Xcel Energy®

Monticello Nuclear Generating Plant
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November 3, 2014

L-MT-14-082
10 CFR 72.7

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Director, Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

Monticello Nuclear Generating Plant
Docket No. 50-263
Renewed Facility Operating License No. DPR-22
Independent Spent Fuel Storage Installation Docket No. 72-58

Exemption Request for Dry Shielded Canisters 11 - 16 Due to Nonconforming Dye Penetrant Examinations, Supplemental Information (TAC No. L24939)

References:
1) NSPM letter to NRC Document Control Desk, L-MT-14-016, Exemption Request for Dry Shielded Canisters 11 - 16 Due to Nonconforming Dye Penetrant Examinations, dated July 16, 2014 (ADAMS Accession No. ML14199A370).
2) NRC letter to Karen D. Fili, Exemption Request for Dry Shielded Canisters 11-16 Due To Nonconforming Dye Penetrant Examinations, Docket No. 72-58 – Supplemental Information Needed, dated September 11, 2014.

Pursuant to 10 CFR 72.7, "Specific Exemptions", the Northern States Power Company, a Minnesota corporation (NSPM), doing business as Xcel Energy, submitted Reference 1 to request an exemption to the requirements of 10 CFR 72.212(b)(3) and 10 CFR 72.212(b)(11) for six (6) NUHOMS® Dry Shielded Canisters (DSCs) due to nonconforming dye penetrant (PT) examinations performed during the loading campaign started in September 2013.

In Reference 2, Spent Fuel Storage and Transportation (SFST) Staff requested supplemental information to support their review. During a public meeting held on September 24, 2014, SFST Staff and NSPM discussed the approach and schedule to address the SFST request. Subsequently, a reply date of November 3, 2014, was established.

Enclosure 1 provides the replies to the Request for Supplemental Information (RSI) questions as well as the Observation questions.

NMSS26

Enclosure 2 provides a report that supports the RSI reply provided in Enclosure 1.

Summary of Commitments

This letter makes no new commitments and no revisions to existing commitments.

Karen D. Fili
Site Vice-President
Monticello Nuclear Generating Plant
Northern States Power Company-Minnesota

Enclosures (2)

cc: Administrator, Region III, USNRC
Terry Beltz, Project Manager, Monticello Nuclear Generating Plant, USNRC
Jennifer Davis, Project Manager, Spent Fuel Storage and Transportation, USNRC
Resident Inspector, Monticello Nuclear Generating Plant, USNRC

MONTICELLO NUCLEAR GENERATING PLANT

EXEMPTION REQUEST FOR DRY SHIELDED CANISTERS 11-16

DUE TO NONCONFORMING DYE PENETRANT EXAMINATIONS

RESPONSE TO NRC REQUEST FOR SUPPLEMENTAL INFORMATION

This enclosure provides responses from the Northern States Power Company, a Minnesota corporation (NSPM), doing business as Xcel Energy, to a Request for Supplemental Information (RSI) provided by the Nuclear Regulatory Commission (NRC) on September 11, 2014.

The NRC questions are provided below in *italic font* and the NSPM response is provided in the normal font.

***RSI-1**: Provide an appropriate technical basis for the modification of the stress reduction factor. Provide supporting calculations using an appropriate modification of the stress reduction factor. Also provide supporting calculations for the inner top cover plate weld.*

The exemption request applies to dry shielded canisters (DSCs) 11-16. These DSCs had non-conforming penetrant testing (PT) during canister closure welding operations. The welds with non-conforming PT included:

- *Inner top cover plate (ITCP) weld (root and cover PT)*
- *Siphon port cover plate (SPCP) weld (root and cover PT)*
- *Vent port cover plate (VPCP) weld (root and cover PT)*
- *Test port plug (TPP) weld (root and cover PT)*
- *Outer top cover plate (OTCP) weld (root, intermediate, and cover PT)*

The exemption request concludes, based on a preponderance of the evidence, that there is a reasonable assurance of safety for the 20-year service lifetime of DSCs 11 - 16 based on the following:

1. *Integrity of the fuel creates a fission product barrier.*
2. *The quality of the welding process employed provides indication of development of high quality welds.*
3. *The advantages of the multi-layer weld technique which includes the low probability for flaw propagation, the subsequent covering of weld layer surface flaws and the indication of development of high quality welds.*
4. *Visual inspections performed on the welds met quality requirements.*
5. *The helium leak and DSC backfill testing results verify confinement barrier integrity.*

6. *The lack of a failure mechanism that adversely affects confinement barrier integrity.*
7. *Stress margins are available in the welds when assuming conservatively large flaws.*

Section 3.2.5.1 - Inner and Outer Top Cover Plate Weld Justification, includes a justification for a modified stress reduction factor for the ITCP and the OTCP welds. It is noted that Interim Staff Guidance (ISG)-15 requires a stress reduction factor of 0.8 applied to closure welds that are examined by progressive PT rather than volumetric examination. It is also noted in the exemption request that the original 61BTH DSC evaluations used a stress reduction factor of 0.7 for conservatism with respect to the ISG-15 requirement. A modified stress reduction factor of 0.7 is calculated for DSCs 11-16 based on the information provided in the ASME Boiler and Pressure Vessel Code. Specifically, the exemption request states:

The permissible weld reduction factors (ASME Boiler and Pressure Vessel Code, Division 1, Subsection NG, 1998 edition through 2000 Addenda, Table 3352-1) for surface PT and surface visual examination are 0.4 and 0.35, respectively. A modified stress reduction factor of 0.70 (0.80 x 0.35/0.40) is calculated for the non-compliant weld, due to the multiple visual inspections.

Section 3.2.5.1 also includes a summary of the calculations using the modified stress reduction factors for normal and accident conditions:

When the modified stress reduction factor and other conservatisms are included as described above are applied for normal conditions, the stress ratio of calculated stress to allowable stress is 0.52 and 0.79 for the ITCP and OTCP welds, respectively. For accident conditions, the stress ratio is 0.84 and 0.71 for the ITCP and OTCP welds, respectively. Therefore, adequate design margins exist for the ITCP and OTCP welds when evaluated against conservative stress allowable values.

Two key points in the analysis provided in the exemption request include point #4, the use of visual inspections that met quality standards, and point #7, the stress margins in the welds assuming conservatively large flaws.

The modified stress reduction factor calculated in Section 3.2.5.1 indicates that stress reduction factors from ASME Boiler and Pressure Vessel Code, Division 1, Subsection NG, 1998 Edition through 2000 Addenda Table NG-3352-1 were used. There are several issues with the proposed approach in the exemption request.

1. *Table NG-3352-1 does not include a weld type and category that is representative of the ITCP and OTCP welds used in the 61BTH canister.*
2. *Table NG-3352-1 does not contain stress reduction factors for multiple visual examinations.*

3. *Table NG-3352-1 and subsection NG-3350 do not identify permissible combinations of stress reduction factors based on combinations of conforming (or non-conforming) examinations.*

Although not specifically identified, it appears that the exemption request is based on the Type VI Category D or Category E welds which are not pressure boundary welds. Table NG-3352-1 indicates that the stress reduction factor for a Type VI Category D or Category E weld is 0.35. Stress reduction factors based on multiple visual examinations are not identified for any of the types and categories of welds included in Table NG-3352-1. In the exemption request, the calculated stress reduction factor for multiple visual inspections for the ITCP and OTCP is 0.7. By this calculation, the exemption request uses allowable stresses for welds with multiple visual examinations that are a factor of 2x (0.7/0.35) greater than the same welds with a single surface visual examination. The technical basis for this modified stress reduction factor is not provided.

The 2x increase in allowable stress with the modified stress reduction factor in the exemption request is also inconsistent with the stress reduction factors for multiple versus single examination methods that are included in Table NG-3352-1. For example, the stress reduction factors for surface PT, root and final PT, and progressive PT for a Type VI Category D or Category E welds are 0.4, 0.45, and 0.55 respectively. In other words, based on the stress reduction factors in Table NG-3352-1, the allowable stresses in Type VI Category D or Category E welds with progressive PT are a factor of 1.375x (0.55/0.4) greater compared to allowable stresses in welds where only a surface PT was performed. For welds with a root and final PT, the allowable stresses are a factor of 1.125x greater (0.45/0.4) compared to the allowable stresses in weld where only a surface PT was performed.

It is noted that the final PT reexamination of the OTCP weld on DSC #16 identified an indication that was not identified in the visual examination. This observation calls into question the technical basis of relying on the visual examination to determine the integrity of the OTCP and ITCP welds.

Finally, Section 3.2.5.1 of the exemption request refers to calculations conducted for both the ITCP and OTCP welds. Controlling load combinations stress results are provided in Enclosure 2, Tables 1 and 2 for the OTCP closure weld. No controlling load combination stress results were provided for the ITCP closure weld.

In summary, the exemption request contains calculations using modified stress reduction factors that are not supported by the referenced table NG-3352-1 of the ASME Boiler and pressure vessel code. No technical basis is provided to support the modification of the stress reduction factor used in the supporting calculations. Supporting calculations for the inner top cover plate weld were not provided.

This information is required by the staff to determine compliance with 10 CFR 72.236 (c-f, j, l).

REPLY:

The DSC confinement boundary is designed to the requirements of the ASME Boiler & Pressure Vessel Code Section III, Subsection NB with Code alternatives as identified in Section 1.1.12.4 of the Technical Specifications for the Standardized NUHOMS® system (NRC Certificate of Compliance 1004). As indicated in the approved Code alternatives, the field closure welds do not satisfy all of the requirements of Subsection NB. Therefore, the evaluation of the condition provided in the exemption request is not intended to be compliant with Code requirements, but rather a valid technical argument for accepting the stated condition with a reasonable assurance of safety.

Subsection NB presumes that all welds are subject to volumetric inspection, such that no weld quality factors are defined within Subsection NB. In developing the basis for the exemption request, a key aspect was to develop an appropriate penalty to the allowable stress values for the nonconforming PT examination; e.g., a reasonable and rational basis for analysis. This additional reduction factor is applied to the baseline requirement for the stress allowable value for compliant PT (i.e., ISG-15 establishes a stress allowable reduction factor of 0.80 for compliant PT condition).

NRC requested that NSPM provide technical justification for the modified stress allowable reduction factor of 0.70 selected to evaluate the closure welds with the nonconforming PT examinations. In the exemption request, AREVA TN utilized the ASME Boiler & Pressure Vessel Code guidance provided in Table NG-3352-1 to apply an appropriate stress allowable reduction factor to the field closure welds involving nonconforming PT.

Upon further discussion with the Staff at the public meeting held on September 24, 2014, it was apparent that the NRC Staff did not concur with the approach proposed in Reference 1. In response, an alternative analytical approach has been developed to derive a value of modified stress allowable reduction factor. This approach is described in Enclosure 2 of this submittal. It uses a finite element model (FEM) of the field closure welds for the ITCP and OTCP together with the associated top closure geometry of the 61BTH DSC. The intent of this engineering study was to develop a quantitative basis for the modified stress allowable reduction factor to address the lack of a compliant PT examination for the Monticello Nuclear Generating Plant (MNGP) DSCs associated with the subject exemption request.

Finite element models were developed based on the geometry of the 61BTH DSC with a sufficiently detailed mesh size in the area of the field closure welds to support the modeling of a variety of weld flaws. Both unflawed and flawed models were developed. In the "flawed models", defects were modeled in the welds in the radial, circumferential and laminar orientations by deactivating elements from the model, essentially creating structural discontinuities in the welds, with a variety of depths and distributions. The flawed models were intended to envelop the type and distribution of flaws that could have remained undetected using a visual test (VT) only examination method, considering the weld process utilized for the field closure welds.

The models were subjected to loading due to internal pressure and side drop load cases. The resultant weld stresses in the unflawed model were then compared to the stresses in the flawed models to quantify the relationship between welds with no flaws to welds with flaws. This comparative analysis supports the definition of a modified stress allowable reduction factor based on the ratio of the comparative stresses for the load cases analyzed, which is considered appropriate for the MNGP exemption request, where only VT examination is being credited for field weld non-destructive examination (NDE).

The results of the engineering study support the use of a modified stress allowable reduction factor of 0.70. For the OTCP, the finite element model of circumferential flaw case Circ #2 involving through-wall flaws with a flaw length of approximately 2" in every 5" of weld represents a flaw population which is extremely conservative for the purpose of evaluating the MNGP canisters subject to the exemption request. As indicated in the SIA calculation, this type of flaw size and distribution is extremely unlikely to exist given the type of weld process utilized, the quality program involved in the welding process, the qualification of the weld operator, the favorable weld conditions, the rather forgiving weld process utilized, and the application of a compliant VT examination. For this flaw distribution (Circ #2), the comparative stress ratio for the pressure load case is 0.703 and for the side drop load case is 0.720. The flaw distribution associated with Circ #1 involving through-wall flaws with a flaw length of approximately 3.5" in every 5" of weld represents a flaw population which is not realistic for the MNGP canisters subject to the exemption request, and therefore is provided for comparison purposes only. The finite element results for the ITCP are bounded by the OTCP. Therefore, based on the results of the finite element analysis, the use of a modified stress allowable reduction factor of 0.70 is justified.

As submitted in Reference 1, the modified stress allowable reduction factor of 0.70 utilized in AREVA TN calculation 11042-0204 has been applied to the structural analysis of record documented in Section T.3 of the Standardized NUHOMS® Updated Final Safety Analysis Report (UFSAR) for the 61BTH DSC, to evaluate the impact of possible flaw distributions on the MNGP DSCs that are the subject of the exemption request. This calculation demonstrates acceptable results.

To better characterize the design margins available for the ITCP and OTCP welds under primary loading, AREVA TN evaluated[1] the controlling load combinations for the design of the ITCP and OTCP welds by removing conservatism in the analysis

[1] These evaluations consist of engineering computations (hand calculations) using existing design criteria except as modified for the "actual" conditions described herein. These were prepared and peer-checked, but not subjected to full design control measures of a 10 CFR 72 Appendix B Quality Assurance Program.

and utilizing the actual mechanical properties of the material. This evaluation was performed to determine the minimum value of the modified stress allowable reduction factor that could be tolerated under more realistic conditions. As indicated in AREVA calculation NUH61BTH-0200 (provided in response to RSI-2), the controlling load case for the ITCP weld during transfer conditions includes internal pressure and corner drop loads (reference Load Case TR-9 from Table 54 of calculation NUH61BTH-0200). During storage conditions, the controlling load case for the ITCP weld includes deadweight, internal pressure and seismic loads (reference Load Case HSM-8 from Table 54 of calculation NUH61BTH-0200). Similarly, the controlling load case for the OTCP weld during transfer conditions includes internal pressure and corner drop loads (reference Load Case TR-9 from Table 52 of calculation NUH61BTH-0200). During storage conditions, the controlling load case for the OTCP weld includes deadweight, internal pressure and seismic loads (reference Load Case HSM-8 from Table 52 of calculation NUH61BTH-0200).

