ENCLOSURE 4

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNIT 1

TECHNICAL SPECIFICATIONS (TS) CHANGE TS-431
EXTENDED POWER UPRATE (EPU)

STRUCTURAL INTEGRITY ASSOCIATES, INC. CALCULATION PACKAGE 0900833.302, REVISION 0, "STEAM DRYER HOOD STIFFENER STRESS RELIEF MODIFICATION STRESS REDUCTION FACTOR (SRF) COMPUTATION"

Attached is Structural Integrity Associates, Inc. Calculation Package 0900833.302, "Steam Dryer Hood Stiffener Stress Relief Modification Stress Reduction Factor (SRF) Computation."

Structural Integrity Associates, Inc. **CALCULATION PACKAGE**	**File No.:** 0900833.302 **Project No.:** 0900833 ☒ Q ☐ Non-Q

PROJECT NAME:

BFN Steam Dryer Technical Support

CONTRACT NO.:

63268 CWA P5160

CLIENT:	**PLANT:** Browns Ferry Units 1, 2 & 3
Tennessee Valley Authority (TVA)	

CALCULATION TITLE:

Steam Dryer Hood Stiffener Stress Relief Modification Stress Reduction Factor (SRF) Computation

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1.0 INTRODUCTION

Background

The Browns Ferry steam dryer has been analyzed using a shell finite element model, which does not specifically model the weld at connections between plate members. The results show that there are localized high stresses due to structural discontinuity at some of the welded connections. Based on past experience, it has been established that if the connections are modeled using solid elements to represent the weld, the weld can better distribute the stresses in the region of high stress discontinuity. Coupled with the use of the stress linearization approach, the maximum stress intensity computed using the solid model (with the weld modeled) generally gives a better prediction of stresses compared with shell elements in region of high structural discontinuity.

The computation of the stress reduction factor (SRF) for the hood stiffener is documented in Reference 1. The computed SRF for the hood stiffener is 0.79.

In order to achieve a stress reduction at the peak stress location at the bottom of the stiffener / hood connection, a number of stress relief schemes have been considered. A parametric study of a stress relief modification involving the use of a semi-circular cut-out near the peak stress location has been performed and this study is documented in Reference 2. This study forms the basis of the stress relief approach adopted in this calculation.

Objective

This calculation documents the stress analysis and the computation of the SRF for a hood stiffener with a stress relief scheme. This stress relief scheme places a semi-elliptical cut-out (with a major radius of 1.75" and a minor radius of 1.25") at the bottom of the stiffener. The edge of this cut-out is located at 3/16" from the edge of the fillet weld (see Figure 3-1).

The finite element analyses in this calculation are performed using ANSYS Version 11.0 (Reference 5).

2.0 METHODOLOGY / ASSUMPTIONS / MATERIAL PROPERTIES

The methodology, assumptions, and material properties used in this calculation are similar to those used in Reference 1. For completeness, some of the key parameters are summarized in this section.

Unit Load Application

A unit load of 1,000 lb is applied to the bottom 1.75" section of the stiffener. This unit load is applied to the solid sub-model. The computation of the SRF is based on stresses resulted from the unit load application.

Material Properties

The material properties for A-240, Type 304 stainless steel (Reference 3) at 550°F are used for the analysis. Similar material properties are assumed for the weld.

The material properties used are as follows:

Modulus of Elasticity	=	25.55E6	psi (Reference 4, Page 12)
Poisson's Ratio	=	0.30	(Reference 4, Page 12)

3.0 STRESS RELIEF SCHEME

The stress relief scheme for the hood stiffener consists of placing a semi-elliptical cut-out at the bottom of the stiffener. The dimensions of this semi-elliptical hole are 1.75" (major radius) by 1.25" (minor radius). The edge of this cut-out is located at 3/16" away from the edge of the fillet weld. An illustration of the stress relief scheme is shown in Figure 3-1.

