#33

Long's handwritten notes on p2.

August 5, 2002

MEMORANDUM

From: Mark Kirk RES

To: Nilesh Chokshi RES
Steve Long NRR

Re: Status of ORNL Calculations of Burst Pressures for Cavities that are Larger than the Cavity Found at Davis Besse.

This memorandum provides the status of our analysis. Paul Williams (ORNL) is in the process of preparing a letter report that will containing all of the details; his report will be available next week.

1. The purpose of our analysis has been to assess how much larger the cavity in the Davis Besse head could have been before rupture of the cladding was likely at pressures at or near the operating pressure. Figure 1 shows the finite element model we have used in these calculations: it features a global model of the head and a local model of the area near the wastage cavity. This global/local approach allowed us to better refine the mesh in way of the cavity. In all of our analyses we have used
   a. A uniform cladding thickness of 0.24-in. (this was the minimum thickness reported by FENOC based on UT measurements made on a ½-in. square grid).
   b. Tensile properties at 600°F that represent a lower bound to all available 308 SS results available at this temperature.

2. Figure 2 depicts the two patterns of wastage growth we have investigated. Our initial analyses used the "self similar" growth pattern. In performing these analyses we noted that the boundaries of the wastage cavity had expanded to interact with the boundaries of the local model. This caused us concern that the predicted burst pressures could be influenced by the modeling approach we had adopted. To help assess this we performed some calculations with a more idealized growth model (the ellipsoidal model) wherein we could better control the growth of the cavity, keeping it away from the boundaries of the local model.

3. Failure pressures predicted using both growth models (see DRAFT ORNL Letter Report dated 7-15-02, "Stochastic Failure Model for the Davis-Besse RPV Head," by Williams and Bass for mode details on failure pressure prediction) are compared in Figure 3. Figure 3 also shows the relationship between failure pressure and area predicted for circular disks by a closed-form plasticity model developed in 1970 by Chakrabarty and Alexander (CA) (the error bars and error bounds are based on how well finite element analysis analysis was able to predict failure of burst disks reported by Riccardella, again see the DRAFT ORNL Letter report of 7-15-02 for further details). The close agreement between the burst pressures predicted for the two cavity geometries shown in Figure 2 and the closed-form CA formula suggests that cavity geometry is not a factor that exerts significant control on the burst pressure.

4. Since cavity geometry does not appear to be a major variable, a first order appreciation for how much larger the cavity would have to be to rupture at pressures near the operating pressure can be obtained by thinking of these cavities as circles, as described in the following table. To express these results in terms of time they obviously need to be used together with an appropriate corrosion rate, and expressed in the context of an uncertainty analysis. It is my understanding Bill Cullen is currently in the process of establishing a contract with ANL to define corrosion growth rates. It is also relevant to point out that there is currently a disagreement between ourselves and FENOC regarding the size of the original cavity (FENOC is using an initial

G/36

area of 20½ in²). We are in the process of resolving this discrepancy.

Cavity	Area [in²]	Radius of an equivalent circle [in]	Growth of radius (from original cavity) needed to cause failure [in]
Original cavity	36	3.4	N/A
Cavity with a 5% failure pressure at the set-point pressure (2500 psi)	165	7.2	3.9
Cavity with a 5% probability of rupture at the operating pressure (2165 psi)	215 [redacted]	8.3 [redacted]	4.9 [redacted]

Ex5

6. In Figure 4 we compare [redacted]ure pressures predicted by SIA (FENOC's contractor) with the CA theoretical model. At least in terms of trends there is good agreement between SIA's analysis and the CA theory, and I think it is safe to say that SIA is predicting lower burst pressures than would our analysis under identical conditions. Clearly we could go into greater detail regarding why the SIA analysis is providing the answers that it is, and we are prepared to do that, if so requested.

7. It is, of course, always possible to do more analysis (if warranted). Some features of these analyses that could be improved (that is, made more realistic) include the following:

   a. The geometry of the original cavity could be made to agree with the dimensions taken from the dental impression made of the wastage cavity, once these dimensions become available.
   b. The dimensions and surface relief of the cladding could be made to agree with the dimensions taken from the dental impression made of the wastage cavity, once these dimensions become available. This improved cladding model could include modeling of the increased cladding thickness due to the J-groove weld (a feature which has currently been omitted)
   c. The stress-strain properties of the cladding could be made to agree with measurements made on the Davis Besse cladding, once these measurements become available.
   d. Nozzle 11, which becomes fully engulfed by the cavity by some of the large wastage areas, could be restrained against motion in the vertical direction (in our current model the nozzle "floats" freely on the cladding) to better model the restraints imposed by structures above the RPV head. In the ORNL letter report of next week such an analysis will be reported. However we do not expect this change of boundary conditions to significantly change the outcome of this analysis, largely because the wastage area is already so large when nozzle 11 is corroded away from the RPV head.

