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Assessement on the Evolution of a Flaw in a Class 1 ASME Nuclear Equipement

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Abstract
This paper addresses an evaluation of the flaws (weld indication) at PZX found during the inaugural inspection for the Cernavoda NPP#2 Pressurizer. All the indications have been evaluated based on the procedure in ASME Code Section XI. From the analysis, it has been that all the flaw is stable and grows of the flaw over the service transients is small. It is concluded that these indications are acceptable for service.

1. Purpose and Scope

Based on the UT reports for PZX [3], all the indications were assessed using the acceptance standards stipulated in ASME Code Section XI (IWB-3500). For the indications exceeding the ASME Code acceptance standards, analytical evaluations were performed based on the procedure in ASME Code Section XI (IWB-3600). Stress data obtained from Stress Analysis for transient conditions were used to perform crack growth analysis for indications exceeding ASME Code acceptance standards. Maximum stress intensification factors for these indications with end-of-service sizes were calculated and compared with ASME Code Compliance.

A 3D finite element model was generated for the lower head/heater nozzle/shell assembly and used for stress analysis under the Level A to D and Hydro Test[2]. Stress data obtained from Stress Analysis were used for crack growth analysis and calculation of maximum stress intensity factors for the weld indications at “PZX”.

2. Analysis Approach

Level A to D transients conditions for the Pressurizer was specified in the Cernavoda U#2 NPP PHT Design Manual [2]. Surface heat transfer coefficients for these transients were determined for subsequent thermal and structural analyses. Details of all transients and tests considered in Level A to D analysis are listed in Table 2.-1

A 3D finite element model was generated for the lower head/heater nozzle/shell assembly and is shown in figure below: (Fig.2.-1)

Considering the coupled thermal – structural analysis two types of compatible elements from view point of coupling, were used, namely for the thermal analysis – element 90 type 3D prismatic solid with 20 nodes and for structural analysis – element 95 type 3D elastic prismatic solid with 20 nodes. So, one single mesh(generating the same number of elements and nodes for both analyses), necessary for information transfer between these two analyses is provided. The mesh is a mapped type, performing a special control of elements dimension in the nozzle zone, in order to get an accurate thermal distribution over the wall thickness and fatigue analysis. So, the thickness of the lower head and the nozzle R4 was meshed with 10 segments.

Table 2.-1 Operating Conditions (Thermal/Pressure Transients)

Item	Name	Nr. cycles
1.	Heatup & Cooldown	250
2.	Startup & Shutdown	1000
3.	Power Maneuvering	10000
4.	Loss of Feedwater from 100% Power	100
5.	Reactor Trip from 100% Power	500
6.	Loss of Class IV Power from 100% Power	50
7.	Loss of Regulation (Reactor Overpower)	200
8.	Turbine Trip	100
9.	Stepback	500
10.	Pressurizer Startup During Commissioning	50
11.	Emergency Over pressurization	1
12	System Hydrotest	20

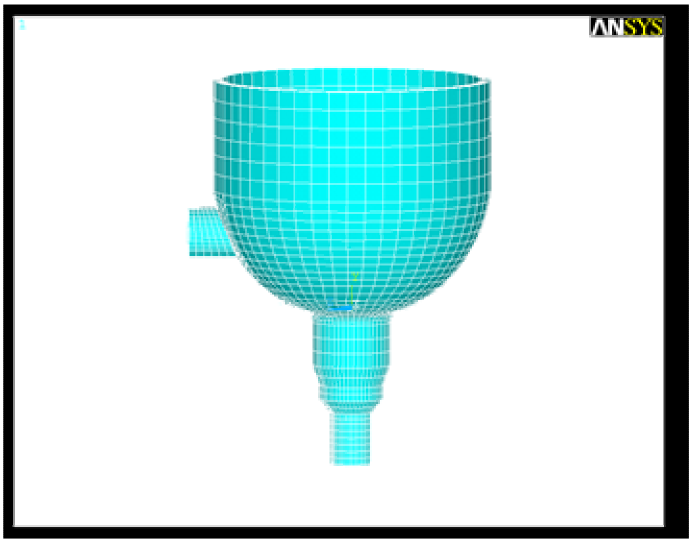

Figure 2.1. The simplified geometric model

For the lower head/heater nozzle/shell assembly model, stress analysis was performed based on the transients conditions provided in the Design Manual [2]. Thermal Transients analysis was used to obtain temperature distributions for the model under different Level A, B, C & D Transients.

Structural analyses were then carried out with pressures and temperature distributions applied (see Fig 3.-2). Stress class lines across different weld sections were defined for the model and fatigue usage factors for these stress class lines were calculated (see Fig 3.-3). Stress data at the weld locations with the highest fatigue usage factors were summarized for subsequent assessment of the indications.