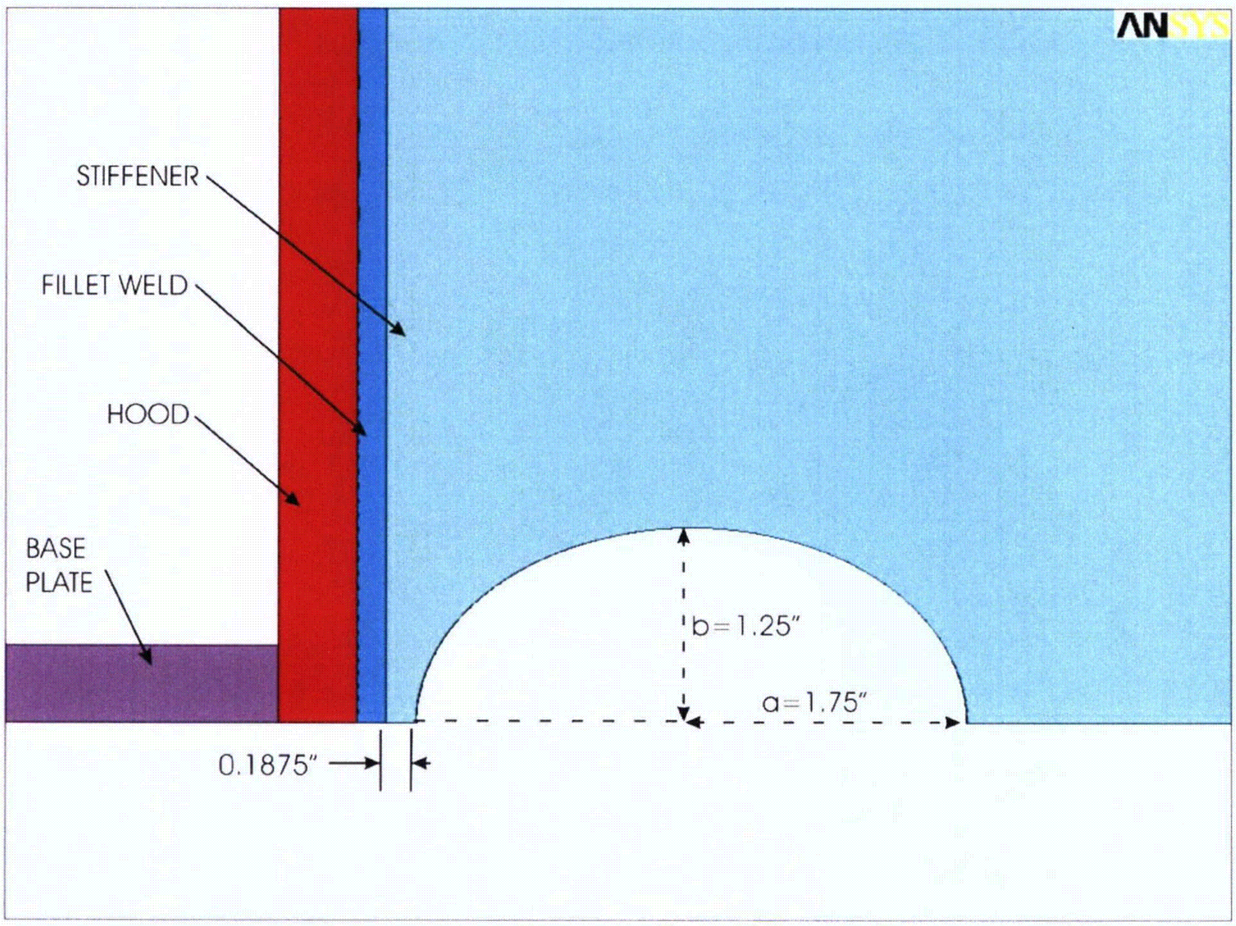

Figure 3-1
Hood Stiffener Stress Relief Scheme

4.0 STIFFENER ANALYSIS

The stiffener sub-model consists of three key parts: the stiffener, the hood, and the base plate.