Please let me know if you have any questions or concerns.

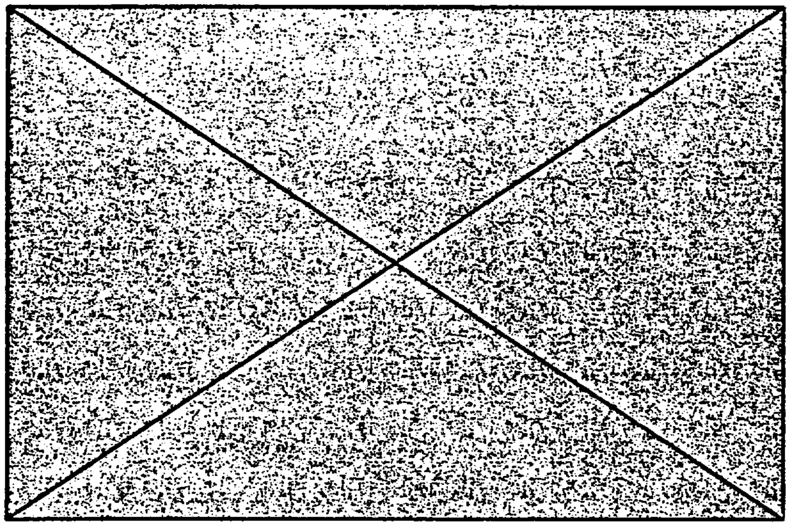
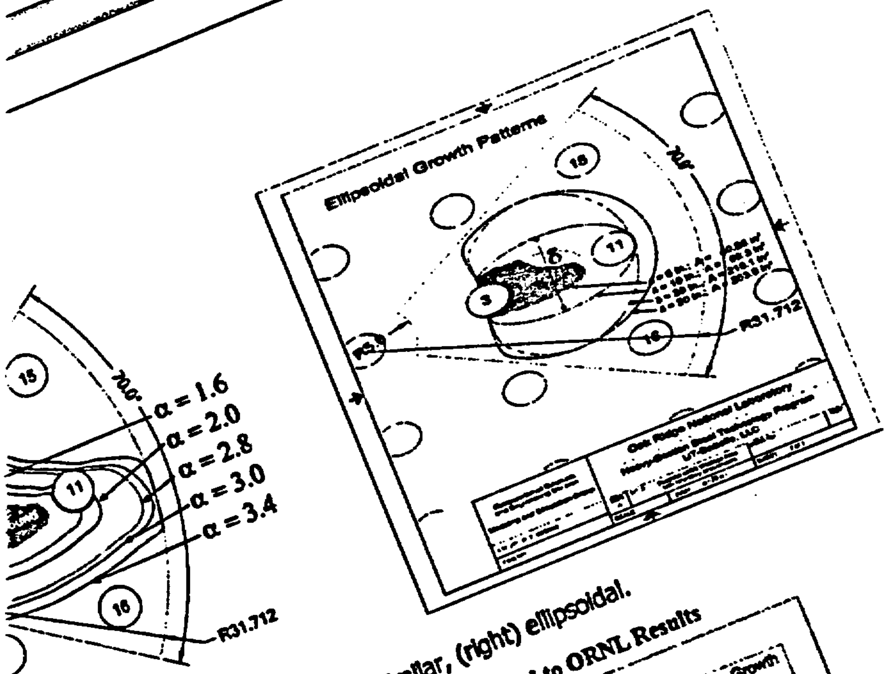


Figure 1. Finite element model used by ORNL.



Wastage growth patterns: (left) self similar, (right) ellipsoidal.