For the storage condition subject to seismic loads, the MNGP site specific seismic requirements are significantly less than the design basis seismic input for the NUHOMS® system which specifies a Zero Period Acceleration (ZPA) of 0.30g horizontal and 0.20g vertical for the HSM-H with the 61BTH DSC. The MNGP site specific design basis earthquake has a horizontal ZPA of 0.12 with a vertical ZPA of 0.08, which is only 40% of the NUHOMS® design basis.

The actual material test values for the base material and weld filler material associated with the ITCP and OTCP components were obtained to provide a more realistic evaluation of the mechanical strength of the welds. Thus, the most limiting yield strength is 45 ksi which represents an approximate 50% increase over the nominal yield strength of 30 ksi for Type 304 stainless steel. The most limiting tensile strength is 82 ksi which represents an approximate 10% increase over the nominal tensile strength of 75 ksi for Type 304 stainless steel.

Applying these more realistic conditions for primary loading, the calculated stress may be reduced and the allowable stress increased accordingly. For the transfer load case TR-9, this would result in no change to the calculated stress, but an increase in allowable stress to approximately 51 ksi which would support a modified stress allowable reduction factor as low as 0.45 for the most limiting condition for both the ITCP and OTCP welds. For the storage load case HSM-8, this would result in a calculated stress of approximately 9 ksi, with an allowable stress of approximately 24.5 ksi, which would support a modified stress allowable reduction factor as low as 0.40 for the most limiting condition involving the ITCP weld.

In summary, the modified stress allowable reduction factor of 0.70 utilized in the evaluation is justified based on the results of the FEM analysis performed by SIA. However, using more realistic conditions, a modified stress allowable reduction factor of 0.45 could be tolerated for primary loading, while continuing to ensure the design basis functions of the DSC closure are maintained and the confinement boundary function of the ITCP weld is preserved.

RSI-1 provided an observation that the VT examination performed on the OTCP weld for DSC Unit #16 did not identify an indication that was subsequently identified in the final PT reexamination. This is not unexpected as VT examination provides a less rigorous interrogation of the weld surface than PT examination, which forms the basis for imposing the greater penalty associated with the modified stress allowable reduction factor. Enclosure 2 of this submittal provides further discussion about the expected weld quality and the flaw sizes that could reasonably be identified for the DSCs of this exemption request.

RSI-1 questioned why the load combinations provided in the calculation submitted with the exemption request were limited to the OTCP closure weld. The controlling load combinations provided for the OTCP closure weld are included in the exemption request for the purpose of demonstrating that the reduced thickness of the OTCP weld is acceptable. The ITCP closure welds are not subject to a reduced thickness condition, and therefore, those controlling load combinations were not provided in the supporting calculation 11042-0204, Rev. 2. However, the controlling load combinations for the ITCP weld are included in the design basis structural calculation NUH61BTH-0200, Rev. 0 provided in response to RSI-2.

***RSI-2**: Submit Reference 5.2, TN Calculation NUH61BTH-0200, Rev. 0, "NUHOMS-61BTH Type 1 Dry Shielded Canister Shell Assembly Structural Analysis," and, for Load Cases TR-9, -10, and -11, provide schematics and summary descriptions of the finite element analysis (FEA) models with proper notations to depict model attributes, including geometry, element types, loading, and boundary conditions to facilitate staff review. Also, include the input and output files for the FEA, per ISG-21, in the submittal.*

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY: Reference 5.2 and the input / output files for the FEA associated with Load Cases TR-10 and TR-11 have been stored on electronic medium and hand-delivered to Spent Fuel Storage and Transportation (SFST) Staff at a public meeting held on September 24, 2014. Stresses on the weld, allowable stresses and stress ratios for the OTCP and ITCP can be found in Tables 52-54 (pp. 113-115) of the NUH61BTH-0200 R0 evaluation. A summary description and schematics of the finite element model including weld details can be found in Section 8 (pp. 44-52) in the calculation. The weld stress analysis can be found in Section 9.2 (p. 55) of the evaluation. These electronic files contain information that is proprietary to AREVA-TN. Accordingly, NSPM and AREVA-TN request that this information not be released to any third parties and that it be destroyed or returned after use.

No FEA was performed for Load Case TR-9. This case was evaluated by hand calculation. Therefore, no further information is provided for this load case.

***RSI-3**: Provide a technical basis for the "line welds," pin-connection, assumption for the ½" partial penetration lid-to-shell weld for the OTCP, given that, in previous FEAs for the canister shell assemblies, including those listed in Tables K.3.7-13 and T.3.7-16 of the NUHOMS® Updated Final Safety Analysis Report (UFSAR), the subject weld was not explicitly called out for stress margin evaluations. Specifically, using load combination TR-10 as an example, justify that the calculated primary stress of 11.4 ksi for the weld in Table 1 of the calculation in the exemption request, is a conservative representation of the primary membrane and the primary membrane-plus-bending stress intensities of 32.34 ksi and 55.21 ksi, respectively.*

It is unclear how the lid-to-shell weld FEA discretization and the section cut for post-processing of nodal values to obtain the membrane and membrane-plus-bending stress intensities as reported in Table K.3.7-13 referenced above, are simulated with line weld stresses involving both shear and normal components. Similarly, it is unclear how the stress acceptance criteria are applied conservatively for the line welds as modeled. The basis and justification are needed for staff to perform its safety review.

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY: The technical basis for modeling the "line weld" and pin-connection for the OTCP to shell weld is described in section 8 of design calculation NUH61BTH-0200 provided in response to RSI-2.

The 61BTH Type 1 DSC is shown on drawing NUH61BTH-1000-SAR in UFSAR Section T.1.5. Drawing NUH61BTH-1000-SAR also documents the additional features/options implemented in the 61BTH Type 1 DSC. The 61BTH Type 1 DSC design is the same as the 61BT DSC documented in Appendix K with a few additional features/options.

The ANSYS analytical models for drop analyses of the 61BTH DSC shell assembly are summarized in UFSAR Section T.3.7.4.2.3 and results are summarized in Table T.3.7-2 for the NUHOMS® 61BTH Type 1 DSC shell. Table T.3.7-16 provides the results for ITCP and OTCP stress analysis, but does not include the associated field closure welds. The primary membrane and the primary membrane-plus-bending stresses of 32.34 ksi and 55.21 ksi, respectively, for TR-10 reported in Table 43 of NUH61BTH-0200, Rev. 0 and Table T.3.7-16 of the UFSAR are the controlling load combination stress results for the ITCP, not the OTCP closure welds, and therefore are not applicable for comparison. The maximum stresses in the welds are summarized in Table T.3.7-2, where maximum primary stresses are 0.36 ksi and 11.40 ksi for vertical and horizontal drop accidents, respectively. No new evaluations have been made for this exemption request except for the scaling up of the stresses in a 0.48" closure weld on the OTCP from a design value of 0.50".

Table NB-3217-1 classifies membrane stress at a junction of shell and flat head as local membrane stress and bending stress at the junction as secondary stress. The above classifications can be made provided that the bending moment at the edge is not required to maintain bending stress in the middle of the flathead (i.e., OTCP) to acceptable limits. Due to these classifications, two models are analyzed for Level A conditions. The first model has the OTCP to shell weld explicitly modeled and the second model pins the OTCP to shell at the weld location. The primary stresses are calculated from the second, "pinned" model while the secondary stresses are calculated from the first model where the weld is explicitly modeled. For Level D conditions, where secondary stresses do not need to be compared against an ASME allowable stress limit, only the second model is used for the analysis and primary stresses are evaluated.

For the OTCP weld, the primary stresses are determined assuming the OTCP to DSC shell weld as a pin connection with no moment transfer across the weld. Nodal forces are extracted at the root of the weld model and are used to determine the weld stresses. For the secondary stress evaluation, the OTCP weld is modeled using 3-D solid elements. The stresses resulting from this configuration are categorized as primary + secondary stresses. The primary + secondary stresses are determined by linearizing the stresses along three different paths within the weld model. The resulting maximum membrane and bending stress intensity values (the difference between the principal stresses) are then used for the evaluation.

In summary, the modeling assumptions utilized for the original analysis of the OTCP closure weld are appropriate for the geometry of the weld joint, and provide acceptable results.

***RSI-4**: For the structural integrity evaluation of the line welds, identify ASME Code, Section III, Subsection NB, requirement exceptions with justifications and compensatory measures, including the NB-3210 provisions of the design by analysis evaluation methods and stress acceptance criteria for the subject partial penetration lid-to-shell weld.*

The calculation No. 11042-0204 introduces a design by analysis weld evaluation analysis/evaluation method, which appears to be substantively different from those in Subsection NB. As such, similar to those in Table 4.9-1 of the NUHOMS® UFSAR, a code exceptions summary is needed for the staff to consider the exceptions in performing safety review of the exemption request.

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY:

The intent of calculation 11042-0204 provided in support of the exemption request is to perform an evaluation for a potentially flawed weld condition. It is not intended to perform the design of the weld joint, which is addressed in calculation NUH61BTH-0200 provided in response to RSI-2.

The Code Alternatives for the field closure welds of the NUHOMS® 61BTH system are provided in Table T.3.1-2 of the Standardized NUHOMS® UFSAR, as shown below.

Reference ASME Code Section/Article	Code Requirement	*Alternatives*, Justification & Compensatory Measures
NB-4243 and NB-5230	Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or RT and either PT or MT.	The shell to the outer top cover weld, the shell to the inner top cover/weld, the siphon/vent cover welds and the vent and siphon block welds to the shell are all partial penetration welds. As an alternative to the NDE requirements of NB-5230 for Category C welds, all of these closure welds will be multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in ISG-15 for NDE. The multi-level PT Examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. All of these welds will be designed to meet the guidance provided in ISG-15 for stress reduction factor.

For the subject exemption request, the stress allowable reduction factor of 0.80 defined in ISG-15 is modified to define a greater penalty on stress allowable values in order to address the lack of a compliant PT examination for the affected DSCs. The justification for use of the modified stress allowable reduction factor is provided in the response to RSI-1.

The evaluation methodology utilized to address the potential for flaws to exist in the field closure welds is based on flaw evaluation methodology from Appendix C of Section XI of the ASME B&PV Code, which provides an appropriate analytical process for determining allowable flaw size. It is acknowledged that the use of such flaw evaluation methodology is not recognized by ASME Subsection NB-3210 for design by analysis, since NB-3210 provides design rules under Section III which do not account for flaws in welds. Therefore, the evaluation methodology utilized in the subject exemption request to address the field closure welds with noncompliant PT is founded on the design basis for the NUHOMS® 61BTH system, with the application of appropriate analytically based technical considerations.

Observations

***OBS-1**: Provide the measured heat loads at time of fuel loading for DSCs 11-16.*

Provide a table showing the measured decay heat values at time of fuel loading for DSCs 11-16. This is to provide information regarding how much the actual heat loading is below the design heat limit for each DSC. The information will help assure that fuel cladding and cask component temperatures remain below the limits for each DSC (DSCs 11-16).

This information is required by the staff to determine compliance with 10 CFR 72.236(f).

REPLY: Decay heat values at the time of fuel loading are not measured, but are calculated. Total decay heat loads were calculated based on the calculated decay heat rates of individual fuel assemblies that existed several months prior to the actual DSC loading. These total decay heat loads (in kilowatts – kW) are summarized in the table below:

DSC	Total Calculated Decay Heat (kW)
11	10.96
12	10.88
13	10.79
14	10.77
15	10.75
16	10.72

The design decay heat load for the Type 1 DSC 61BTH is 19.4 kW (Reference TS 1.2.1, Table 1-1t, Figure 1-19).

Based on the heat transfer capabilities of the Type 1 DSC 61BTH design, the Technical Specifications (i.e., TS 1.2.18) do not impose any time restrictions for the Transfer Cask when loaded with this type of DSC.

***OBS-2**: Provide the maximum DSC surface temperatures measured at the closure welds at the time of PT examination (DSCs 11-16).*

Provide a table listing the maximum DSC surface temperatures measured at the inner top cover plate weld, the siphon port cover plate weld, and the vent port cover plate weld, at the time of PT examination for all DSCs 11-16.

The information will provide a basis to assure that the satisfactory PT exams have been completed on the closure welds of each DSC (DSCs 11-16).

This information is required by the staff to determine compliance with 10 CFR 72.236(f).

REPLY: The following table provides the highest DSC surface temperatures (in degrees Fahrenheit - °F) that were recorded in work orders for the listed closure welds at the time of PT examination.

DSC	Weld Location	Surface Temp (°F)
11	Inner Top Cover Plate	110
11	Siphon Port Cover Plate	149
11	Vent Port Cover Plate	148
12	Inner Top Cover Plate	158
12	Siphon Port Cover Plate	160
12	Vent Port Cover Plate	162
13	Inner Top Cover Plate	179
13	Siphon Port Cover Plate	176
13	Vent Port Cover Plate	189
14	Inner Top Cover Plate	145
14	Siphon Port Cover Plate	190
14	Vent Port Cover Plate	190
15	Inner Top Cover Plate	151
15	Siphon Port Cover Plate	128
15	Vent Port Cover Plate	130*
16	Inner Top Cover Plate	138
16	Siphon Port Cover Plate	136
16	Vent Port Cover Plate	148

* This value is the highest credible recorded value. One other erroneously high value was recorded for the Vent Port Root PT, and has been discounted. This error is recorded and resolution is tracked in NSPM's corrective action program (CAP 1453122).

***OBS-3**: Clarify the intent of, or modify, as appropriate, the statement in Section 2.0, Conservatism/Assumptions on page 4 of the exemption request, "[h]owever, conservatively the secondary stresses are scaled, increased, for the reduction in the OTCP weld size."*

The "line welds" assumption for the lid-to-shell configuration results in weld reactions in shear and tensile force components, which are necessitated for force equilibrium for the inner and outer top cover plates resisting the canister internal pressure and canister drop inertia forces. As such, stresses associated with the line welds ought to be categorized as primary for invoking appropriate stress acceptance criteria.

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY: Addressed in the reply to RSI-3.

OBS-4: *Clarify the intent of, or modify, as appropriate, the statement in Section 7.1 on page 7, OTCP weld for reduced Weld Size Evaluation, "[t]he three components of the secondary stress are membrane (Pm), bending (Pb) and thermal stress (Q)."*

Only thermal stress can be considered secondary. See technical basis comment in the previous observation (OBS-3).

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY: Addressed in the reply to RSI-3.

OBS-5: *For Table 1 explain the basis for determining the Service Level D, allowable stresses of 32.4 ksi, 29.4 ksi, and 31.1 ksi for load cases TR-9, TR-10, and TR-11, respectively.*

Identical at-temperature stress allowables should be used for the same weld analyzed.

This information is required by the staff to determine compliance with 10 CFR 72.236.