4.1 Key Dimensions

The key dimensions of the sub-model are as follows [1, Table 4-1]:

Table 4-1
Stiffener Model Key Dimensions

Component	Thickness / Size (in)	Modeled Dimensions (in x in)
Stiffener	1/4"	10" (width) x 34" (height)
Hood	1/2"	56" (depth) x 34" (height)
Base Plate	1/2"	56" (depth) x 7" (width)
Weld [(1)]	3/16"	Along the entire connection.

Note: (1) The fillet weld is modeled in the solid sub-model, on both sides.

4.2 Boundary Conditions and Applied Load

The boundary conditions and applied load are identified in Figure 4-1 [1, Figure 4-1].

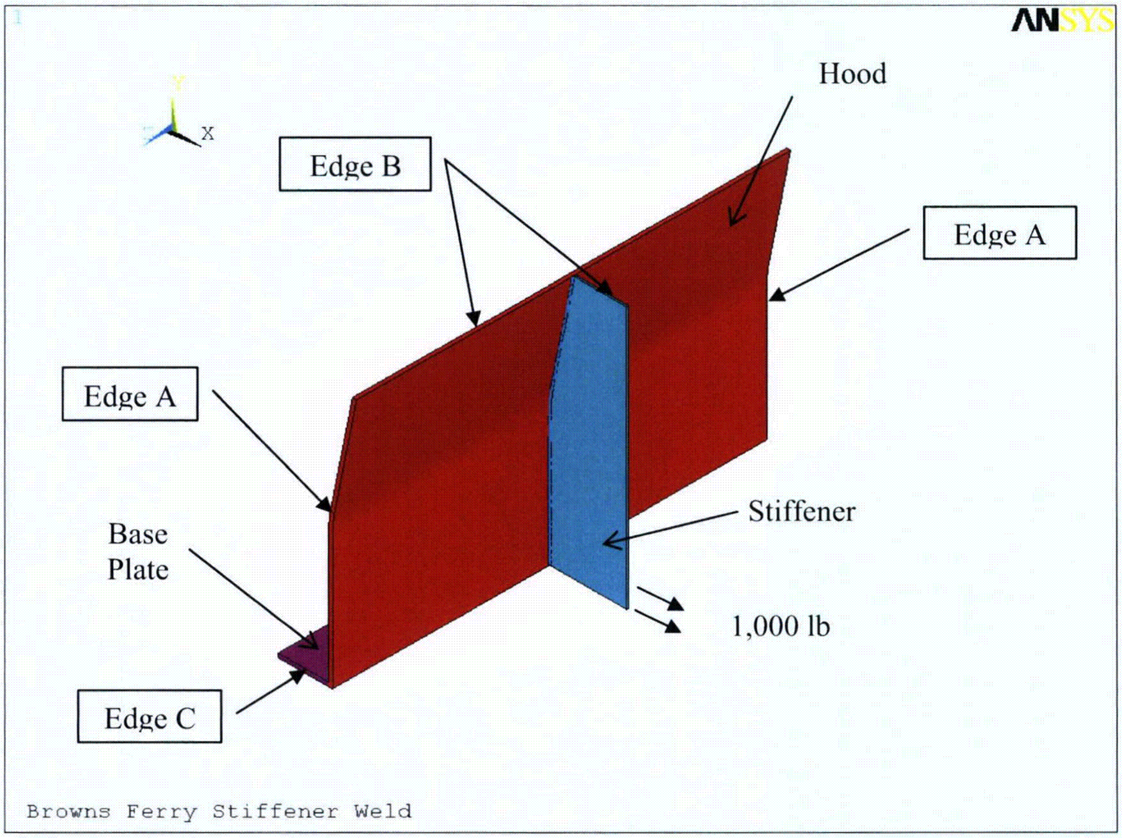

Figure 4-1
Stiffener Model Boundary Conditions and Applied Load

<u>Boundary Conditions</u>

Edge A: Plane of symmetry.

