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Date: 11/27/02 12:13PM
Subject: Fwd: Davis-Besse Cladding Update

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The Davis-Besse hardness profile compares well with the profile in literature (Lippold, OSU Welding Engineering 612 Course Notes: Welding Metallurgy of Stainless Steels). In both the literature and the in the Besse head cladding, the hardness peaks at the fusion boundary between the clad and the base material (Davis-Besse Reactor Head Sample Characterization Phase 3 Status Report, 9/19/02). The fusion boundary is roughly 0.015" wide as measured on the Besse hardness profile.

In the Besse head cladding, the base and clad material are about 200 Knoop hardness (500g) at about 5 mils from the interface. The interface hardness then jumps to 275 Knoop Hardness.

The hardness profile done by Lippold is on an interface between 309L and A508 Class 3 materials. The A508 and 309L hardness near the fusion boundary is about 190 Vickers hardness. The fusion boundary hardness spikes to 305 Vickers hardness. This relatively brittle interface may be conducive for the cracking observed in the Besse head. However, the question arises as to where these micrographs and hardness traverses were taken from in the Besse head.

According to the B&W design drawing # 120784D Revision 0, the head plate (533 Grade B, Class 1) contains several cladding/welding processes. From phone conversations with B&W Senior Welding Engineer Dave Dawes, the head plate would have been 6-wire SAW clad by rotating the reactor head plate while indexing the welding head inward toward the center up to a point. According the 6-wire SAW report by Ian Barnes, the welding parameters for 6-wire are:

Current: ~1200A for 5 DCSP wires
Voltage: ~33-35V
Travel Speed: ~5 inches per minute

In order to maintain the travel speed of 5 IPM, the radial speed of the rotating head plate must be increased as the welding head indexes toward the center. As the welding head approaches the center of the head plate, a maximum rotational speed will be achieved. Thus, the top dead center of the head must actually be clad with a manual process as indicated in drawing # 120784D Revision 0.

According to Dave Dawes, this manual process is a two layer SMAW (or "stick welding") process. It is not certain what the diameter of this manual cladding area is. It is possible that a portion of the area surrounding the Nozzle was clad with this manual process. It is also possible that the cavity may contain some of this manual cladding.

B&W Owners Group Report BAW-2274, September 1996 contains a diagram (Figure 2-1) that shows the single wire clad extending all the way to the center lines of nozzles 6 and 8. From Drawing number 154628E, this results in a radius of 17.18". The center of Nozzle three is 12.15" from top dead center of the head. The radius of the nozzle is 2". The cracking in cladding starts at about 2" from the OD of nozzle 3. According to Figure 2-1 of BAW-2274, the manual process would have included the cracks in the cavity of the Besse head.

The cladding material in the cavity of the Besse head contains a complex chemical make-up and thermal processing history that will be difficult to replicate for purposes of burst testing. The material contains 182 buttering, 182 J-groove weld and possibly at least one of the following: two layer manual SMAW and/or 6-wire SAW.

Therefor, when cross-sectioning the material, it is recommended that a macroscopic view across the entire cavity is first taken to allow the various bead geometries to be determined. From this, the location of the cracking in relation to the various cladding and welding processes can be determined. Further cross-section could then be performed to allow higher resolution photo-micrographs to be taken where appropriate.

The use of the Besse cladding for the purposes of burst testing may prove to be cost prohibitive due to radioactivity concerns. The PVRUF cladding is currently the first choice in the use of material for burst testing due to the high-heat input wide strip cladding process that was likely used in the construction of this vessel. The wide strip cladding process deposits a weld bead similar in geometry to the 6-wire cladding process used in construction of the Besse head. As of 10/12/02, no 6-wire clad samples have been located, however, Ian Barnes or BWXT-Mount Vernon may have some.

Wally McAfee offered to cross-section the PVRUF cladding in order to view the bead geometry and micro-structure. Addition testing could include high temperature tensile testing (similar to the testing performed on the Besse head cladding) and surface tension ("Hole drilling Rosette" and "Parting-Out Specimen"). This testing was performed on cladding by Westinghouse Owners Group and the results are published in WCAP-15338: A Review of Cracking Associated with Weld Deposited Cladding in Operating PWR plants, 2000.

The "parting-out specimen" along with the "layer removal method" were both employed and the stresses summed to yield a residual stress profile (Figures 4-7 and 4-8 of WCAP-15338). Macroscopically, the stress profile describes the cladding in tension and the base material in compression. However, near the fusion boundary, the cladding dives into compression. It is not clear, however what the tension would be on the surface of exposed cladding, since the removing of the base material would allow the stress in the cladding to "relax".

Surface tension testing could be done at high temperature on the Besse head cladding in the cavity and in an area remote from the cavity. Testing in an area remote from the cavity would give insight into the stress conditions prior to deformation and cracking. This may give insight into how and/or why the cracking is present in the cladding. Furthermore, the surface tension testing would be able to show differences and similarities between the burst test mock-up and the besse head. The "hole drilling rosette" technique appears to be the most appropriate test method.