radiological Services Div.
P. O. Box 4312
Baton Rouge, LA 70821-4312

Attachment 1

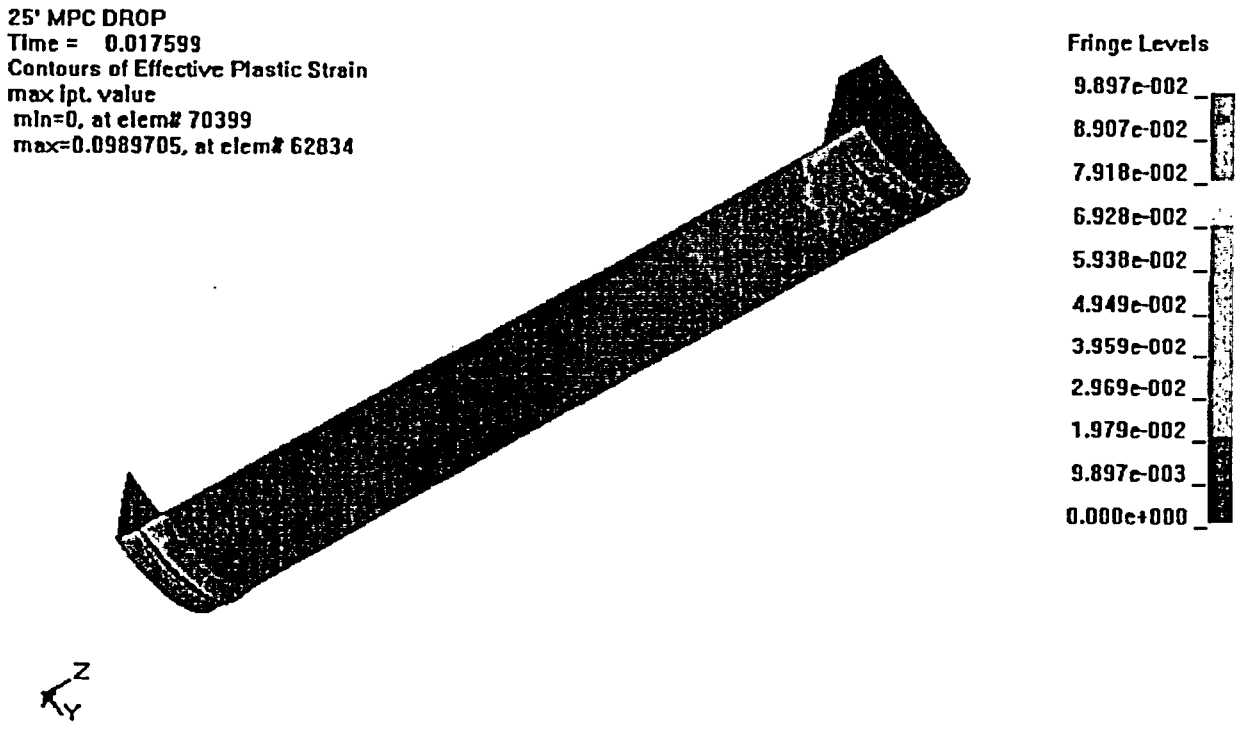
RBG-46495

Response to Additional RAIs for LAR 2004-26

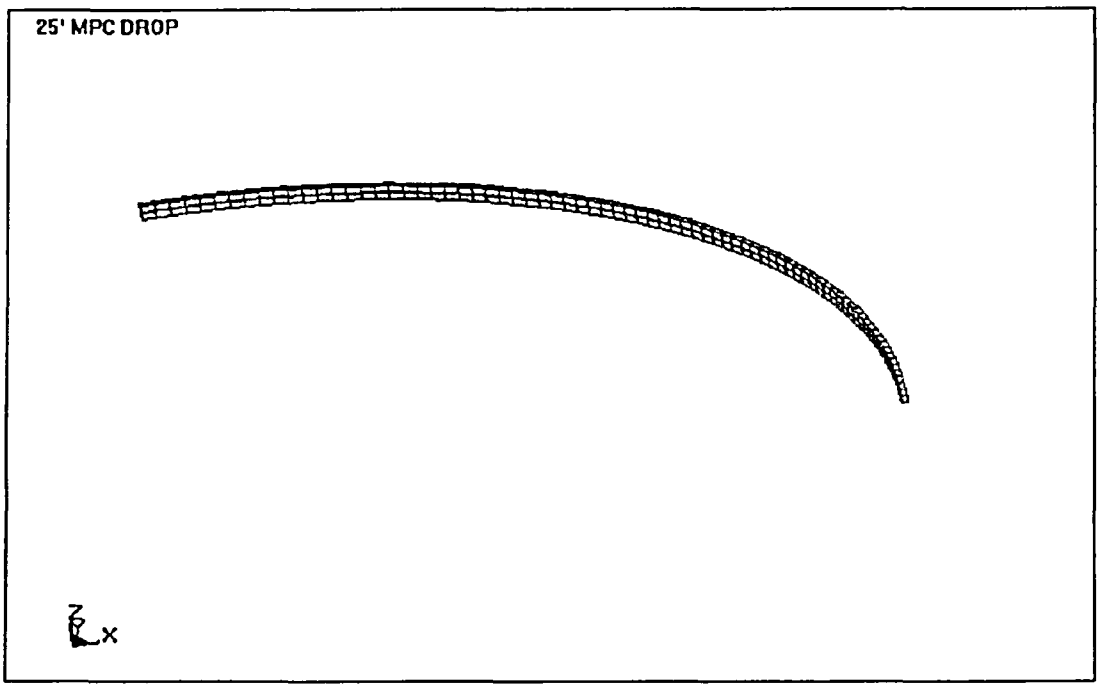
Response to Spent Fuel Project Office Comments as Discussed in Teleconference of October 7, 2005 and Teleconference of November 14, 2005

Correction to response to question 2.1

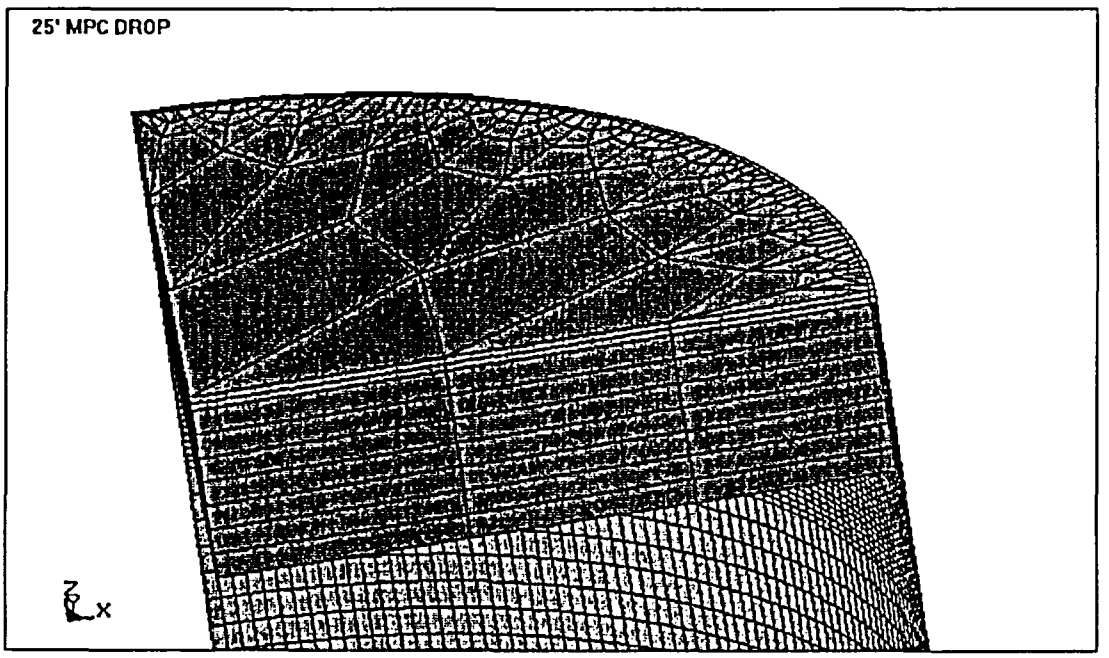
In the HI-TRAC drop analysis, the MPC lid-to-shell weld joint was modeled by using the LS-DYNA command "*CONSTRAINED_SPOTWELD" at 26 locations around the circumferential weld line of the quarter MPC model with full consideration of the 1/16" gap between the lid and the shell body (a constrained spot weld every 2"). Since the ½" thick MPC shell was modeled with shell elements, each pair of constrained shell/lid nodes that represent the local weld connection are distanced at 0.3125" radially, which is the sum of the lid-to-shell radial gap (1/16") and one half of the shell thickness (1/4"). The following figure shows the weld connection of the LS-DYNA MPC model. The figure shows the top view of the MPC lid (modeled using solid elements), and an end view of the shell (modeled using thin shell elements). It should be pointed out that the HI-STORM FSAR has demonstrated that the MPC lid-to-shell weld joint will not fail as long as the design basis deceleration is not exceeded, which is true for the analyzed 3.5" drop event.