REPLY: The stress allowable values reported in Table 1 for load cases TR-9, TR-10 and TR-11 differ from one another because they are taken at different temperatures; each case using the temperature associated with the particular load cases analyzed. This accounts for the difference in stress allowable values between the load cases. Refer to Section 7.5 of AREVA calculation NUH61BTH-0200.

References:

1. NSPM letter to NRC Document Control Desk, L-MT-14-016, Exemption Request for Dry Shielded Canisters 11 - 16 Due to Nonconforming Dye Penetrant Examinations, dated July 16, 2014 (ADAMS Accession No. ML14199A370).

2. NRC letter to Karen D. Fili, Exemption Request for Dry Shielded Canisters 11-16 Due To Nonconforming Dye Penetrant Examinations, Docket No. 72-58 – Supplemental Information Needed, dated September 11, 2014.

L-MT-14-082
Enclosure 2

ENCLOSURE 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.

CALCULATION PACKAGE 1301415.301

TITLE:

DEVELOPMENT OF AN ANALYSIS BASED

STRESS ALLOWABLE REDUCTION FACTOR (SARF)

DRY SHIELDED CANISTER (DSC) TOP CLOSURE WELDMENTS

REVISION 0, OCTOBER 2014

39 pages follow

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1301415.301

Project No.: 1301415

Quality Program Type: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Monticello ISFSI – DSC 11 through 16 Exemption Request

CONTRACT NO.:
1005, Release 48, Amendment 6

CLIENT:
Xcel Energy

PLANT:
Monticello Nuclear Generating Station

CALCULATION TITLE:
Development of an Analysis Based Stress Allowable Reduction Factor (SARF) – Dry Shielded Canister (DSC) Top Closure Weldments

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 – 30 A-1 – A-2 B-1 – B-7	Initial Issue	Richard Bax 10/23/14 James W. Axline 10/23/14	Preparer: Wilson Wong 10/23/14 Checkers: J. Wu 10/23/14 C. Fourcade 10/23/14

Structural Integrity Associates, Inc.®

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1.0 OBJECTIVE

The objective of this calculation is to develop a quantitative basis for a stress allowable reduction factor (SARF) to address weld quality in the inner top cover plate (ITCP) and outer top cover plate (OTCP) weldments of the NUHOMS dry shielded canister (DSC) system. This workscope is in support of the USNRC CofC Exemption submittal for DSC's 11 through 16, currently at the Monticello Nuclear Generating Plant (MNGP).

Weld quality is described as a global effect, for which a factor is used to reduce the stress allowables to account for potentially less than sound weldments. The SARF has historically been tied to the level of non-destructive examination (NDE) performed on the weldment. That is to say, the greater the degree of NDE performed (such as volumetric) the greater the SARF (less reduction in stress allowable).

The ASME Code [5, NG-3352] contains values for SARF for a range of NDE. Specifically, a VT only scope of NDE would state an SARF of 0.35 for a partial penetration weldment. However, it should be clearly noted that the ASME Code table for SARF's has no limitations/definitions/requirements on the weld size, the weld/base metal materials, the welding configuration, the welding position, and most importantly, the welding process. In addition, as this table is from NG, the level and comprehensiveness of the design analysis is less than that for an NB-type component, such as the DSC. The 0.35 SARF is a conservative factor that addresses all types of welding. In the case of the DSC weldments, these are specific joint geometries, with high quality materials, favorable welding positions, and again, most importantly, a high purity welding processes (GTAW), and therefore, strict adherence to the 0.35 SARF number for a VT only NDE examination weldment is not warranted.

The intent of this calculation, for this exemption request only, is to evaluate a series of postulated weld flaws and determine, for each configuration, the effect on the unflawed stress results. The effect of the stress results will be comparative, performed by comparing the analysis results of the flawed configuration to those from the same geometry, but in an unflawed configuration.

The determination of the impact on stress results will be performed by finite element analysis (FEA) in which selected elements of the ITCP and OTCP weldments will be "removed" to represent "flawed/suspect" weld quality.

Various distributions of flaw size (length and depth) and frequency (spacing), will be examined.

The intent of this calculation is to analytically determine the type of flaw distribution that would justify a specific SARF. A separate work scope has been performed to evaluate, for the specific DSC weldments (DSC's 11 through 16), what are the expected type and density of flaw distributions. It is the overall intent for this project workscope that it can be shown that the type of flaw distribution, which would support an acceptable SARF, will be of significantly greater magnitude than those populations that would be expected for the type of welding used for the DSC weldments.

2.0 TECHNICAL APPROACH

The determination of the impact of weld quality on stress results (SARF) will be performed by the finite element methods. Both the flawed and unflawed geometry of the top end of the DSC will be modeled. To represent the presence of postulated flaws, selected elements within the model will be removed and analyses performed using representative load cases. By comparing the results from the unflawed and flawed FE models for these loads cases, a ratio, or stress allowable reduction factor can be determined. A range of flaws will be analyzed to develop a range of SARF values corresponding to the range of flaw populations.

Typical types of flaws will be considered, and a range of distributions of flaw size (length and depth) and frequency (spacing), will be examined.

Three types of flaws will be addressed.

- Radial: a postulated flaw oriented in a plane radial to the DSC longitudinal axis and spanning the weldment from cover plate to shell.
- Circumferential: a planar flaw oriented in a plane parallel to the DSC axis and oriented circumferentially around the DSC.
- Laminar: a planar flaw in a plane perpendicular to the longitudinal axis of the DSC and spanning the weldment from cover plate to shell.

In the determination of what flaw types to analyze in the OTCP and the ITCP, the size/volume of the weldment was considered. The OTCP weldment is both large in size and volume absolutely, and also relative, to the weldment volume of the ITCP. Therefore, all three types of flaws are evaluated for the OTCP. The ITCP weldment, due to its reduced weldment size, is evaluated using a single flaw of significant cross-section, which represents elements of all three types. Figures showing these flaw types, location, and orientation are shown in Figures 2 through 9.

2.1 Finite Element Model and Flaw Simulation

A single finite element model (FEM) is developed using the ANSYS finite element analysis software [2]. The model represents a 180° sector of the upper end of the DSC. The model includes the outer top cover plate and weldment, the inner top cover plate and weldment, and a portion of the DSC shell.

The FEM utilizes the ANSYS 3-D structural element (SOLID45). The unflawed model contains all portions of the two weldments.

The modeling of the postulated flaw is done by "killing" the selected elements that represent the flaw size and location, using the EKILL command in ANSYS. This command deactivates the element such that it contributes near zero stiffness to the overall stiffness matrix. The result is a redistribution of loading and stresses around "killed" elements.

The ANSYS model of the top end geometry is shown in Figure 1 which illustrates the full model and then localized sections through the OTCP and ITCP.

3.0 ASSUMPTIONS / DESIGN INPUTS

The top end geometry of the DSC is defined in Reference 3. The OTCP, ITCP, and DSC shell dimensions, as well as the materials, are provided in Reference 3. A number of assumptions were made during development of the finite element model, which are listed as follows:

- The model consists of a half-symmetric portion of the inner top cover plate (ITCP), outer top cover plate (OTCP), and the top 20 inches of the outer DSC cylinder. The 20 inches equates to greater than $4.0\sqrt{Rt}$, thus avoiding any end affects at the free end constraint. The model is constructed of approximately 840,000 SOLID45 elements to ensure adequate mesh refinement for the ITCP and OTCP welds in the circumferential direction.
- The OTCP is modeled with the top surface set 1/8 of an inch below the end of the DSC. The J-groove weld preparation is as shown in Reference 3. The weldment is shown flush with the surface of the OTCP and not set below, as is allowed by the Reference 3 field assembly drawing. The modeled set back weldment is considered acceptable as this is a comparative analysis and the same geometries are used in both the flawed and unflawed condition.
- The ITCP is modeled as a flat plate and the closure weldment is modeled flush with the top surface of the ITCP.
- The DSC shell, the OTCP, the ITCP, and the OTCP and ITCP weldments are modeled as SA-240, Type 304 stainless steel. Material properties are taken from Reference 4. Standard room temperature material properties for Type 304 stainless steel are used: Young's Modulus = 28.30E6, Density = 0.283 lbs/in^3, and Poisson's Ratio of 0.3.
- The analysis is performed at 70°F. This temperature is selected as this is a comparative analysis and both the unflawed and flawed runs utilize the same temperature.
- The bottom edge of the outer cylinder is fixed in the axial and circumferential directions, and symmetry boundary constraints are placed on the symmetry plane. For the side drop runs, the outer cylinder is released in the circumferential direction and is supported at the point of "impact" via radial displacement couples to a support block with reduced stiffness properties.
- The analyses are all treated as elastic.
- The localized effects of the vent and siphon block and the ITCP weldment are not modeled. This is acceptable as the weldment connection to the V/S block (1/4" groove) is similar to the majority portions of the ITCP weldment, and the intent is to determine the effects of global weld quality, not localized stress concentrations. The effect of stress discontinuity at the V/S block will be addressed by the design analysis which models this explicitly, and then uses the SARF to further modify the stress allowables.
- The siphon/vent port cover plates are not modeled as the nominal stresses (primarily due to pressure) are sufficiently low to accommodate extremely low SARF's. Assuming a 3/16" closure groove weld [3] on a nominal 2 inch diameter cover plate results in a weld shear stress of

less than 500 psi. Thus even a worst case SARF of 0.10, would be acceptable given the nominal weld filler metal shear stress allowable of 0.6 Sm [5, NB-3227.2] = 0.6 * ~16 ksi = ~9.6 ksi.

- Dimensions for the components are taken as the nominal. This is acceptable as this is a comparative analysis.
- The evaluated paths for which the stress results are extracted and used for comparison (flawed vs unflawed) are shown in Figure 13.

4.0 CALCULATIONS

The determination of the SARF, as a function of weld quality (number and density of postulated flaws), is performed using two load cases. The pressure load is the primary normal and off normal load for these weldments and consists of internal pressure applied to the inner top cover and outer top cover. The specific definition and modeling details are described below for the pressure load case.

The drop load cases consist of a canister end drop, a canister corner drop, and a canister side drop. For this comparative analysis the canister side drop load case is utilized as it best represents the behavior of the drop event (an event that is germane to the MNGP ISFSI DSC hardware configuration) and is a more easily evaluated/modeled condition. The side drop load case develops localized stresses along a line of contact similar to the corner drop. The specific details for the side drop load case are described below.

4.1 Pressure Loading

The pressure loading consists of a nominal 100 psig internal pressure applied to the top cover plates. For evaluation of the ITCP (the nominal pressure boundary) weldment quality, the pressure is applied to the inside surface of the ITCP and the DSC shell, and the contacting surfaces between the ITCP and OTCP are bonded with sliding capability using ANSYS contact elements to allow for load transfer from the ITCP to the OTCP. For the ITCP pressure analysis, CONTA174 and TARGE170 contact elements were used to prevent the ITCP from penetrating the OTCP. In these cases the OTCP acts as a non-pressure retaining structural support for the ITCP. Figure 11 shows the displaced shape for the ITCP pressure load case.

For evaluation of the OTCP weldment quality, the pressure is applied only to the inside surface of the OTCP and the inside surface of the DSC. The ITCP and the weldment to the shell are both contained within this model and are not modeled as containing flaws, nor are they loaded by pressure. The intent of applying the pressure loading to the OTCP alone is to maximize the response of the OTCP-to-DSC shell weldment, as a result of postulated flaws within the weld. Applying the pressure to the ITCP, which in turn will load the OTCP, will diminish the response of the OTCP, as there exists supplemental stiffness from the ITCP. Figure 10 shows the displaced shape for the OTCP pressure load case.

4.2 Side Drop Loading

The side drop loading case is evaluated as a static 75G load case in which the FEM of the DSC shell is oriented with the symmetry plane in the direction of the drop. For the side drop analysis, the same contact element types (CONTA174 and TARGE170) were used to prevent the ITCP from penetrating the DSC outer cylinder. These are not used for the OTCP weld prep-to-DSC shell potential contact region, as the area of potential contact is small relative to the OTCP weld size.

To simulate the support of the transfer cask, the lower 20° of the DSC model is supported by a material which represents the stiffness of the transfer cask given that there is a difference in diameter between the DSC and the transfer cask. In the transfer condition, the DSC is supported within the Transfer Cask on thin guide rails, and the use of a lessor stiffness support in the lower 20° degree region is representative. Again this is a comparative analysis and the intent is to show the effect of weld quality in the weldments in the most highly stressed area of contact, which is at bottom dead center. Radial displacement couples between the DSC and support block are used. Figure 12 shows the geometry of this load case.

5.0 RESULTS OF ANALYSIS

The determination of the SARF for a given postulated flaw population is performed by extracting the stress results from the unflawed geometry, and the flawed geometry for the specific load case. These stresses are extracted and linearized along identical paths to capture the change in stresses due to the missing/flawed elements.

The comparison to determine the change in stress results, as a result of the postulated flaw population, typically compares the linearized membrane (P_m) and membrane plus bending ($P_m + P_b$) stress intensities for a path adjacent to the postulated flaw and at other regular spacings between the postulated flaws. These discrete ratios are then combined to produce a weighted SARF for the weld flaw pattern. Figure 13 shows the path locations and orientations for the three types of flaws for which stresses are extracted.

In general the comparison of stress results is done by comparing linearized membrane (P_m) and membrane plus bending ($P_m + P_b$) stress intensities. However, in the case of the side drop event for the radial and laminar flaws, the high compressive stresses in all three principal stresses make the use of stress intensity not representative. In these cases, where all three principal stresses are compressive, and the resultant stress intensity is of lesser magnitude than the principal stresses, the resulting SARF's are unrealistic. In these cases the greater stress values of the three principal stresses are combined by SRSS and compared for the flawed and unflawed configuration.

An initial set of postulated flaw populations for the radial, circumferential and laminar flaw were developed and analyzed. Subsequent to initial runs, additional flaw populations for the radial and circumferential flaw cases were run. The specific geometry of the flaw populations are shown in Tables 1 through 4, along with the resulting SARF's.

It should be noted that the intent of the calculation is to show a flaw population that is severe and thus demonstrate that large flaw populations (size, length, and density) can be tolerated, as the calculated SARF is acceptable. In the selection of the flaw population parameters, the depth of the flaws is typically set as a through-wall flaw. Obviously, such a flaw would have been unacceptable, and would have been identified by leak test examination. However, the intent of this calculation is to address structural capacity of the weldment, not confinement.[1] Thus the use of the through-wall flaw allows for a conservative determination of the SARF.

Table 1 documents the calculated SARF's for the OTCP weldment subjected to pressure loading. Table 2 documents the calculated SARF's for the OTCP weldment subjected to the side drop loading.

Table 3 documents the calculated SARF's for the ITCP weldment subjected to pressure loading. Table 4 documents the calculated SARF's for the ITCP weldment subjected to the side drop loading.

