From: Michael Mayfield, RES
To: Ellis Merschoff, RIV
Date: 9/6/02 10:14AM
Subject: Response to Comments on Davis Besse Head Analysis

Ellis -

First of all thank you for taking the time to review this work in considerable detail. It is always appreciated when a senior manager from outside RES takes the time to review our work this carefully.

I know that you discussed your comments with Nilesh Chokshi and Mark Kirk last week. The attachment to this email documents our response to your comments.

Briefly, I would note that we do have a basis we think justifies the assumption of no flaws. Your comments on anisotropic behavior is correct; these materials absolutely exhibit this behavior. Since more information is needed than we currently have to fully model the behavior, we chose to approximate the behavior by using lower bound tensile properties for these materials. Also, in terms of material properties, use of Poisson's ratio of 0.5 (equivalent to the assumption of constant volume) is appropriate for the elastic-plastic analyses we are performing. Your value of 0.3 obviously is correct for elastic behavior.

As I think was clarified in your discussions, the model for Davis Besse included sharp corners of the edge of the corroded region. The rounded corner model characterizes the specimens tested by the industry in 1972.

Let me close the way I started -- Thanks for taking the time to review and comment on our work. If you would like to discuss this further, please give me a call.

Mike

CC: Allen Hiser; Ashok Thadani; Bill Bateman; Brian Sheron; Bruce Boger; Cynthia Carpenter; Deborah Jackson; Edwin Hackett; Elmo Collins; F. Mark Reinhart; Farouk Eltawila; Gary Holahan; Jack Strosnider; Jim Dyer; John Grobe; Jon Johnson; Mark Cunningham; Mark Kirk; Michael Johnson; Nilesh Chokshi; Richard Barrett; Richard Borchardt; Samuel Collins; Scott Newberry; Steven Long; Suzanne Black; Terence Chan; William Cullen; William Dean

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Responses to Comments
Raised by Ellis Merschoff via e-mail on 8-30-02 Regarding ORNL Stress Analysis of Davis Besse Corrosion Wastage

This information discussed by telephone on 9-3-02. Call included Nilesh Chokshi (ncc1@nrc.gov), Mark Kirk (mtk@nrc.gov), and Ellis Merschoff (ewm@nrc.gov)

Original comments in bold.

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1. The assumptions (p11) that the membrane is isotropic and flawless seems to be particularly unrealistic and non conservative. It seems that the method of deposition of the clad would result in anisotropic mechanical properties. Additionally, the lack of any meaningful post welding NDE should make us question the "...free of pre-existing defects " assumption.

- Assumption of no flaws

  - Our assumption has been that any flaws that exist will be shallow, short, or both and would not significantly reduce the burst resistance of the cladding. This assumption is supported by:
    - Previous experimental work on both cladding and clad beams
    - Detailed NDE of and RPV beltline that included examination of the cladding, and
    - The results of an expert elicitation we recently completed to define generic flaw distributions for use in re-evaluating the PTS rule (Jackson and Abramson, MEB-00-01, September 2000).

    Owing to the significant ductility and toughness typically exhibited by stainless steels, even very substantial flaws will not stop the material from exhibiting the fully plastic limit load, a fact that is well documented by experimental data. Furthermore, the operational experience at Davis Besse prior to shutdown substantiates the assumption that there were no flaws in the wastage area of sufficient size to cause premature rupture (premature meaning failing at a load substantially below the limit load) of the section of cladding exposed by the corrosion cavity at the operating pressure.

  - In the final report, the potential for the presence of flaws and the basis for our assumption will be addressed

- Assumption of isotropy

  - The weld deposited cladding will exhibit anisotropic behavior; the degree of anisotropy being influenced by the particulars of the welding process. To rigorously incorporate the effect in the analysis would have required knowledge of the specific material response and the orientation of the weld beads relative to the corroded region. Access to this information

and the need to obtain results to support the SDP argued for taking a more approximate approach.

- The effects of anisotropic behavior have been compensated for, at least in part, by our use of a lower bound stress strain curve (ref. Fig. 10, p. 42 of the ORNL report). It should be noted that the materials data against which this lower bound was constructed were determined by testing tensile bars removed from A308 cladding material. As such, the tensile data reflect in some way both the anisotropy and the flaw distribution characteristic of the 308SS cladding process.

- The rationale for our choices of materials data, and for our treatment of uncertainties in general, will be described in more detail in the final report.

- FENOC is in the process of testing 2 flat tensile bars removed from the DB clad. These results will provide insight regarding how appropriate our tensile properties/curve is, as well as some insight regarding the effects of anisotropy.

2. Page 11 states an assumption of a Poisson ratio of 0.5. This is the proper value for rubber, steel runs around 0.295. While I'm not familiar with ABAQUS FEM, I am familiar with ANSYS. The governing equations for ANSYS will not allow use of 0.5 for Poisson ratio, as it results in division by zero.

The use of a Poisson's Ratio (PR) of 0.5 is correct under conditions of plastic flow. Please note that under elastic loading conditions our analysis uses a value of PR=0.3

3. The model assumed a radius at the point where the membrane attaches to the vessel base metal. I would guess that the corrosion mechanism at work could leave this as a sharp edge (stress riser). Has anyone looked? If it is a sharp edge, it would reduce the predicted failure points appreciably.

The analysis of the Davis Besse head made the appropriate assumption that there is a right-angle between the corrosion cavity in the RPV steel and the cladding that remains at the base of the wastage cavity. In our model there is a sharp angle between the RPV-steel side-wall and the cladding material. This angle is not rounded in any way.

Based on discussions with Mr. Marshall, it became clear that this comment refers to the radius on the burst disks, not on the Davis Besse finite element model. The model reflects the actual geometry of the test specimens.

4. The reason I'm interested and following this is that shortly after the event, I did some handbook calculations that predicted failure at 2500 psi. I confirmed these calculations with an ANSYS axisymmetric FEM model using a very simplified geometry, and obtained a similar (2500 psi) result. Thus, I was surprised to see the very high pressures coming from the licensees ANSYS run and ORNLs ABAQUS run.

Differences in the basic finite element model (elastic *vs.* elastic plastic), in the geometry modeled, and in the failure criteria selected (finite stress limits (in the elastic analysis) or strain limits (in the elastic-plastic analysis) *vs.* a failure criteria of membrane instability adopted by

both ORNL and the licensee, and supported by experimental evidence), can be expected to lead to the differences in failure pressures reported by the various investigators. With the assumption of no flaws and the approximation to deal with the anisotropic behavior of the cladding, we believe that the ABAQUS analyses appropriately model the corroded region of the Davis Besse head.