Contours of Effective Plastic Strain



MPC lid-to-shell weld model



Model showing the MPC lid, shell and connecting weld

Attachment 2

RBG-46495

Holtec International Position Paper DS-307

CONSTRUCTION OF TRUE-STRESS-TRUE-STRAIN CURVE FOR LS-DYNA SIMULATIONS

by John Zhai, Ph.D.
Revision 0: November 10, 2005

Introduction

The engineering stress-strain curve of a ductile metal, which is conveniently established based on the original cross-sectional area of the tensile test specimen, does not give a true indication of the stress/deformation characteristics of the material. The actual stressed area of the specimen continuously decreases during the course of the tensile test. Once the maximum tensile load is reached, the specimen typically starts to neck down after the initial uniform deformation phase, and the load required continuing deformation falls off until the fracture of the specimen, which produces the fall-off in the engineering stress-strain curve beyond the point of the maximum stress. Because of the continuous reduction of the stressed area, the engineering stress-strain curve may significantly underestimate the actual stress and strain experienced by the material. Note that once necking develops in the specimen, the stress state of a round bar specimen changes from the uniaxial tensile stress to complicated triaxial stresses, which makes it impossible to directly draw an uniaxial true-stress-true-strain curve from the load-deformation data of the tensile test.

For finite element analyses (FEA) involving large plastic deformation or even material disintegration, results obtained by using the engineering stress-strain curve to characterize material behavior is obviously very conservative. In fact, the FEA code LS-DYNA expects that the input stress-strain relations are true stress-strain relations. A number of methods, such as those documented in [1] through [3] may be used to develop a fairly accurate true-stress-true-strain curve for the ductile metal. However, they either rely heavily on the test data that is not usually measured in tensile tests or involve extensive numerical simulations. For easy implementation in finite element analysis, a simple and reasonably conservative method is presented herein for the construction of the true-stress-true-strain curve based on limited material tensile test data in conjunction with the material properties specified in the ASME code.

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Method

Based on the stress and strain definitions, the following relationship between the engineering stress/strain and the true stress/strain can be easily established for the tensile specimen under uniaxial plastic deformation (i.e., up to the peak stress calculated using engineering stress-strain relations).

Engineering strain: $$\varepsilon_e = \frac{L - L_o}{L_o} \quad (1)$$

True strain: $$\varepsilon_t = \int_{L_o}^{L} \frac{dL}{L} \quad \text{or} \quad \varepsilon_t = \ln\frac{L}{L_o} \quad (2)$$

where L_o and L are initial and current specimen lengths, respectively. Therefore, the true strain and engineering strain can be related as

$$\varepsilon_t = \ln(1 + \varepsilon_e) \quad (3)$$

Engineering stress: $$s = \frac{F}{A_o} \quad (4)$$

True stress: $$\sigma = \frac{F}{A} \quad (5)$$

where F is the applied tensile force, and A_o and A are the initial and current specimen cross-sectional areas, respectively. Using the following volume conservation relationship

$$A_o L_o = AL$$

the true stress and engineering stress can be related as

$$\sigma = s(1 + \varepsilon_e) \quad (6)$$

Similarly, Eq. (2) can be expressed in the following form

$$\varepsilon_t = \ln\frac{A_o}{A} \tag{2A}$$

The above equations are only valid before necking occurs, however, Eq. (2A) may be used to conservatively estimate the true fracture strain of the material [4], i.e.,

$$\varepsilon_{t\_f} = \ln\frac{A_o}{A_f} \qquad \text{or} \qquad \varepsilon_{t\_f} = \ln\frac{1}{1-q} \tag{2B}$$

where A_f is the cross-sectional area of the specimen at fracture and q is the corresponding area reduction relative to the original. The parameter q is reported in most tensile tests.