Edge B: Restrained in Y translation, and rotation about X and Z.

Edge C: Plane of symmetry, and restrained from translation in X.

<u>Applied Load</u>

Load: 1,000 lb is evenly applied at the bottom 1.75" section of the stiffener.

4.3 Solid Finite Element Model

The solid finite element model is modeled using SOLID45 elements. Variable mesh sizes, with finer mesh around the region of high stress concentration and coarser mesh away from the high stress concentration region, are used. Six layers of elements are modeled across the plate thickness, therefore, providing adequate discretization through the plate thickness to capture the stress variations across the thickness. The entire model consists of approximately 320,000 nodes and 375,000 solid elements. The finite element mesh is shown in Figure 4-2.

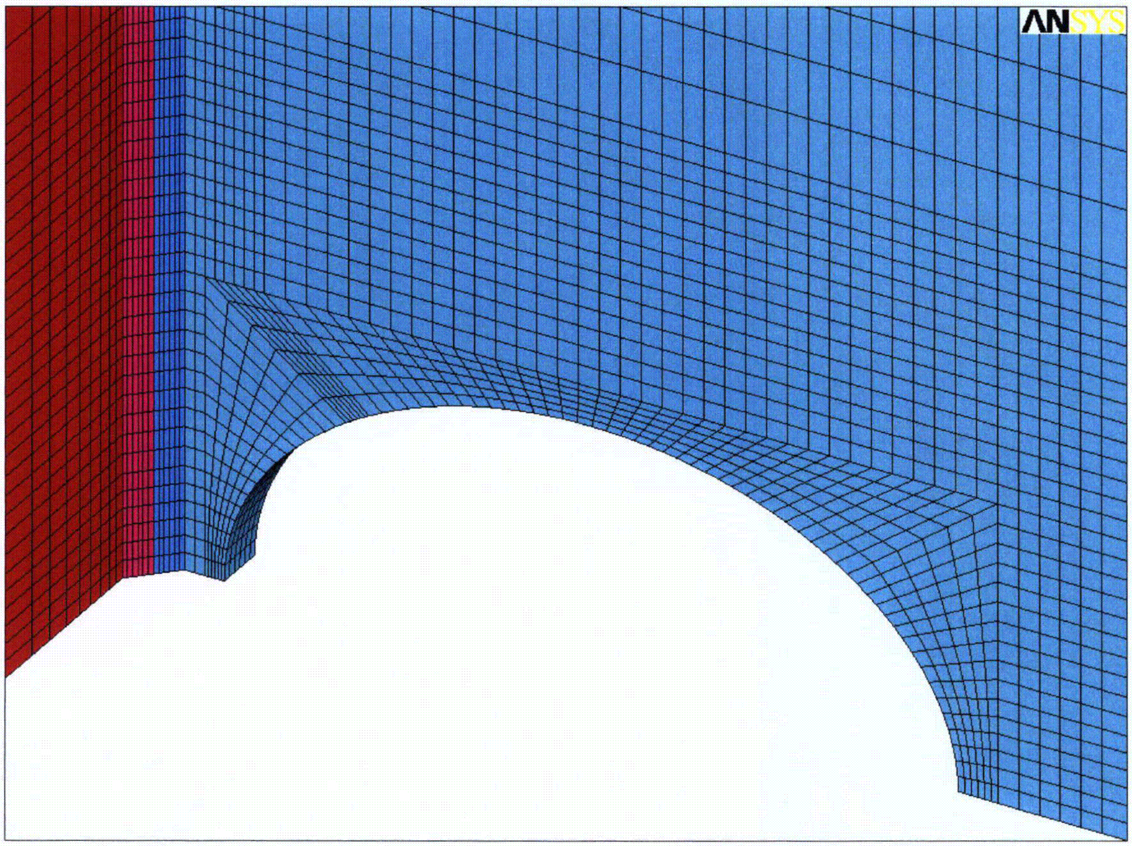

Figure 4-2
Stiffener Solid Finite Element Model Mesh
(Isometric View)

4.4 Solid Model Stress Paths

Linearization stress paths are taken from the weld root to the component surface in the vicinity of the high stress region. In addition, linearization stress paths are also taken from the weld toe to the opposite surface of the connecting parts. The stress paths used for the stiffener solid model are shown in Figure 4-3.