Table 5 presents the axial deflection at the centerline of the OTCP for the various flaw configurations analyzed for the pressure load case. The intent is to show that, as expected, the stiffness of the combined OTCP and ITCP is greater (less deflection) than the OTCP alone. This is the reason that the pressure loading was applied to the OTCP alone, so as to maximize the deflection of the OTCP, and therefore challenge to the OTCP weldment. A review of the table shows that the change in deflection of the OTCP as a result of the introduction of postulated flaws, in either the OTCP or ITCP weldment, is relatively low (< 15% in the worst case). Thus the evaluation of flaws does not require the explicit evaluation of concurrent flaws in the OTCP and ITCP, as their responses (unflawed/flawed) are basically similar, and this is a comparative evaluation.

In addition, a comparisons of the deflections of the OTCP in the unflawed and postulated flawed cases shows that for the less severe, but still significant flaw populations (Radial 2, Laminar, Circ 3, and Circ 4), the change in response (OTCP deflection) is small, typically 1% or less. It can therefore be presumed that a mix of flaw types would produce similar results as that for a single flaw type, e.g. a mix of radial, laminar, and circumferential flaws would have similar results as that for the bounding single flaw type. The worst case SARF for the selected flaw types will be utilized, thus any substitution of lesser SARF flaws (e.g. laminar) for greater SARF flaws (Circ) would be bounded.

Finally, the postulated 50% circumferential flaw for Circ 4 is positioned in the upper half of the weldment. The change in SARF values (Tables 3 and 4) between the Circ 3 and Circ 4 cases is an increase of ~4% for the pressure case, and ~14% for the side drop case. A 50% through-wall flaw, located in the lower portion of the weldment, would have an SARF no worse than the Circ 3 case, and the Circ 3 case SARF, for both pressure and side drop, is greater than 0.80. The placement of the 50% through-wall flaw in the lower half of the weldment would thus not change the results to a point where the Circ 3 case would not be bounding.

---

[1] The results demonstrate that the remaining ligaments of the DSC weldments have sufficient structural capacity, even with very severe and conservative penalties (postulated flaws) for nonconforming PT examinations, to perform their design function of restraining the OTCP and ITCP's, and additionally maintaining the confinement function during all service level load cases.

6.0 CONCLUSIONS AND DISCUSSION

The OTCP and ITCP weldments are made using both materials and processes, and in conditions which would result in high quality (very small flaw distribution). Specifically it is a stainless steel weldment made with argon cover gas in a flat position using a machine GTAW process. As such, concerns over weld porosity are minimized and the machine welding process will produce a very uniform and consistent weldment. Report 1301415.405 [1, See Appendix B] details the expected flaw distribution for this type of weldment.

A review of Tables 1 through 4 documents the calculated SARF for the selected flaw populations. The question of which flaw population to consider representative or typical, or bounding is based not on these analytical results but on the separate Reference 1 report. This report is based on the actual elements of the OTCP and ITCP welding, and considers industry experience and ISFSI Vendor experience [1, See Appendix B].

Reference 1 states in the conclusion that:

> *It is suggested a bounding subsurface defect condition is conservatively represented as an intermittent lack of fusion (LOF) defect evenly distributed along the canister weld. Further, the total length for LOF is conservatively estimated at 25% of the canister cover plate weld circumference. The estimated through thickness dimension is 1/8 inch, because this dimension represents a maximum weld bead thickness. One eighth inch is considered to be a conservative assumption, because it is recognized that most weld beads will be thinner especially as the weld cavity begins to fill. No credit is being taken for remelting even though remelting is normally associated with multipass welding."*

Comparing this to the analyzed flaw populations:

> OTCP: Both the radial and laminar flaws are not representative of the circumferentially oriented flaw described above. However, in both cases, the postulated flaws for these types are full thickness and full width, and thus would be considered more severe than a 1/8" thick, 25% total weld length flaw, with a width of one weld bead. As an example, the laminar flaw is the full width of the weld, and covers 72% of the circumferential arc. The radial Configuration 2 flaw (more limiting), shown in Figure 3, is a full height (through-wall) flaw, spanning the full weldment width, and occurring less than 2" apart.
>
> The circumferential flaw, Configuration 3, shown in Figure 7, is a full height (through-wall) flaw, 1" long and occurring every 5". The 1" in 5" spacing is a 20% occurrence of postulated flaws, which although less than 25%, is tempered by the fact that the analyzed flaw is full height, not the expected one bead thickness dimension (~ 1/8") described above. With this consideration, the Configuration 3 circumferential flaw bounds the "conservatively assumed" flaw stated in Reference 1.

ITCP: The 360 degree embedded flaw postulated and evaluated (Figure 9), is much more adverse than the expected flaw of Reference 1 described above.

In both the OTCP and the ITCP weldments, the weld is a multi-layer weldment, and both received multi-level VT and PT examinations. Although the PT cannot be credited, the VT can be assumed to have seen large surface breaking flaws. As a further argument that the postulated and analyzed flaws are bounding for flaws that would have not have been identified by the VT exams, the likelihood that multiple through–layer thickness flaws of the postulated percentage of arc length (e.g. the Circ 3 case flaw covers 20% of the total arc length) would occur in every layer, and would also line up with flaws below and above to create a through-wall combined flaw, and not be detected by the multiple VT's, is highly unlikely and not realistic.

Again the use of through-wall flaws is done to evaluate the structural integrity of the weldments. The validation of confinement of the weldments was separately confirmed by successful leak testing.

7.0 REFERENCES

1. SI Report No. 1301415.405, Revision 0, "Expectations for Field Closure Welds on the AREVA-TN NUHOMS 61BTH Type1 & 2 Transportable Canister for BWR Dry Fuel Storage," October 2014, SI File No. 1301415.405. [Appendix B]

2. ANSYS Mechanical APDL and PrepPost, Release 14.5 (w/ Service Pack 1), ANSYS, Inc., September 2012.

3. AREVA Design Drawings for the 61BTH, Type 1 and 2, NUH61BTH-3000, Rev 1, "NUHOMS 61BTH Type 1 DSC Main Assembly," and NUH61BTH-4008, Rev 1, NUHOMS 61BTH Type 1 & 2 Transportable Canister for BWR Fuel Field Welding, PROPRIETARY SI File No. 1301415.201P.

4. ASME Boiler and Pressure Vessel Code, Section II, Part D, Material Properties, 2004 Edition.

5. ASME Boiler and Pressure Code, Section III, Division 1, Rules for Construction of Nuclear Facility Components, 2004 Edition.

Structural Integrity Associates, Inc.®

Table 1: OTCP Stress Reduction Factor Results – Pressure Loading

	PRESSURE LOADING																				
	Radial			Radial #2			Laminar			Circ #1			Circ #2			Circ #3			Circ #4		
	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)
Average	0.908	0.762	0.900	0.955	0.879	0.973	0.911	0.911	0.950	0.515	0.534	0.436	0.759	0.771	0.703	0.924	0.920	0.888	0.940	0.956	0.919
MIN	**0.762**			**0.879**			**0.911**			**0.436**			**0.703**			**0.888**			**0.919**		
	Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			50% Part Through Wall Flaw		
	Pattern Arc Spacing (in)		0.864	Pattern Arc Spacing (in)		1.734	Pattern Arc Spacing (in)		5.760	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184
	Flaw Width (in)		0.144	Flaw Width (in)		0.144	Flaw Arc Length (in)		4.176	Flaw Arc Length (in)		3.600	Flaw Arc Length (in)		2.016	Flaw Arc Length (in)		1.012	Flaw Arc Length (in)		1.012
	Un-Flawed Arc Spacing (in)		0.720	Un-Flawed Arc Spacing (in)		1.590	Un-Flawed Arc Spacing (in)		1.584	Un-Flawed Arc Spacing (in)		1.584	Un-Flawed Arc Spacing (in)		3.168	Un-Flawed Arc Spacing (in)		4.172	Un-Flawed Arc Spacing (in)		4.172

Table 2: OTCP Stress Reduction Factor Results – Side Drop Loading

	SIDE DROP																	
	Radial			Laminar			Circ #1			Circ #2			Circ #3			Circ #4		
	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)	Pm	Pm+Pb(I)	Pm+Pb(O)
Average	0.976	0.921	0.912	0.882	0.957	1.000	0.542	0.606	0.762	0.720	0.756	0.903	0.846	0.861	0.972	0.979	0.974	0.974
MIN	**0.912**			**0.882**			**0.542**			**0.720**			**0.846**			**0.974**		
	Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			Through Wall Flaw			50% Part Through Wall Flaw		
	Pattern Arc Spacing (in)		0.864	Pattern Arc Spacing (in)		5.760	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184	Pattern Arc Spacing (in)		5.184
	Flaw Width (in)		0.144	Flaw Arc Length (in)		4.176	Flaw Arc Length (in)		3.600	Flaw Arc Length (in)		2.016	Flaw Arc Length (in)		1.012	Flaw Arc Length (in)		1.012
	Un-Flawed Arc Spacing (in)		0.720	Un-Flawed Arc Spacing (in)		1.584	Un-Flawed Arc Spacing (in)		1.584	Un-Flawed Arc Spacing (in)		3.168	Un-Flawed Arc Spacing (in)		4.172	Un-Flawed Arc Spacing (in)		4.172

Table 3: ITCP Stress Reduction Factor Results – Pressure Loading

ITCP		
Pressure		
Pm	Pm+Pb(I)	Pm+Pb(O)
0.964	1.000	0.954
0.954		
Flaw Cross Section Area		0.006 in^2
Pattern Arc Spacing (in)		5.184
Flaw Arc Length (in)		2.590
Flaw Arc Spacing (in)		2.590

Table 4: ITCP Stress Reduction Factor Results – Side Drop Loading

ITCP		
Side Drop		
Pm	Pm+Pb(I)	Pm+Pb(O)
1.000	0.931	1.000
0.931		
Flaw Cross Section Area	0.006 in^2	
Pattern Arc Spacing (in)	5.184	
Flaw Arc Length (in)	2.590	
Flaw Arc Spacing (in)	2.590	

Table 5: OTCP and ITCP Deflection Load Cases – Pressure Load Case

Component	Flaw Type	Axial Deflection - Unflawed Configuration (inches)[(1)]	Axial Deflection - Flawed Configuration (inches)[(1)]	Ratio of Increase (Percent change) Flawed/Unflawed
OTCP	Radial 1	0.9089	0.921	1.3%
	Radial 2	0.9089	0.9149	0.7%
	Laminar	0.9089	0.918	1.0%
	Circ 1	0.9089	1.0391	14.3%
	Circ 2	0.9089	0.9507	4.6%
	Circ 3	0.9089	0.9208	1.3%
	Circ 4	0.9089	0.9169	0.9%
ITCP	Circ	0.629	0.6314	0.4%

Note:

1) The deflection value was taken at the center top of each plate.