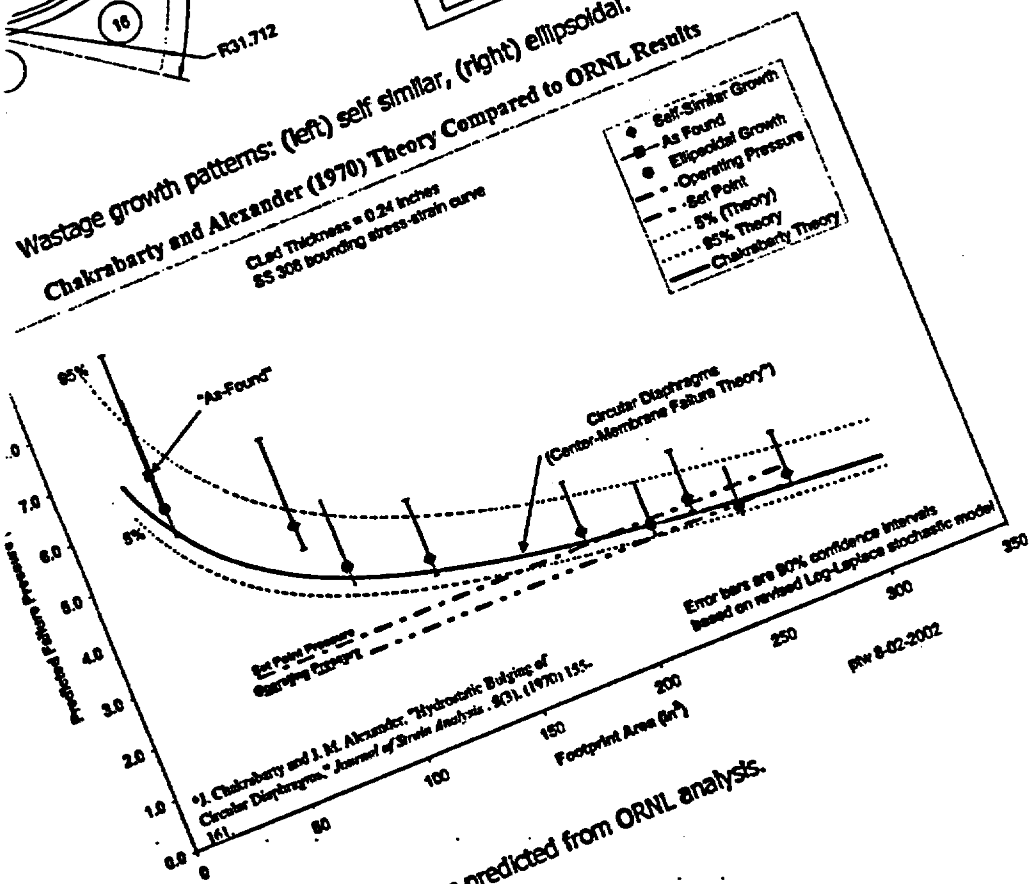
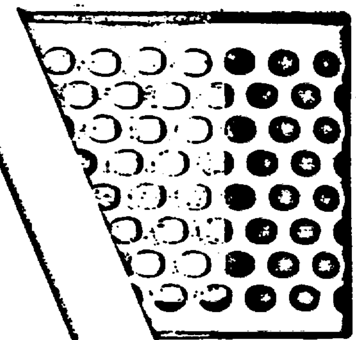


Figure 3: Burst pressures predicted from ORNL analysis.



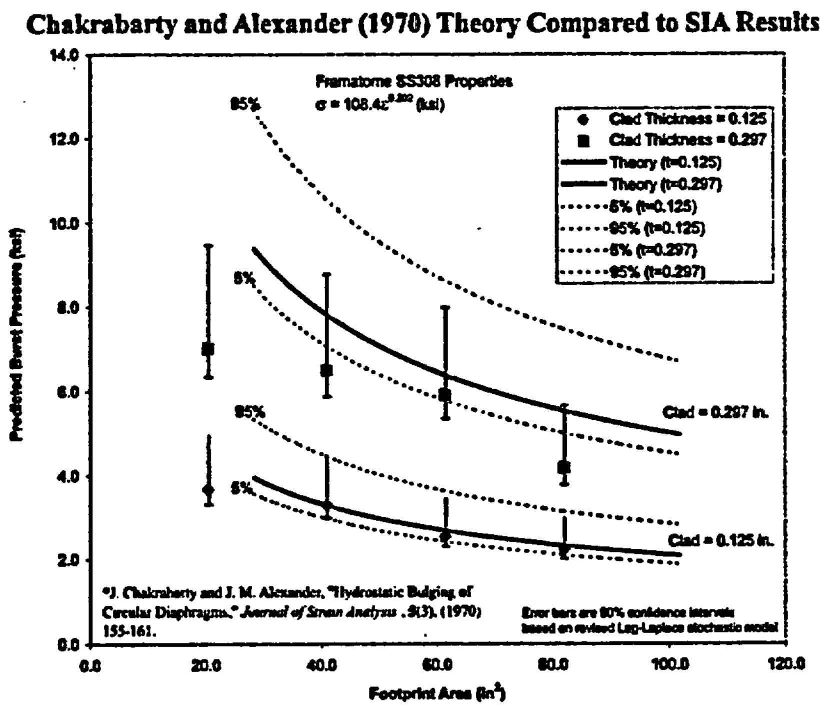


Figure 4: Comparison of SIA predicted burst pressures with theoretical predictions for circular disks.