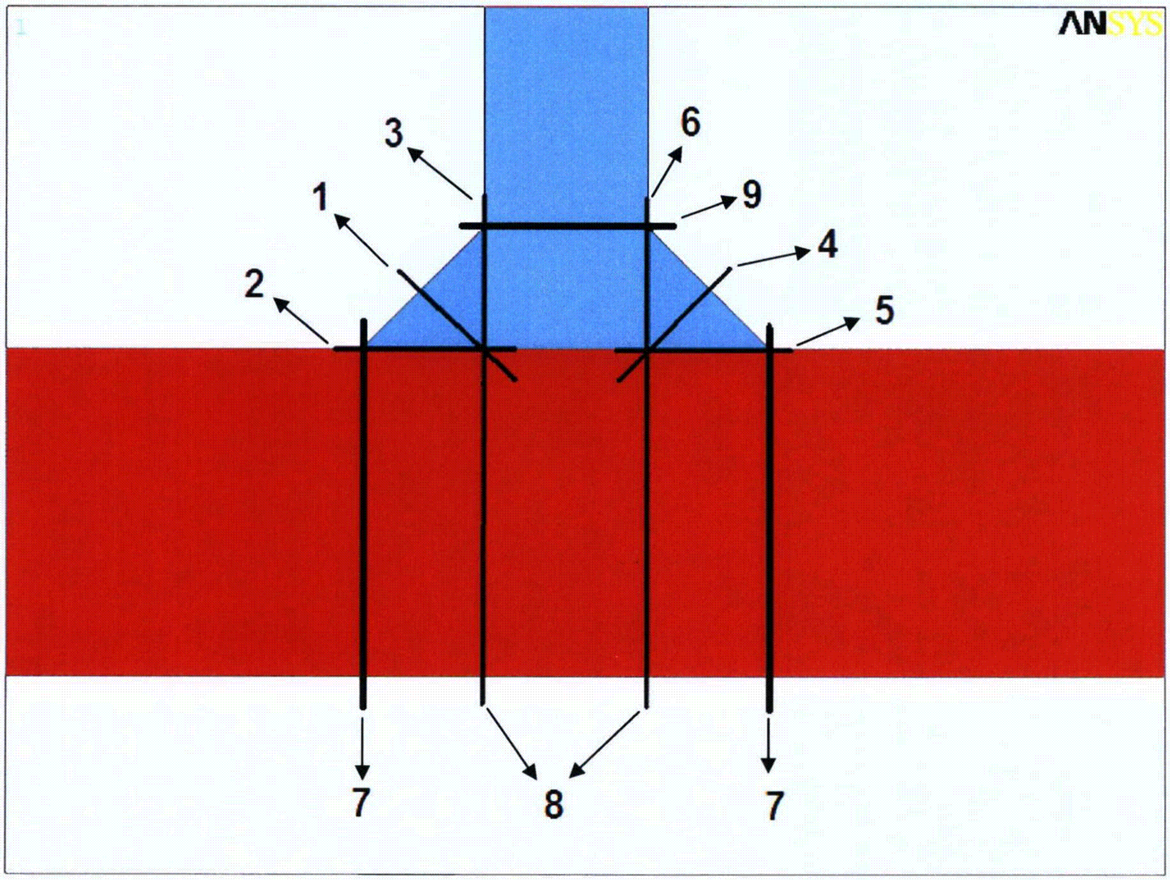

Figure 4-3
Stiffener Solid Model Stress Paths

4.5 Solid Model Results

The stress intensity plots for the solid model are provided in Figure 4-4 and Figure 4-5.

