ASME
SETTING THE STANDARD

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February 23, 2010

Ms. Michele Evans, Director
Division of Component Integrity
Office of Nuclear Reactor Regulation
USNRC
Washington DC 20555

Dear Ms. Evans:

The determination of residual stresses for use in the prediction of PWSCC crack growth is extremely important in the evaluation of indications in the dissimilar welds of PWR operating plants. This need for better guidance was highlighted in the activities associated with a recent flaw evaluation for an operating plant, and the discussions which resulted.

The purpose of this letter is to transmit, for your information, the results of a discussion conducted at the Section XI Working Group on Flaw Evaluation. This working group has primary responsibility for development of flaw evaluation rules in Section XI. The goal of the discussion was to develop a set of recommendations for the calculation of residual stresses, for use in Section XI flaw evaluations of indications in Alloy 82/182 dissimilar metal welds.

The attached slides represent the key attributes for such calculations and are the consensus of the Working Group. Since these guidelines were not voted at the Standards Committee or the Board on Nuclear Codes and Standards, these guidelines have not been formally endorsed by ASME, and are for your information only. The vote at the Working Group was 16 affirmative, no negatives, and 1 abstaining. Additional work is ongoing, and is expected to lead to more precise guidelines in the future that would be approved by ASME. Again, the purpose of this letter is to document the current status of the guidelines.

A more extensive technical report on this topic is being prepared by the EPRI Materials Reliability Project (MRP). The MRP report currently is undergoing member utility review and its draft recommendations are entirely consistent with the content of the attached slides, as the author participated in the discussion held at the Work Group meeting described above. This report will be issued to all operating PWRs as interim guidance for the spring outage season, and we anticipate that it will be transmitted to you once it is finalized.

Sincerely,

Bryan A. Erler

Bryan Erler, Vice President
ASME Codes and Standards

Flaw Evaluation Issues with a Recent Inspection

Warren Bamford
ASME Subgroup Evaluation Standards

Background

- Recently an indication was found in the DM weld of the RV Outlet nozzle of Seabrook
- Mitigation was not planned for this outage, so a flaw evaluation was called for
- The evaluation was completed and submitted to NRC
- NRC review turned up a large number of questions about the proper residual stresses to be used in the analysis

Actions Taken in Response

- A lunch meeting was held with NRC staff on the Monday of ASME Code week
- It was decided that a meeting of experts would be held on Nov. 19-20 at NRC Research offices in Rockville
- The agenda was developed in a brain storming session the next day in the WG Flaw Evaluation
- The meeting brought together NRC staff and consultants with industry experts on operating plant flaw evaluation

The Meeting

- The meeting was held the afternoon of Nov. 19, and the morning of Nov. 20, and was hosted by Al Csontos
- It was a public meeting
- Invitees were reps of those organizations who perform flaw evaluations, and those who have developed stress information for such evaluations. Included are:
  - Westinghouse
  - Areva
  - Structural Integrity
  - Dominion Engineering
- The meeting was useful, in that the results helped to clarify the NRC issues

Findings and Actions

- Here are the key findings of that meeting:
  - The stainless steel closure weld creates a beneficial stress distribution in the DM weld, for both axial and hoop stresses
  - Safe end length is critical, longer safe ends could negate the beneficial effect of the stainless steel closure weld
  - NRC expects residual stresses used in flaw evaluations to be based on analyses appropriately representative of the actual weld joint geometry and fabrication processes and sequence
- Follow-up actions
  - Discussions will continue at the next ASME Code meeting, the first week in February
  - MRP preparing a topical report that provides guidance on PWSCC flaw evaluations
- The goal of this discussion is to reach agreement on two key issues:
  - What are the key (required) attributes of an effective residual stress finite element modeling process?
  - What depth of repair must be assumed

Attributes of an Acceptable Residual Stress Calculation

- Geometry
- Weld Fabrication Sequence
- ID Surface Repairs, if any
- Stainless Steel Closure Weld Effect
- Benchmarking of Analysis Methodology
- Proper Curve-fitting of Stress Profile
- Correct Operating Temperature and Pressure
- Consistency with inspection results
- Sensitivity Analysis