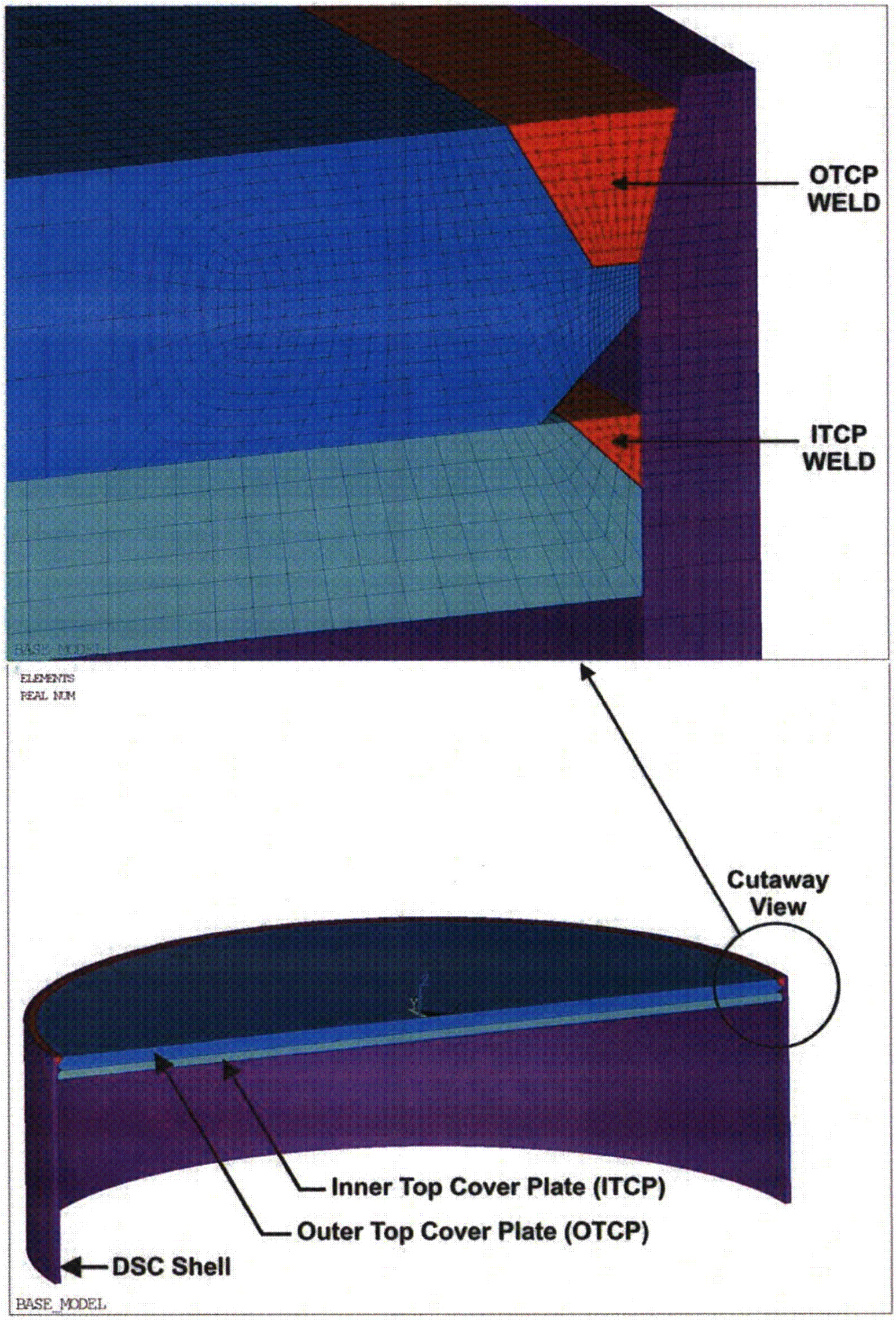

Figure 1. Finite Element Model and OTCP and ITCP Details

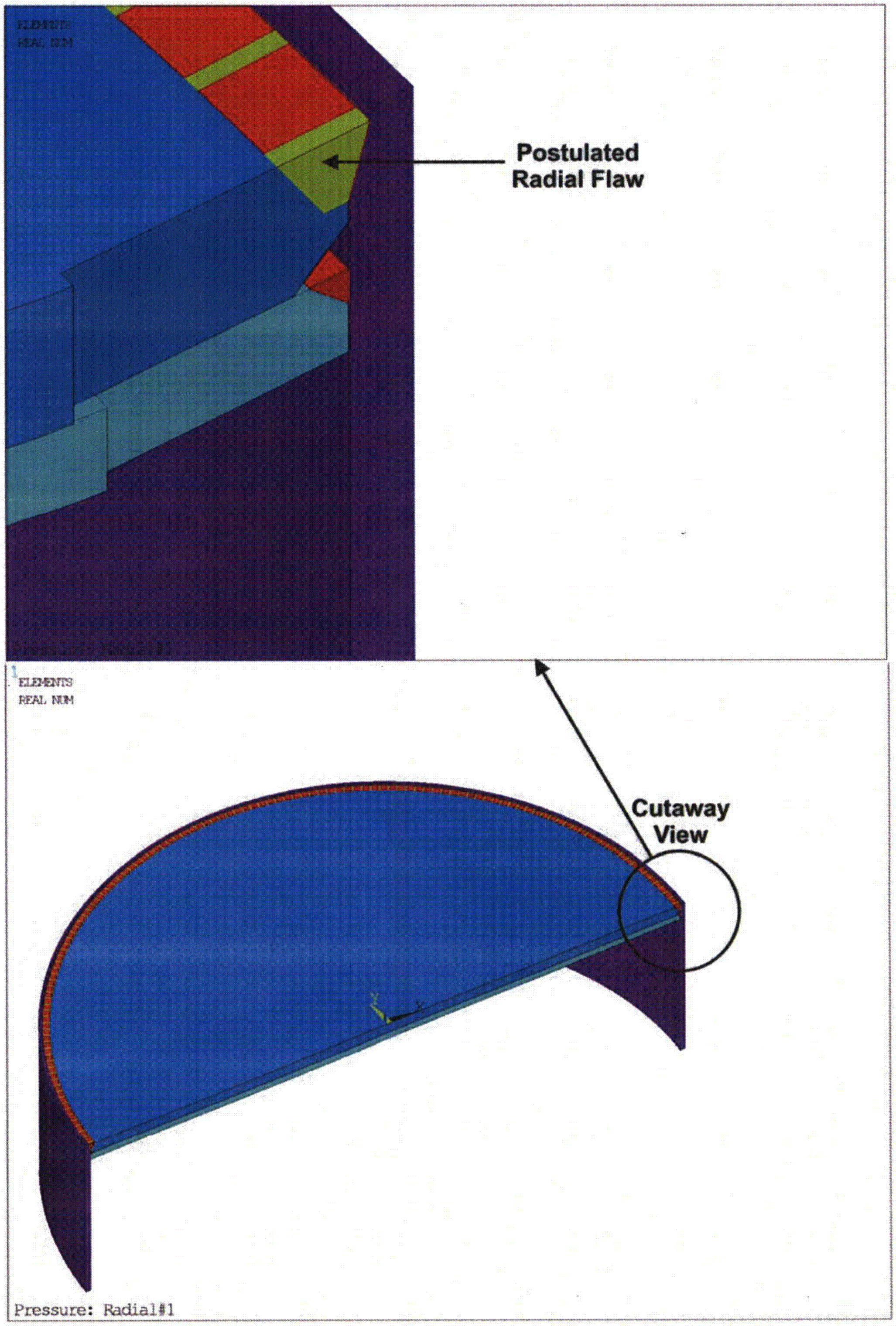

Figure 2. OTCP Postulated Flaw Configuration – Radial #1

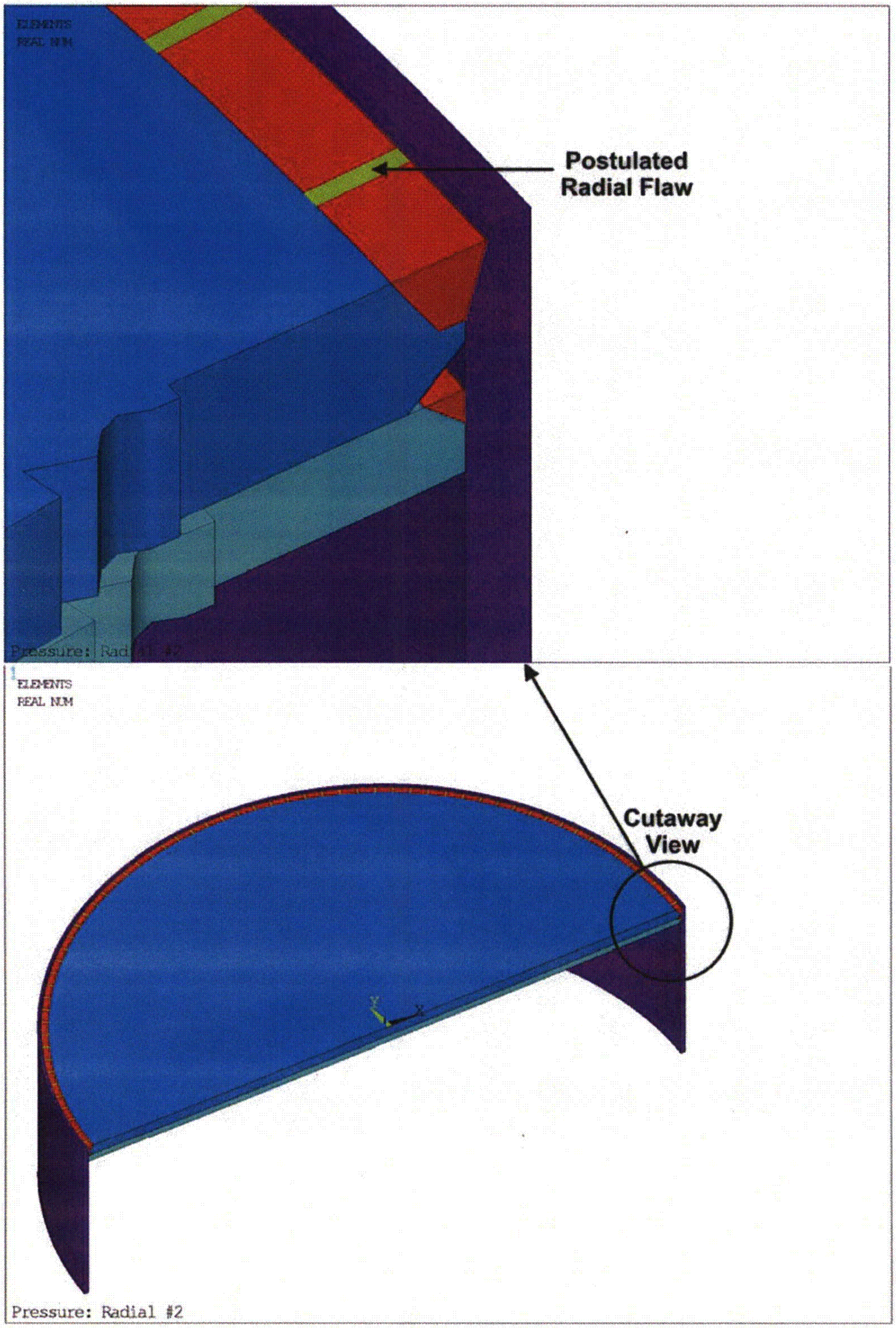

Figure 3. OTCP Postulated Flaw Configuration – Radial #2

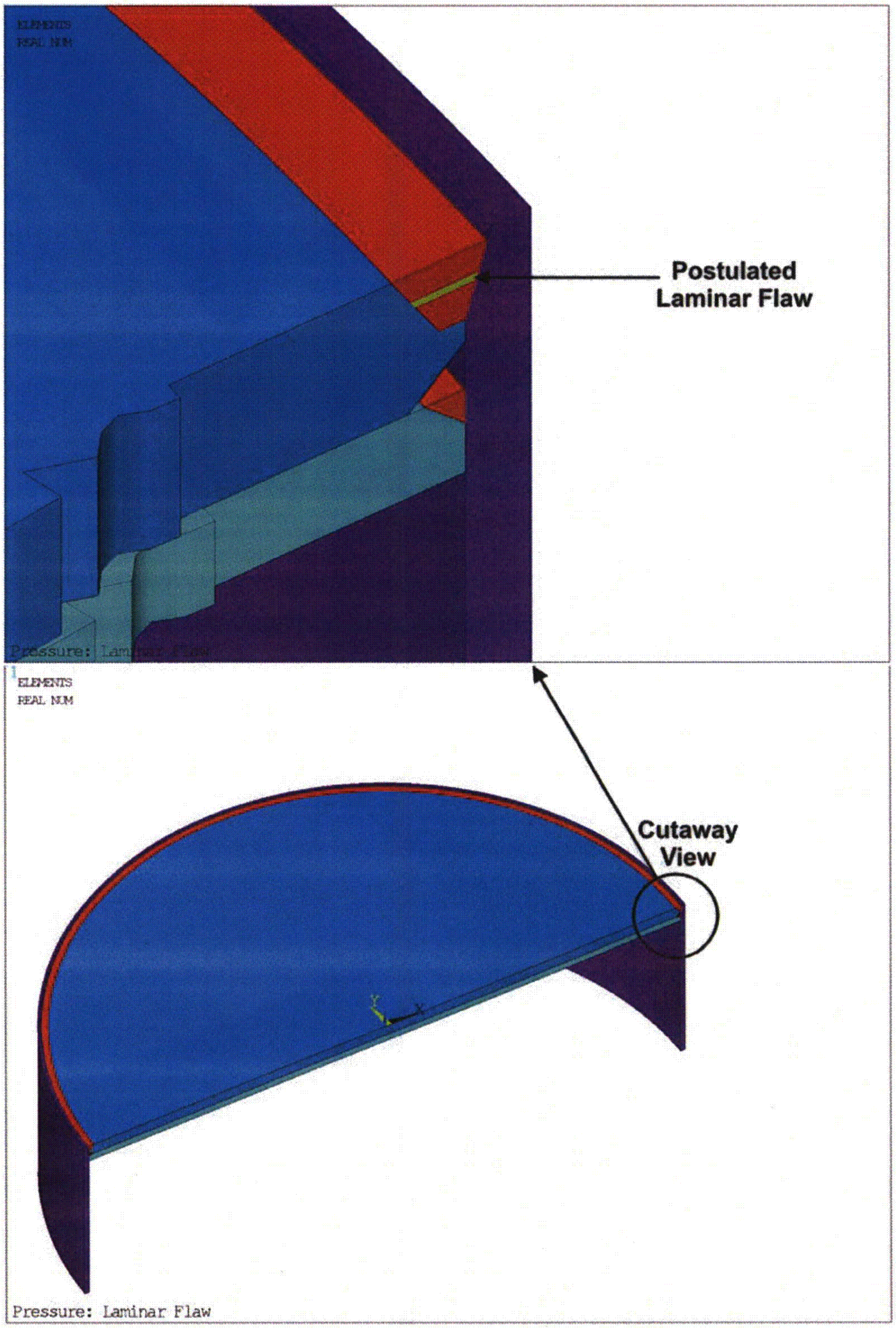

Figure 4. OTCP Postulated Flaw Configuration – Laminar

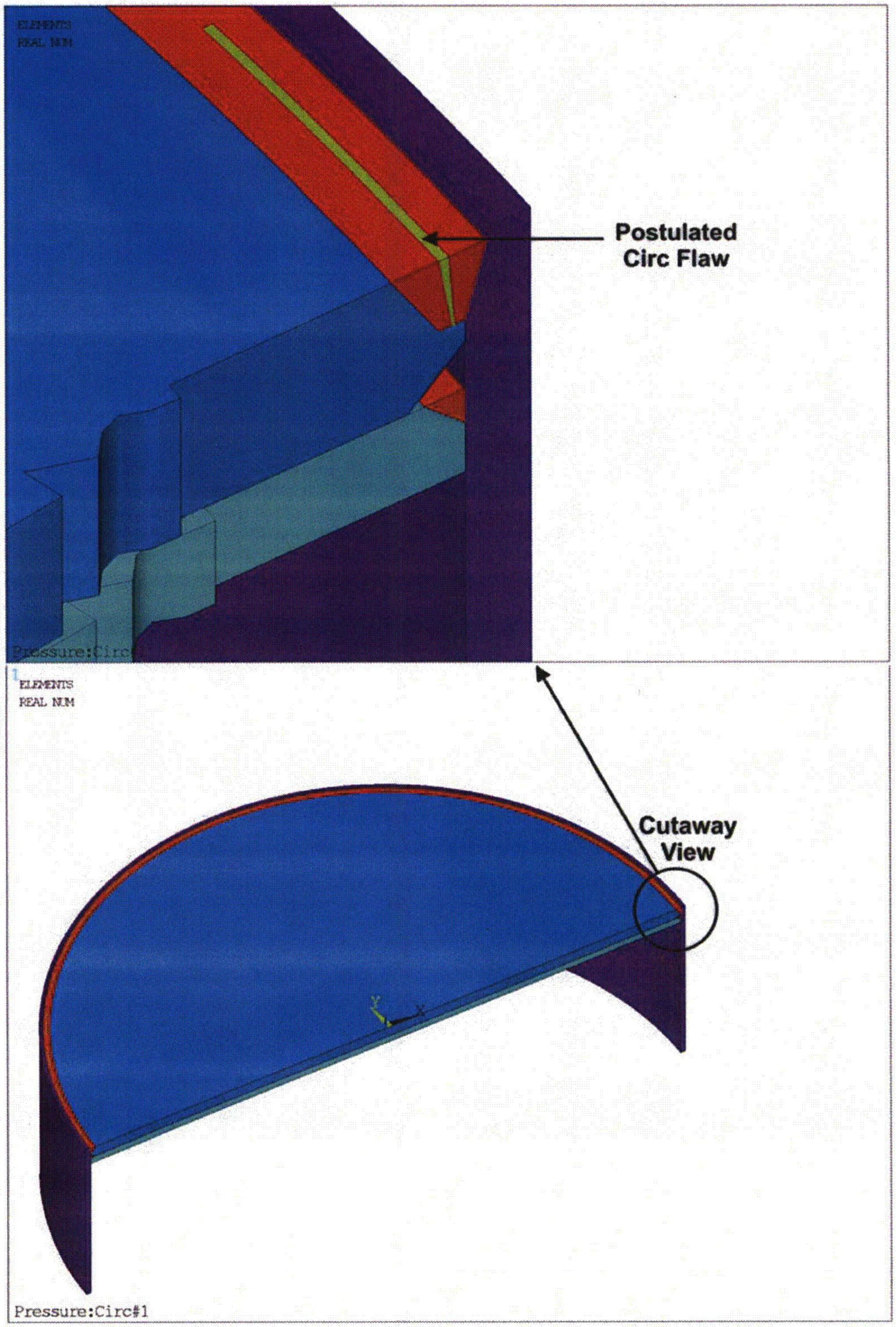

Figure 5. OTCP Postulated Flaw Configuration – Circumferential #1

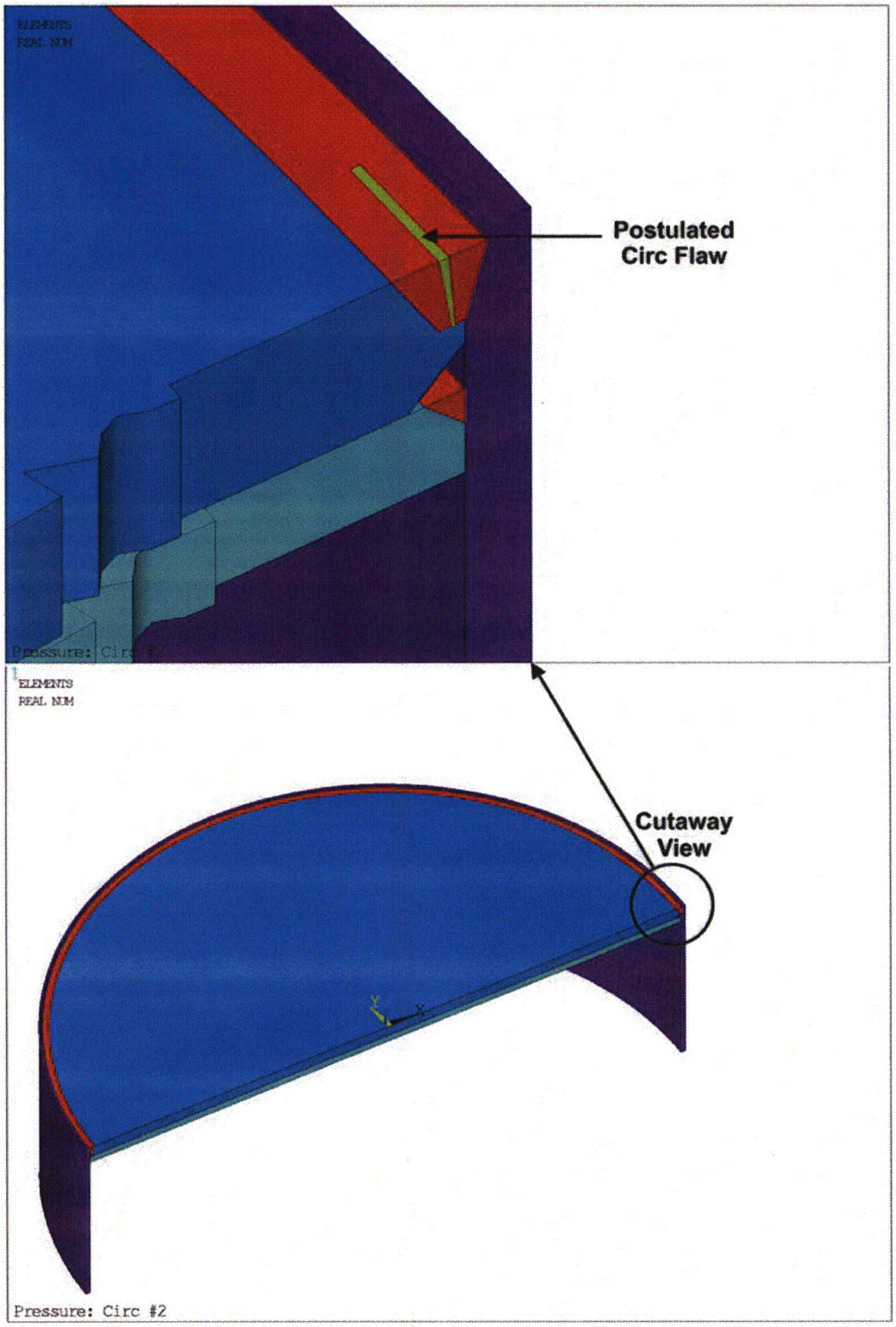

Figure 6. OTCP Postulated Flaw Configuration – Circumferential #2

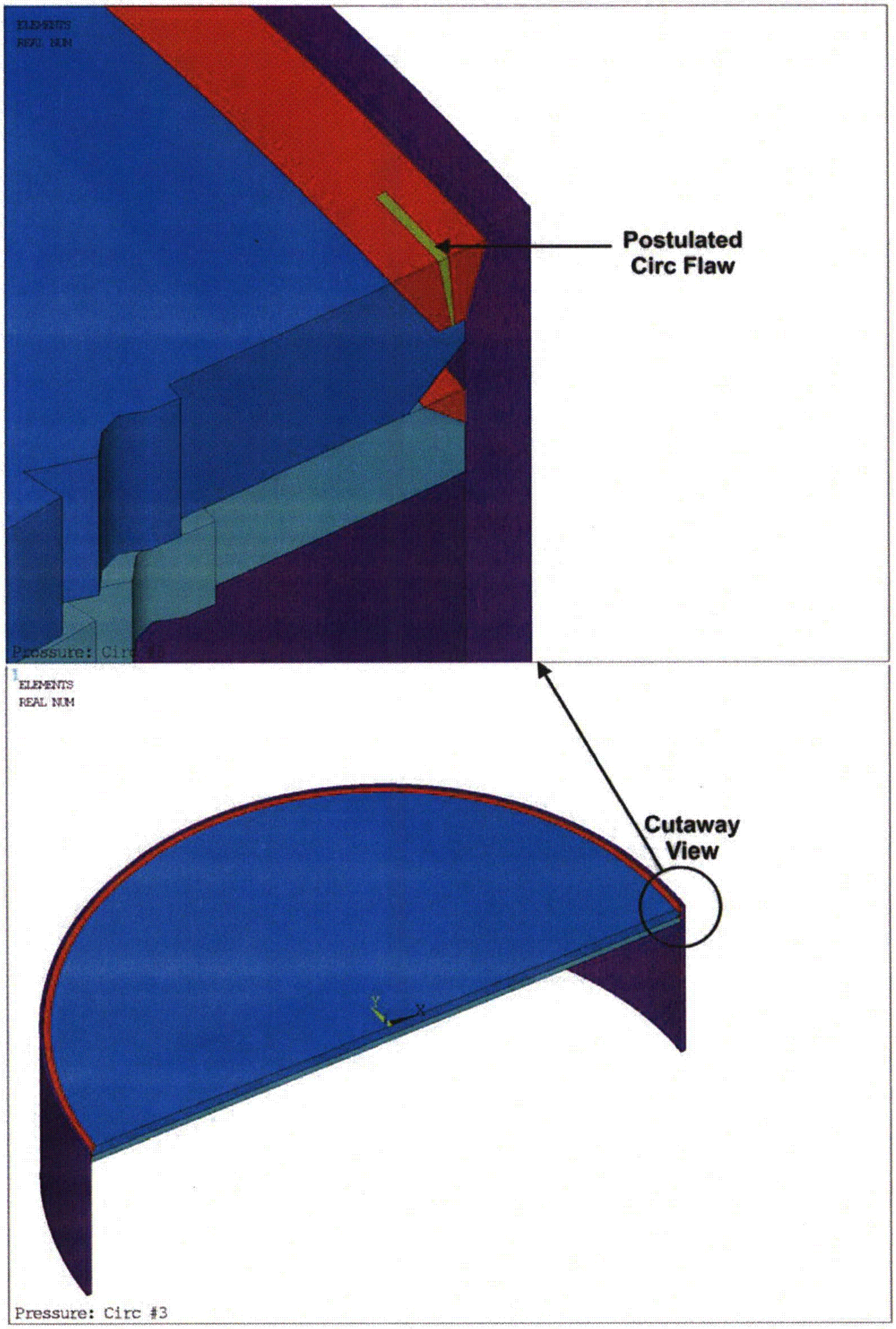

Figure 7. OTCP Postulated Flaw Configuration – Circumferential #3

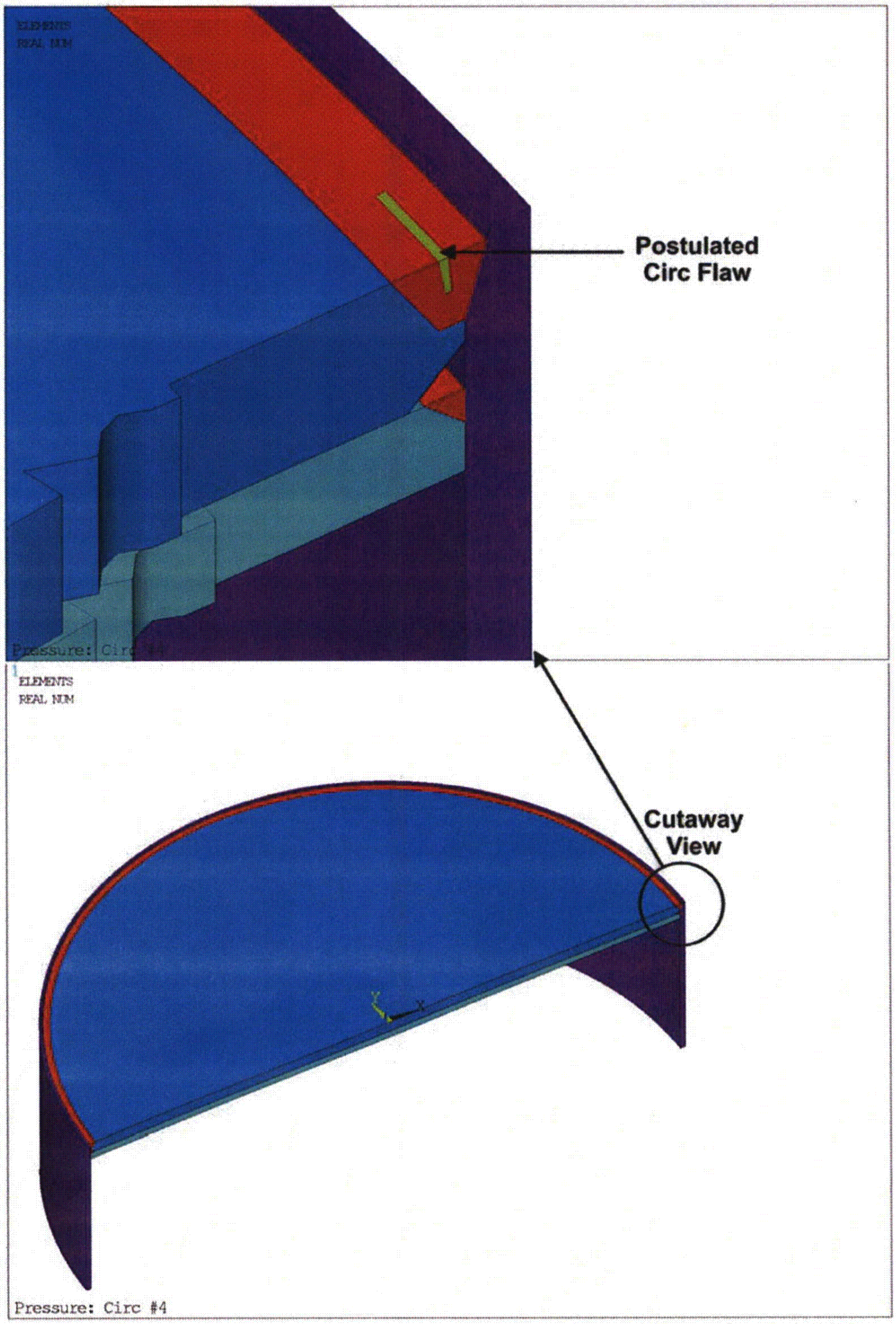