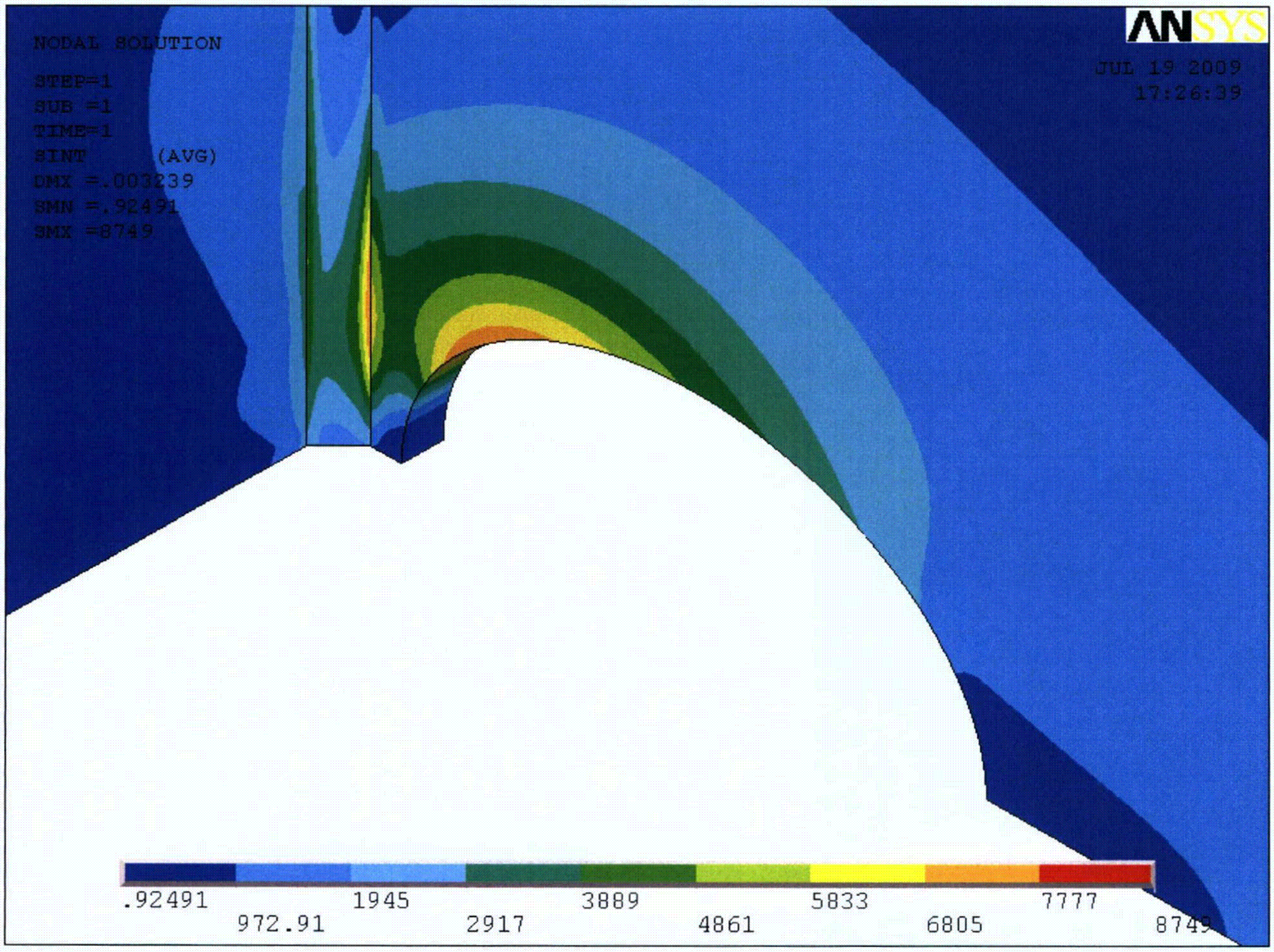

Figure 4-4
Stiffener Solid Model Stress Intensity
at High Stress Region
(View 1)