Geometry

- The plant-specific diameter, thickness and other geometrical features need to be accounted for
- All materials need to be appropriately modeled (mechanical & thermal properties)
- Using a generic design or published solution is acceptable as long as all relevant differences between the analyzed geometry/configuration and the plant specific geometry/configuration have been properly reconciled, with technical justification

Weld Fabrication Sequence

- The model must account for the fabrication process followed at the fabrication facility
- For example, if the ID of the nozzle to safe end weld region is machined after the initial welding process, this can affect the residual stresses
- The buttering, if present, should be explicitly modeled
- Any deviation in the modeling of the actual weld sequence (e.g., buttering and PWHT) shall be justified

Example: Safe End to RV Nozzle Weld Fabrication for Combustion Engineering

- A summary of the nozzle fabrication process:
  - Alloy 82/182 buttering applied to low alloy steel (multi-layer)
  - Nozzle bore clad with stainless steel
  - Nozzle buttering machining to prep for U-groove weld
  - RV, including the nozzle and buttering receives PWHT
- Safe End is fit up to the nozzle, with the lands of the machined weld preps butted together
- At this point the ID of the nozzle is smaller than the design requires
- Layered Alloy 82/182 weld passes are applied from ID to OD to complete the weld
- The nozzle buttering and safe end weld lands are now removed by machining the ID (and sometimes the OD), and Dye penetrant (ID and OD), UT and radiography exams are completed
- Weld repairs to the ID would not be in-process, since they would involve a break in the fabrication traveler sequence, requiring documentation

ID Surface Repairs, if any

- It is well known that ID surface repairs result in tensile residual stresses at the pipe ID
- A search of available repair and NDE records should be made, and documented
- It is also important to have knowledge of the fabrication practices and procedures of the shop where the DM weld was produced
- This information, along with the repair information, may enable a defendable estimate to be made of the maximum repair depth to be modeled. If this information is not available, then
  - For large bore welds (>16 NPS), a repair depth of 25% should be assumed
  - For smaller bore nozzles, a repair depth of 50% should be assumed
  - A repair length of 100% of the circumference can be assumed with justification
- Alternatively, a screening analysis with a 50% repair depth and 100% of the circumference may be used to bound the weld repair stresses

Closure Weld Effects

- The stainless steel closure weld may create a beneficial stress distribution in the DM weld, for both axial and hoop stresses
- The magnitude of this effect is dependent on the proximity of the closure weld to the DM weld
- Safe end length is therefore critical; a longer safe end could negate the beneficial effect of the stainless steel closure weld. This distance needs to be determined in a defendable manner for the application of interest
- Safe ends are often cut to fit in the field, so as-built dimensions are best.

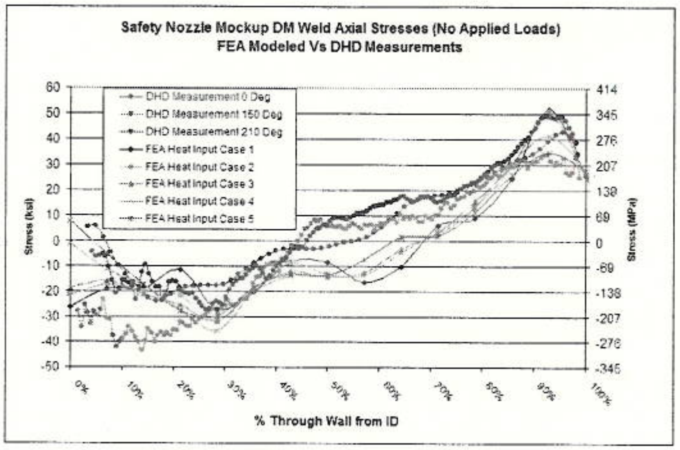
Benchmarking of Analysis Methodology

- The modeling methodology used must be verified and validated through comparison with actual measurements of residual stresses, on a mock-up
- A mock-up is not required for every analysis
- The mock-up should have sufficient complexity that it provides a realistic test of the residual stress predictions
- An example of bench-marking is shown in the next two slides, which are for a safety/relief nozzle in a Westinghouse-designed pressurizer mock-up