Figure 8. OTCP Postulated Flaw Configuration – Circumferential #4

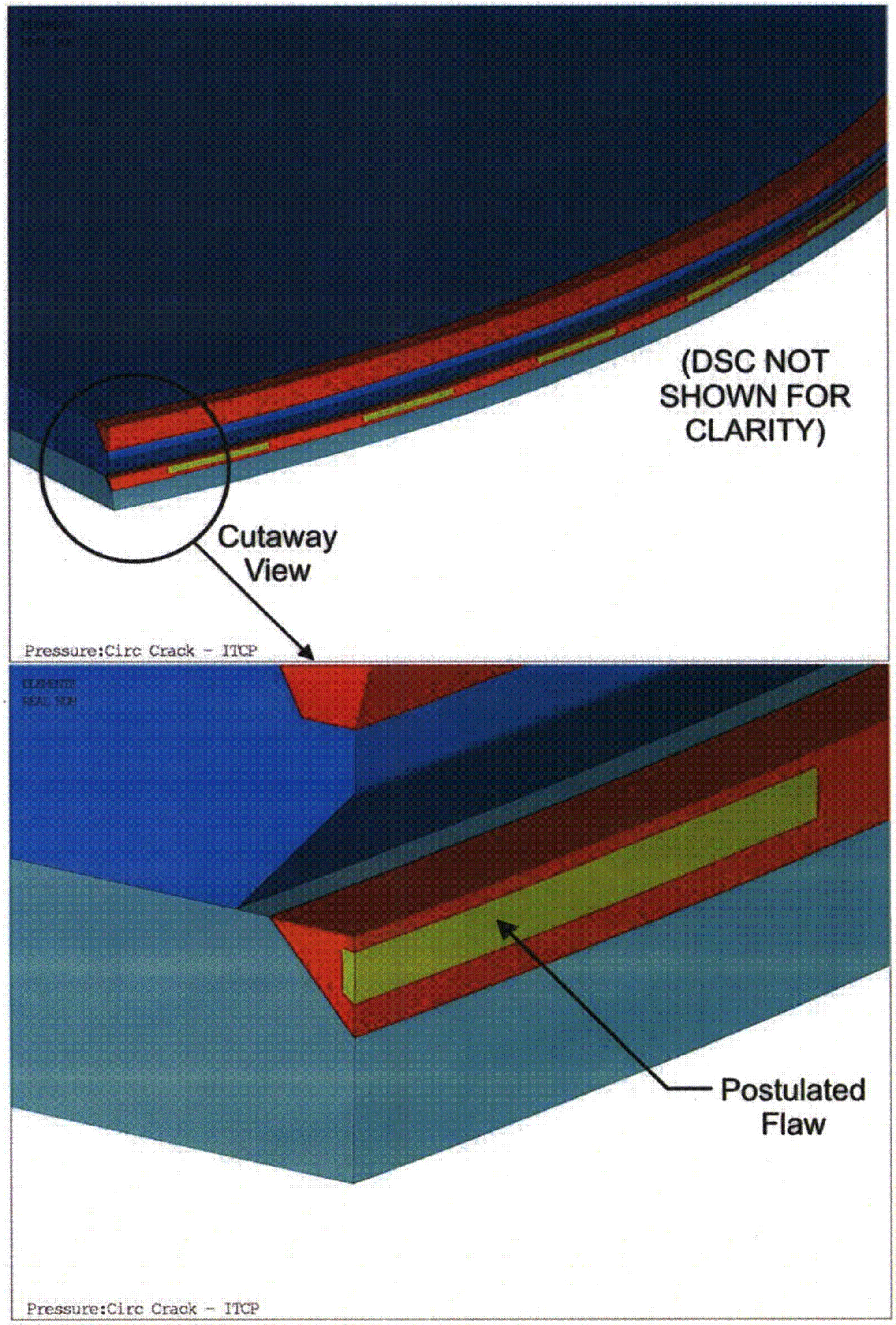

Figure 9. ITCP Postulated Flaw Configuration – Circumferential

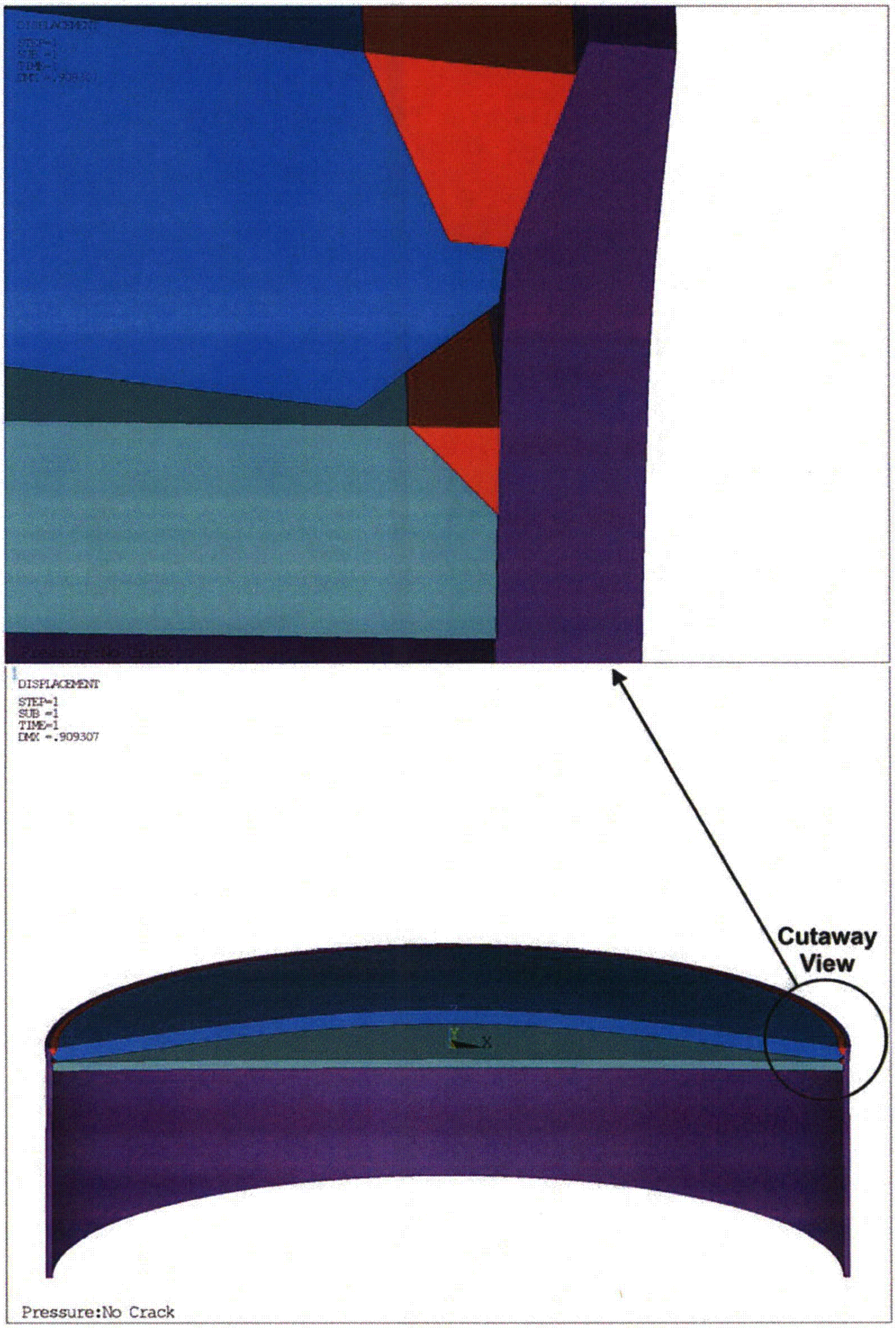

Figure 10. OTCP Pressure Load Case – Displaced Shape (Exaggerated)

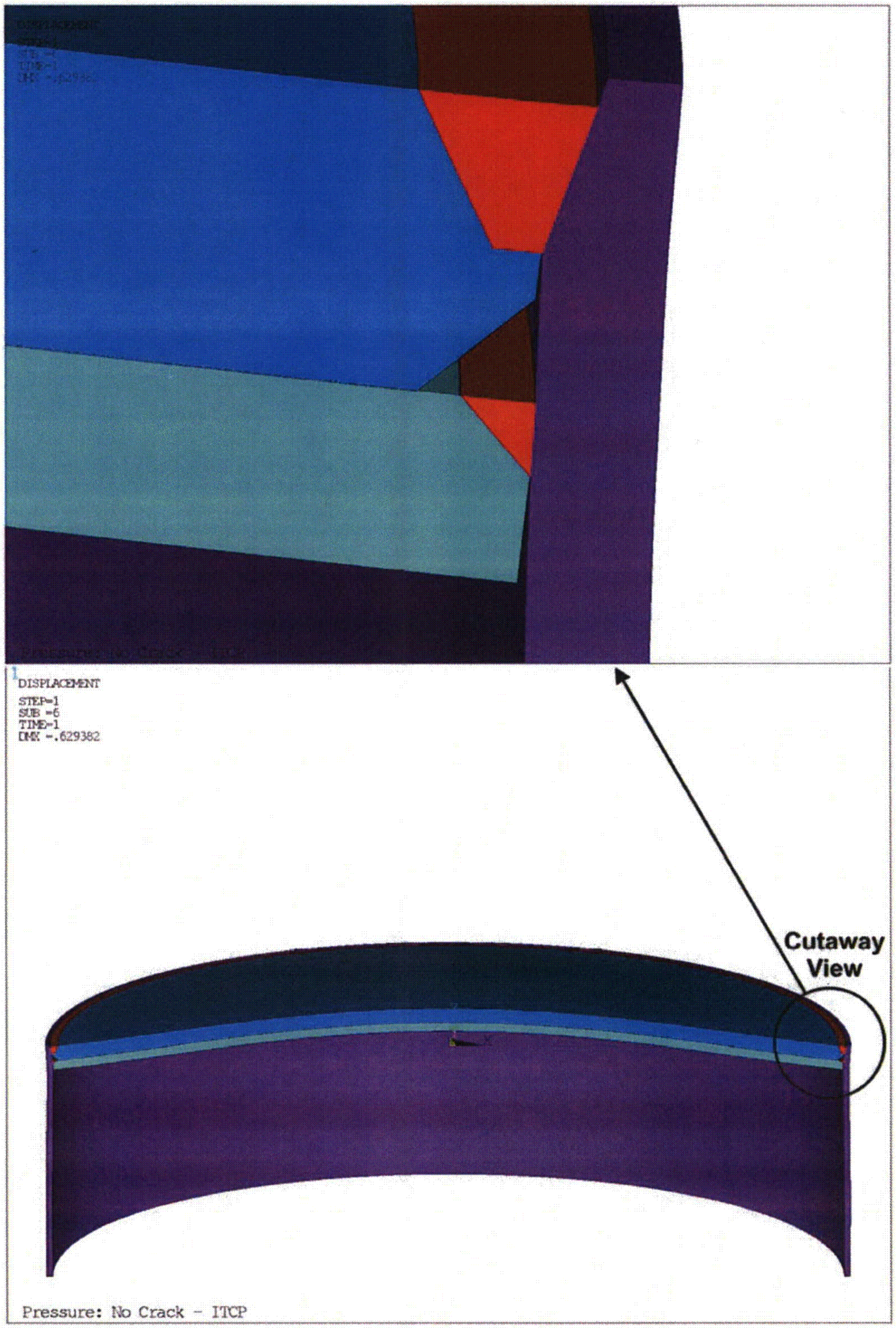

Figure 11. ITCP Pressure Load Case – Displaced Shape (Exaggerated)

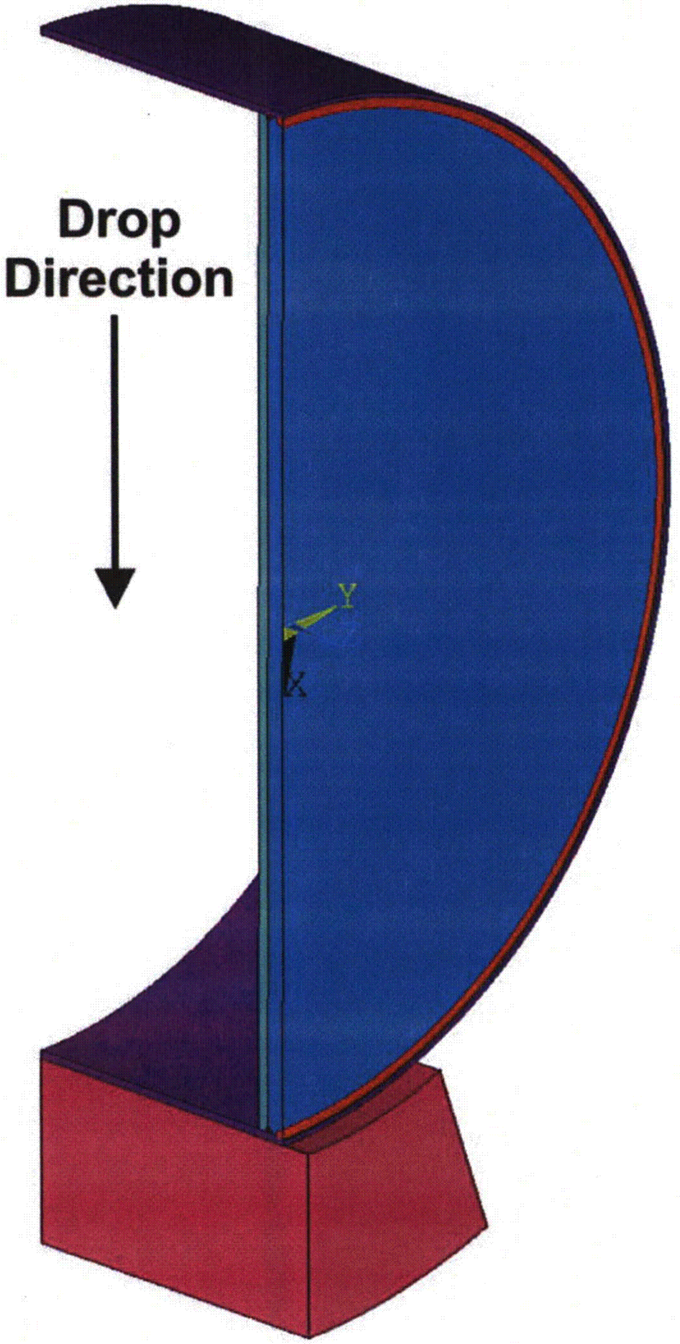

Figure 12. Side Drop Model

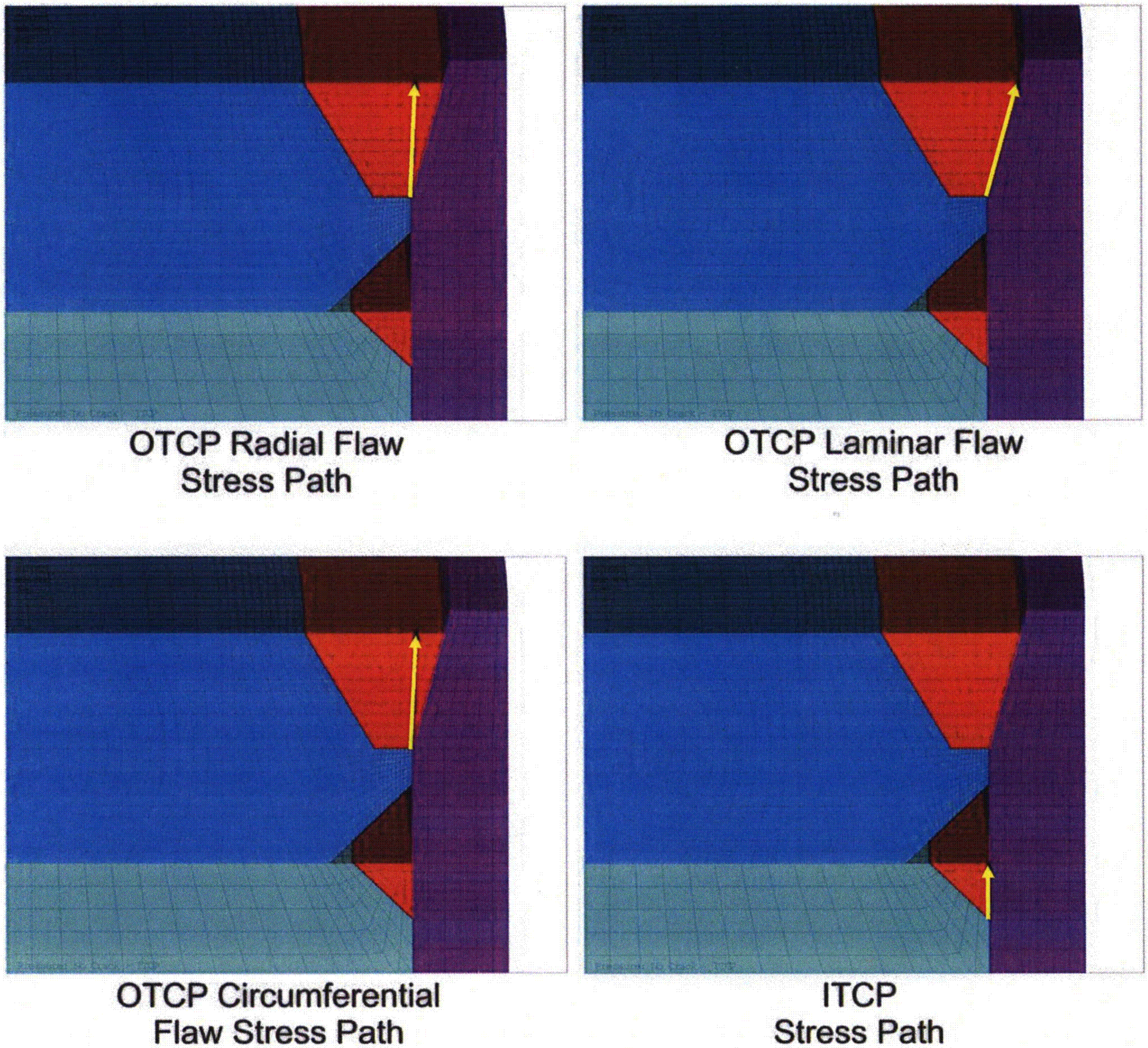

Figure 13. OTCP and ITCP Stress Path Definitions

APPENDIX A

ANSYS INPUT FILES

File Name	Description
Base_Model.INP	ANSYS input file to construct the 3-dimensional model.
C*_$_%.INP	ANSYS input file to perform OTCP flawed stress analyses * = 1-4 (Case Number) $ = Side, Pressure (Loading) % = Radial, Circ, Lam (Flaw Direction)
I1_$_CIRC.INP	ANSYS input file to perform ITCP flawed stress analyses $ = Side, Pressure (Loading)
Pressure.INP	ANSYS input file to perform OTCP non-flawed pressure stress analyses.
Side.INP	ANSYS input file to perform OTCP non-flawed side drop stress analyses.
I1_Pressure.INP	ANSYS input file to perform ITCP non-flawed pressure stress analyses.
I1_Side.INP	ANSYS input file to perform ITCP non-flawed side drop stress analyses.
Genstress.mac	Macro to perform linearized path stress extraction.
Lin_out.mac	Macro to perform linearized path stress extraction using the native ANSYS PRSECT command.
GETPATH.TXT	Path listing for stress extraction.
Data.xlsm	Excel file to compile stresses and compute ratios.