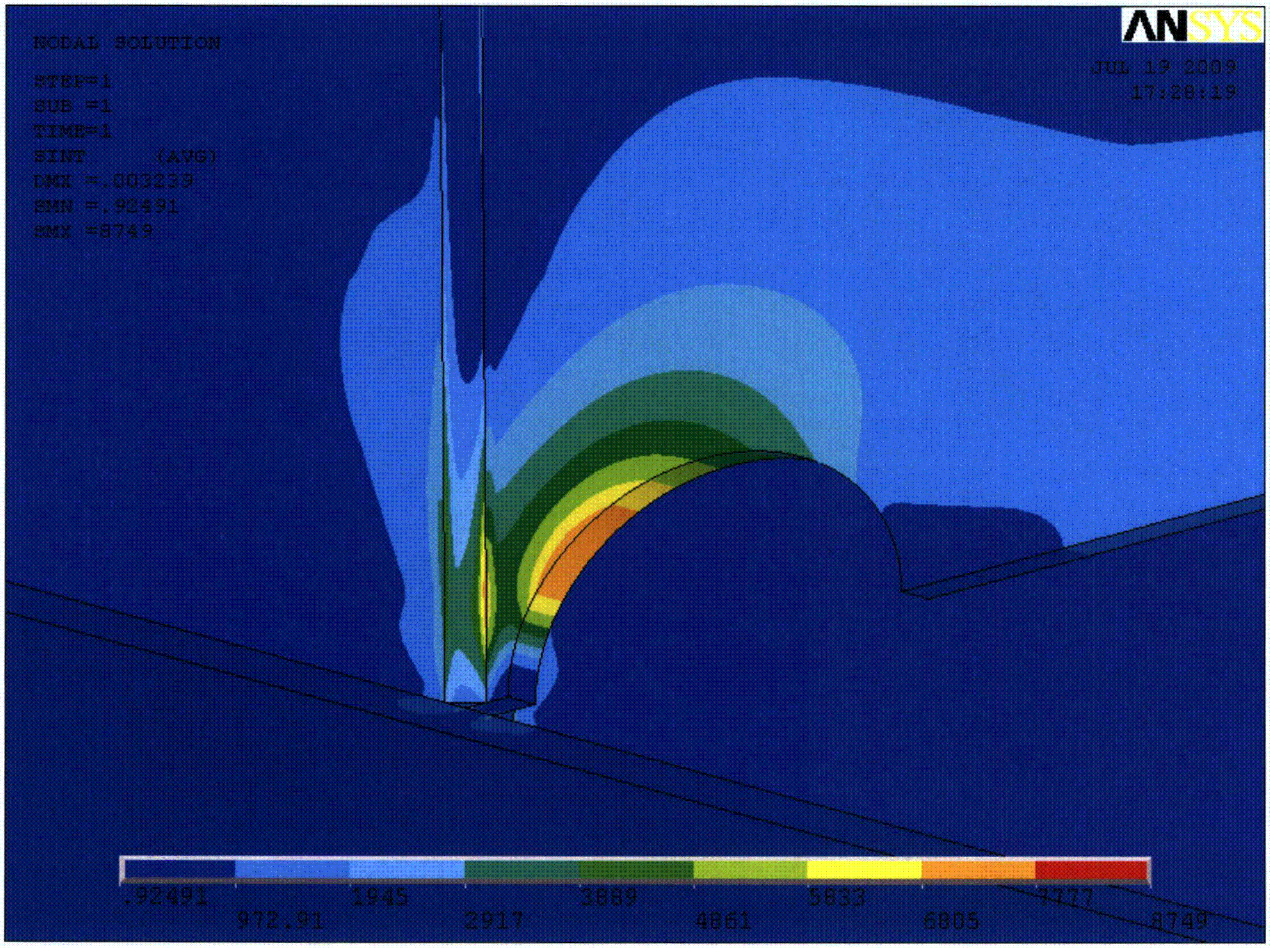

Figure 4-5
Stiffener Solid Model Stress Intensity
at High Stress Region
(View 2)

Maximum Stress Intensity

The stress intensity is computed for the different stress paths. There are multiple locations for each of the paths, and the largest magnitude is identified as the maximum stress intensity for that path. The maximum stress intensity for the different paths are summarized in Table 4-2.