Example of Bench-marking

SIMULATION AND MEASUREMENT OF THROUGH-WALL RESIDUAL STRESSES IN A STRUCTURAL WELD OVERLAID PRESSURIZER NOZZLE

By Steve Marlette et al, to be published at PVP 2010



Example of Bench-marking

from **SIMULATION AND MEASUREMENT OF THROUGH-WALL RESIDUAL STRESSES IN A STRUCTURAL WELD OVERLAID PRESSURIZER NOZZLE**

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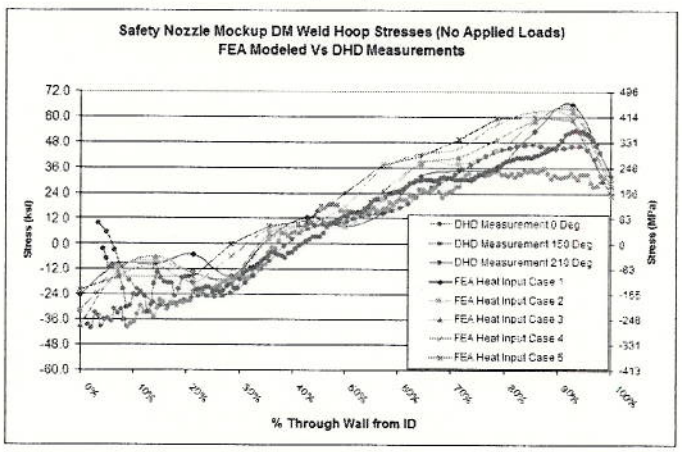

FM Stress Input and Curve-fitting of Stress Profiles

- Often residual stress profiles are complicated curves, and may not be amenable to third order curve fits
- Care needs to be taken to ensure that the fitting approach taken does not misrepresent the residual stress profile
- Fourth order fits are available to generate stress intensity factors when the third order fit is not adequate.
- Weight function methods may be used as an alternative to curve fitting the stress distribution
- Stress paths should be taken at the flaw location, or the bounding path of multiple locations within the DM weld should be chosen

Correct Operating Temperature and Pressure

- The operating temperature and pressure both have important impacts on the level of residual stress, so both must be modeled correctly
- Steady state conditions should be used, as these are the conditions which will grow a crack under PWSCC
- Superposition may be used to combine residual stresses with operating pressure and piping loads, since the residual stresses are strain controlled and highly localized
- Hydrotest pressure and few operating cycles should be included to account for change in residual stress

Consistency with Inspection Results

- The residual stresses used in the evaluation should be consistent with the NDE findings being evaluated
- It is recognized that repairs or other forms of ID welding often contribute to the initiation and growth of PWSCC cracks
- For example, Ringhals 3 and 4 (double-Vee welds) both experienced PWSCC in the RV nozzle DM weld region
- One had extensive repairs, and the other did not

Sensitivity Analysis

- Sensitivity calculations that account for uncertainties in input parameters should be performed.
- Such studies are informational and not intended to impose additional constraints on inspection interval
- The objective of the sensitivity analysis is to demonstrate the robustness of the calculation

What's Next

- It is important to document agreements reached at the WG on Flaw Evaluation
- The plan is to issue a letter from ASME to the NRC staff, documenting the agreed-upon criteria for an acceptable residual stress evaluation
- Meanwhile, the MRP is working to finalize a more extensive written set of flaw evaluation guidelines, which are entirely consistent with the residual stress guidelines presented here, and are to support spring 2010 outages
- By the end of 2010, a document providing a detailed set of analytical guidelines for the finite element analysis itself will be issued by MRP