APPENDIX B

SI REPORT 1301415.405, REVISION 0, "EXPECTATIONS FOR FIELD CLOSURE WELDS ON THE AREVA-TN NUHOMS 61BTH TYPE 1 & 2 TRANSPORTABLE CANISTER FOR BWR DRY FUEL STORAGE,"

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October 23, 2014
Report No. 1301415.405.R0
Quality Program: ☒ Nuclear ☐ Commercial

Mr. James F. Becka
Xcel Energy
Project Supervisor – 2013 DFS Loading Campaign
Monticello Nuclear Generating Plant
2807 W. Country Road 75
Monticello, MN 55362

Subject: Expectations for Field Closure Welds on the AREVA-TN NUHOMS 61BTH Type 1 & 2 Transportable Canister for BWR Dry Fuel Storage

References:
1. Xcel Energy Contract No. 1005, Release 48, Amendment 6.
2. SI Report 1301415.402 R0, "Review of TRIVIS INC Welding Procedures used for Field Welds on the Transnuclear NUHOMS 61BTH Type 1 & 2 Transportable Canister for BWR Fuel", January 30, 2014
3. SI Report 1301415.403 R2, "Assessment of Monticello Spent Fuel Canister Closure Plate Welds based on Welding Video Records", May 2014
4. "E-mail train on Questions Regarding Postulated DCS Welding Flaw Distrubutions.pdf, from Peter Quinlan to Dick Smith, October 10, 2014, SI File No. 1301415.205.
5. Repair Rates in Welded Construction – An Analysis of Industry Trends, TWI, Cambridge/UK, Welding and Cutting, November 2012, SI File No. 1301415.204.

Dear Mr. Becka:

Details of the machine gas tungsten arc welding (GTAW) field closure welds used on the NUHOMS 61BTH transportable dry shielded canisters (DSC) located at Xcel Energy's Monticello Nuclear Generating Plant (MNGP) have been reviewed in an attempt to perform a qualitative assessment of the likelihood that the welds might contain unacceptable defects. It is known that the required NDE acceptance testing was not performed according to approved procedures. Sequential dye penetrant (PT) examinations were required on the inner top cover plate weld – first after the weld root and hot pass(es) were completed and again, after the final weld layer was completed. This is a relatively small weld (3/16 inch partial penetration weld) and it was not required to perform an intermediate inspection. The second weld is a 1/2 inch partial penetration weld that requires a root, intermediate, and final PT inspection due to the larger size. The problem identified was that the dwell times used for both dye penetrant and developer were less than required by procedure. The PT tests were performed, but procedures were not followed. This point is being emphasized because large open defects are seen very quickly with PT testing and likely would have been identified even though the dwell times were too short to meet procedure. Smaller tight defects might have been missed as the dye requires sufficient dwell time to wick and then be pulled out via the developer. This statement is in no way intended to justify the failure to follow approved PT procedures, but rather to apply perspective from a qualitative sense.

There are a number of reasons to believe that the field closure welds in their current condition do not contain large discontinuities that could challenge the effectiveness of the closure welds to meet their intended design function. It is the purpose of this review, performed in accordance with Reference 1, to identify valid reasons to support this conclusion. A qualitative justification is provided that is outlined in the listing below:

Reasons to expect the subject spent fuel canister welds are free from large discontinuities:

1. Use of qualified and proven welding procedures and techniques. [Reference 2]
2. Use of a machine GTAW process. [Reference 2]
3. Application of a proven and robust welding system designed specifically to support these types of field welds in these specific types of canisters. [Reference 5]
4. Use of ductile and easily weldable base materials (SA-240 Type 304 stainless steel). [Reference 2]
5. Use of solid wire filler metal designed for welding these base materials and formulated to eliminate hot cracking and other types of microfissures (SFA 5.9 ER308 austenitic stainless steel filler metal and welding grade gases for shielding the weld puddle. [Reference 2]
6. Canisters are oriented in the vertical position during welding such that the weld is performed in the flat welding position (the most forgiving welding orientation). [References 2,3 and 4]
7. Weld roots are typically about 1/8 inch or slightly thicker which is good practice for GTAW machine welds. [Reference 4]
8. Weld layers are thin (between 1/16 inch and 1/8 inch) requiring multiple layers (and multiple weld passes) to assist with developing weld deposit consistency via remelting. Layers become thinner as the groove is filled because the width is greater. [Reference 4]
9. AREVA-TN's historical record with these welds is excellent having a significant history of welds made with this system and these welding procedures that shows 1% repairs rates. [Reference 4]

The welding procedures and welder control documentation were reviewed in detail and specifics of that review are reported in Reference 2. The review concluded that

"... the procedures the GTAW welds in the subject spent fuel canisters can reasonably be expected to be of good quality and free of injurious defects. The expectation was based on the characteristics of the GTAW weld, the excellent controls outlined for the welding program, and the fact that the welds and base materials are austenitic stainless steel. Also the welding consumables are compatible with the structural materials used in the design...." [Reference 2]

The welding application itself is performed entirely in the flat position – a welding position that eliminates any complications related to welding out of position or having to negotiate restricted access. The reason for this viewpoint is that out of position welds have to compete against the forces of gravity and the joint design provides adequate access for arc manipulation. The result of a welding in the flat position is that defects are less likely to be introduced than might be expected with other weld orientations or restrictions.

The spent fuel canister welding system is robust and is proven. The welding head is mounted on a non-metallic shielding material weighing over 1500 lbs and is shown in Figure 1 below.

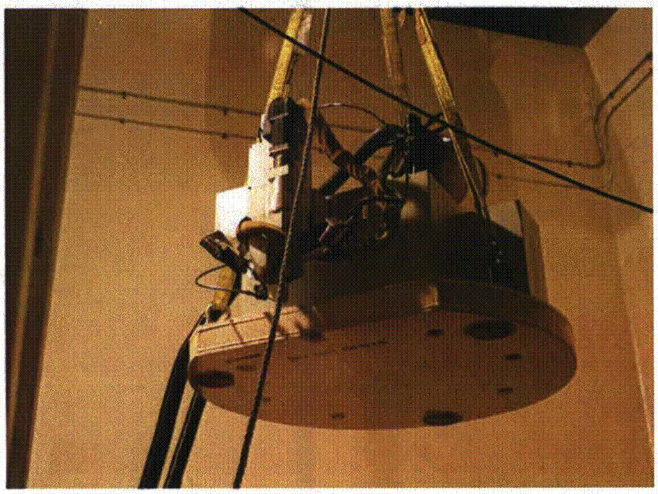

Figure 1 Photo of the robust welding head that is positioned on the dry storage cask as shown in Figure 2. The welding torch is visible in the photo just behind the rope. (Photo provided by AREVA-TN)

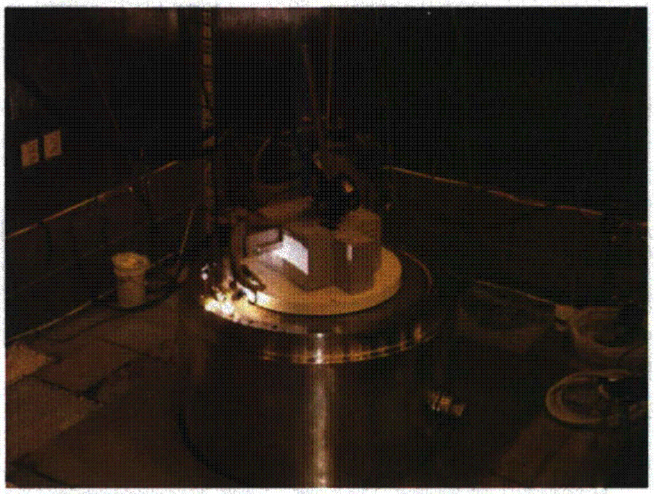

Figure 2 Welding system positioned on the storage canister for welding (Photo provided by AREVA-TN)

The entire welding system rotates similar to a "lazy-susan" and the welding torch is manipulated in and out as required for proper positioning. There are other torch adjustments such as tilt, lead, height, etc. Leading and trailing cameras are mounted to provide video of the front and rear of the torch and weld puddle. Welding videos have been reviewed [Reference 3] in an attempt to assess whether or not weld quality could be assessed. One objective of the video review was to look for key discontinuities such as porosity and evidence for any lack of fusion. The conclusions from the video review were that circumstances were observed at various times during welding that might support the generation of defects such as oxide buildup, weld root burn-thru, localized contamination on the surface, weld deposit surface irregularities, and tungsten drift requiring realignment. However, nothing could confirm either the generation of defects or the lack of defects. Since each weld is a unique entity one must rely on tendencies or trends if post weld inspections are not available. There were also observations of good welding practices as well as those events stated above. These included root repair, periodic adjustment of tungsten positioning, tungsten electrode replacement, electrode steering as needed, etc. Most of the videos were very similar (all having the same types of observations at about the same frequency). Canister No. 16 also had the same types of observations but the frequency appeared to be about twice any of the others. This was a judgment call by the reviewers and not quantitative. It was carefully pointed out that even so, there was no evidence to indicate that any specific discontinuities were generated – only that welding conditions were observed that sometimes lead to the various types of discontinuities. In addition, since these welds use multiple weld beads to complete the weld, there is the opportunity to "heal" conditions created by welding over them.

Historical Perspective

AREVA-TN was asked to describe their historical perspective on the welding of the canisters with this system. It is recognized that all of the canisters were not welded by AREVA-TN but might include a contractor or the utility themselves. However the same welding system likely would have been used (often rented from AREVATN). AREVA-TN noted that typical discontinuities might include local porosity (rare), occasional tungsten inclusions, usually resulting from torch tip contact with the solidifying weld puddle, lack of fusion or overlap. Regarding the potential for any linear indications (holidays or breaks), cracking typically does not occur with austenitic stainless welds. Maximum size of indications typically would be less than 1" to 2". Irregularities at starts and stops can occur, and rollover has been seen in some cases.

AREVA-TN also was asked for their historical experience regarding canister closure weld acceptance rates (i.e. first time PT rate). The response indicated that a best estimate would be less than 1 UNSAT PT per 10 canisters, with an average of 10 PT examinations per canister (includes root and final layer on inner top cover, vent port cover, siphon port cover and test port, with root, mid and final layer on outer top cover for certain DSC models). Therefore, the historical experience suggests a rate of about 1% UNSAT PTs for field closure welds. Further, the recent field experience as the welding process matured produced no weld repairs at all – on 50+ canisters the findings were 1 PT indication from starts and stops was found to hold developer, but light grinding was performed to smooth the surface and eliminated the indication. Thus, these minor indications required no weld repairs.

AREVA-TN was also asked regarding how many stainless steel canisters have been loaded and closed by welding to date. The estimate was for approximately 750 loaded/closed NUHOMS canisters, with closure performed by AREVA-TN, end user or other contractor. This represents an extensive sampling that indicated an indication rate of less than 1% and that rate appeared to significantly improve over the last 50 that have been welded.

There were no applicable mockups that had been used to examine for discontinuities or defects, so that information was unavailable. The historical evidence seems to paint a favorable picture lending a degree of comfort that the canisters in question at MNGP are not likely to have indications of a significant size.

Finally, literature was examined to find information regarding generation of defects in stainless steel weldments. The best paper found is indicated in Reference 5. This paper written by The Welding Institute in Cambridge, UK was published in Welding and Cutting, November 2012. The paper titled "Repair Rates in Welded Construction – An Analysis of Industry Trends" provided good insight. More than 800 professionals were contacted with about 10% responding. There were different kinds of responses such as % of welds requiring repair or % weld lengths requiring repair being the most prevalent. The following applicable conclusions were noted. GTAW stainless steel welds returned under 2% repair rates. The impact of different welding factors were parsed and suggested the following impacts: root repairs at 22.5%, fill layers 7.5%, joint type 15%, access limitations 26%, and other welding factors 11% . Most of these are not present in the canister welds as pointed out previously. It appears that the AREVA-TN canister weld repair experiences are slightly lower, but nevertheless are considered consistent with industrial expectations for a variety of manufactured and installed components. Since all welding is in the flat position using a proven welding system, the 1% defect rate appears to be reasonable. In addition it was pointed out that experience with the past 50 canisters has been even better.

Conclusions

Based on the sum of the information reviewed, it can be said that the likelihood for the occurrence of large defects is not supported by historical evidence. While there remains the potential for long lack of fusion defects either interbead or sidewall, the thin multilayer design and potential for subsequent bead healing by remelting would significantly limit the through-thickness dimension of any long defect. In fact, the most likely lack of fusion indication(s) would be intermittent in nature and not expected to have a through-thickness dimension greater than one weld bead. While a quantitative estimate of a limiting flaw size cannot be produced, the qualitative likelihood that large defects would not be present is assuring.

It is suggested a bounding subsurface defect condition is conservatively represented as an intermittent lack of fusion (LOF) defect evenly distributed along the canister weld. Further, the total length for LOF is conservatively estimated at 25% of the canister cover plate weld circumference. The estimated through thickness dimension is 1/8 inch, because this dimension represents a maximum weld bead thickness. One eighth inch is considered to be a conservative assumption, because it is recognized that most weld beads will be thinner especially as the weld cavity begins to fill. No credit is being taken for remelting even though remelting is normally associated with multipass welding."

Very truly yours,

Richard E. Smith

Richard E. Smith, PhD. FAWS
Senior Associate
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