Table 4-2
Stiffener Solid Model Maximum Stress Intensity

Location	$P_m + P_b$ (psi)
Path 1	4,737
Path 2	4,084
Path 3	5,154
Path 4	4,737
Path 5	4,084
Path 6	5,154
Path 7	2,855
Path 8	3,559
Path 9	5,109
Cut-Out (1)	7,771

Note: (1) The stress intensity at the cut-out is not subject to weld factor of 1.8 [6, Figure 3]. Since the stress intensity of 7,771 psi for the cut-out is less than the stress intensity of 5,154 psi x 1.8 (weld factor) for Paths 3 and 6, the stress at the cut-out does not govern.

Other Observation

The placement of the cut-out at the bottom of the stiffener directs the load path away from the bottom of the stiffener. Since the cut-out is located a short distance (i.e., 3/16") away from the fillet weld, the geometry prevents the load path from returning to the bottom of the stiffener as it approaches the weld. The increased flexibility introduced by the cut-out at the base of the stiffener / hood connection causes the load, and hence the stress, to shift upward. As a result, the maximum stress intensity for the stress relief modification is located at approximately 0.7" from the base. This is consistent with the findings documented in Reference 2.

4.6 Stress Comparison

The stress comparison between the shell and the solid finite element models is summarized in Table 4-3.

Table 4-3
Stiffener Solid Model / Shell Model Stress Ratio

	$P_m + P_b$		
Path #	Solid (psi)	Shell (psi)	SRF
1	4,737	9,809 [1]	0.48
2	4,084		0.42
3	5,154		0.53
4	4,737		0.48
5	4,084		0.42
6	5,154		0.53
7	2,855		0.29
8	3,559		0.36
9	5,109		0.52
		Maximum =	**0.53**

Note: This value is taken from Reference 1.

<u>Summary</u>

The maximum SRF for the solid model stress intensity / shell model stress intensity is 0.53.

5.0 CONCLUSION

With the use of the stress relief modification, the solid model / shell model SRF for the hood stiffener has been reduced from 0.79 (without the stress relief scheme as documented in Reference 1) to 0.53. This ratio is applicable to the stiffener shell stress intensity at the bottom of the welded connection between the stiffener and the hood.

6.0 REFERENCES

1. SI Calculation No. 0006982.301, "Shell and Solid Sub-Model Finite Element Stress Comparison," Revision 2, SI File No. BFN-15-301.
2. SI Calculation No. 0900833.301, " Hood Stiffener Plate Stress Relief Scheme Parametric Study," Revision 0, SI File No. 0900833.301.
3. Email with attachments from George Nelson (TVA) to Marcos Herrera (SI) on 04/22/08 at 9:02 am, "Steam Dryer - Drain Channel," SI File No. BFN-15-224.
4. Email with attachment from Rick Cutsinger (TVA) to Soo Bee Kok (SI) on May 20, 2008 @9:02 am, "RE: Weld Structure Evaluation," SI File No. BFN-15-227.
5. ANSYS Mechanical and PrepPost w/ Service Pack 1 (ANSYS 11.0 SP1), May 2009.
6. GE Report DRF GE-NE 0000-0039-4817-1, "Recommended Weld Quality and Stress Concentration Factors For use in the Structural Analysis of Exelon Replacement Steam Dryer," April, 2005.

Appendix A - Computer Files

Filename	Description
StiffSM7.inp	Stiffener Solid Model analysis input.
StiffSM7PP.inp	Stiffener Solid Model post-processing input.
StiffenerSummarySM7.xls	Stiffener result summary spreadsheet.