The following simple power law relation is often used to represent the flow curve of metal in the region of uniform plastic deformation.

$$\sigma = K\varepsilon^n \tag{7}$$

where n is the strain-hardening exponent and K is the strength coefficient. A log-log plot of the true stress and true strain up to the maximum load (i.e., immediately before necking) will result in a straight line for the flow curve represented by Eq. (7). Note that n = 0 and n = 1 represent the two extreme cases, i.e., perfectly plastic and elastic, respectively. As noted previously, the stress state in the specimen changes from uniaxial tensile stress to complicated triaxial stresses as the necking develops.

To characterize the true-stress after necking, Eq. (7) and a linear stress-strain relationship have been used as lower bound and upper bound, respectively in [2] to predict the actual true-stress-true-strain curve after necking using the finite element method in conjunction with test data. For simplicity, we conservatively extend the use of Eq. (7) to the entire flow curve and determine n and K based on limited material properties.

For most materials necking begins at maximum load and at a value of strain where the true stress equals the slope of the flow curve [3] [5], i.e.,

$$\sigma_u = s_u(1+\varepsilon_{e\_u}) \tag{8}$$

$$\sigma_u = \left.\frac{d\sigma}{d\varepsilon_t}\right|_{\varepsilon_t=\varepsilon_{t\_u}} \tag{9}$$

$$\sigma_u = K\varepsilon_{t\_u}{}^n \tag{7A}$$

where σ_u and ε_{t_u} denote the true stress and true strain at the maximum load, s_u and ε_{e_u} are the engineering stress and engineering strain at the maximum load (i.e., the ultimate strength as specified in the ASME code and the corresponding engineering strain).

The following relationship can be derived from the above three equations:

$$n = \varepsilon_{t\_u} \tag{10}$$

$$K = \frac{s_u e^n}{n^n} \tag{11}$$

where e = 2.718. Applying Eq. (7) again to the yielding point, we have

$$K\varepsilon_{t\_y}{}^n = s_y\left(1+\frac{s_y}{E}\right) \quad \text{or}$$

$$K = \frac{s_y\left(1+\frac{s_y}{E}\right)}{\left(\ln\left(1+\frac{s_y}{E}\right)\right)^n} \tag{12}$$

where s_y is the engineering yield stress and E is the Young's Modulus of the material.

Eliminating K from Eqs. (11) and (12) results in the following equation.

$$s_u\left(\frac{e}{n}\ln\left(1+\frac{s_y}{E}\right)\right)^n = s_y\left(1+\frac{s_y}{E}\right) \tag{13}$$

Based on the Young's Modulus and engineering yield/ultimate stresses, one can easily solve for the strain-hardening exponent n of the material from the above equation. With the true fracture strain determined from Eq. (2B) based on the area reduction data from the tensile test, the entire true-stress-true-strain curve can be constructed using the linear relationship for the elastic region and Eq. (7) for the plastic region.

References

[1] P.W. Bridgman, "Studies in Large Plastic Flow and Fracture," McGraw-Hill, New York, 1952.

[2] K.S. Zhang and Z.H. Li, "Numerical Analysis of the Stress-Strain Curve and Fracture Initiation for Ductile Metal," Engineering Fracture Mechanics, 49, 235-241, 1994.

[3] Yun Ling, "Uniaxial True Stress Strain after Necking," AMP Journal of Technology, Vol. 5, June, 1996.

[4] W.F. Hosford and R.M. Caddell, "Metal Forming: Mechanics and Metallurgy," PTR PrenticeHall, Englewood Cliffs, NJ, 1993.

[5] "True Stress - True Strain Curve," Knowledge Article from www.Key-to-Steel.com.

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by John Zhai, Ph.D.
Revision 0: November 10, 2005

Author: John Zhai, Ph.D.

Reviewer: Alan I. Soler, Ph.D.

Attachments:

Attachment 1 (10 pages)
Attachment 2 (4 pages)