Based on the UT reports for PZX [3], all the indications were assessed using the acceptance standards stipulated in ASME Code Section XI (IWB-3500). Some indications are close other and were combined to form larger indications. For indications exceeding the ASME Code acceptance standards, analytical evaluations were performed based on the procedure in ASME Code Section XI (IWB-3600). Stress data obtained from Stress Analysis for transient conditions were used to perform crack growth analysis for indications exceeding ASME Code acceptance standards. Maximum stress intensification factors for these indications with end-of-service sizes were calculated and compared with ASME Code Compliance. Details of the analyses for these locations are documented in calculations attached to this report

3. Results and Conclusions

3.1 Flaws

There are 17 planar indications reported in [3] and the all indications are actually in the weld material. Figure 3.1.-1 shows the orientation of the indication around the weld.
Of these, 2 indications have an amplitude result that exceed-6 dB, for with vertical extent data of the indications is given. The 2 indications are compared to the allowable planar flaws of Table IWB-3512 (Ref.1), and presented in Table 3.1-1.The second combined of indications is not acceptable

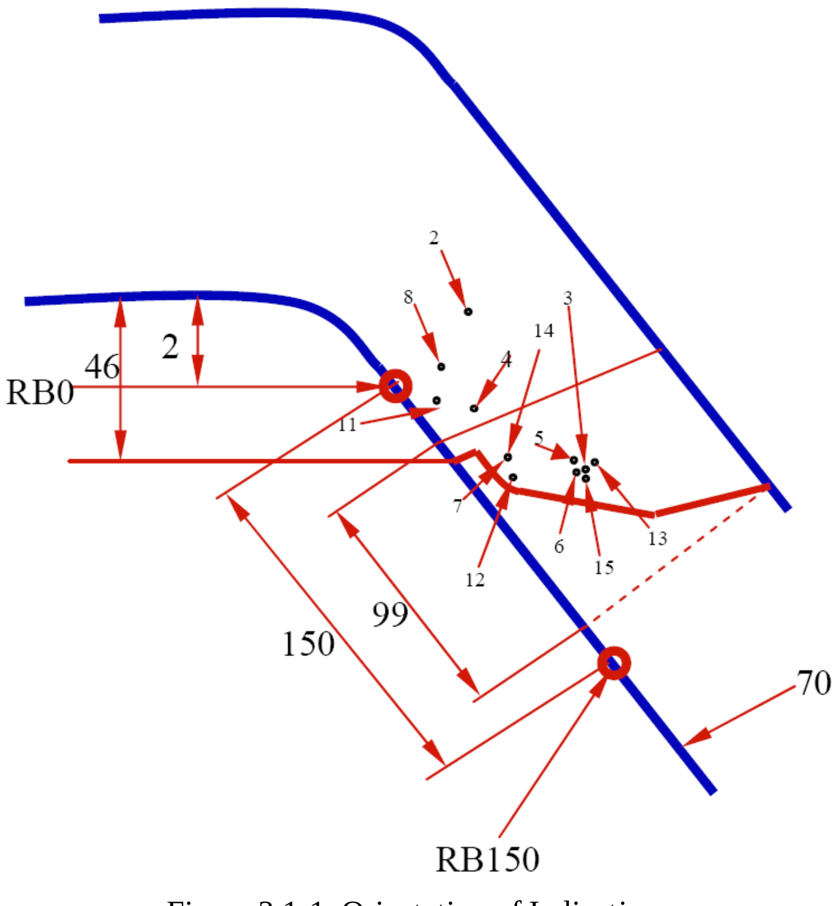

Figure 3.1-1. Orientation of Indications

Table 3.1-1 Planar Indications Assessment

Indication Number	Amp.	Left end A	Right end A	Defect Length (mm)	Defect Vertical Extent (mm)	Defect Depth from OD (mm)	t (mm)	a (mm)	l (mm)	a/l	a/t %	Limit of a/t %	**Comments**
	all flaws are subsurface flaws (Table IWB-3512-1 of Ref.2 is used)												
6	-2	63.0	57.0	6.0	1.5	19.5	74.0	0.8	6.0	0.125	1.014	2.7	4' allowable ratio of a/t is used
14	1	65.0	57.0	8.0	1.0	8.0	75.1	0.5	8.0	0.063	0.7	2.3	
Multiple flaws													
4,7,12,14	1	45	92	47.0	2.5	7.25	75.1	1.25	47.0	0.027	1.7	2.1	1.0 mm for #12 vertical extent
3,5,6,13,15	**-2**	**56**	**84**	**28.0**	**4.25**	**20.875**	**74.0**	**2.125**	**28.0**	**0.076**	**2.9**		**1.0 mm for #13 vertical extent**
Parameters for finding Mm and Mb, Figs. A-3310-1 & A-3310-2, Ref.2													
e (mm)	16.1	2a/t	0.1	2e/t	0.44	Mm	1.05	Mb	0.6				

3.2 Flaw Analysis

3.2.1 Configuration of Flaws

From Table 3.1-1, it can be seen that combined flaw is a subsurface flaw and a is 2.125mm, l is 28 mm and depth from OD is 20.875mm. All the flaws are around circumferential direction.

3.2.2 Stress data

Level A to D analysis for the lower head/heater nozzle/shell assembly was performed using Ansys-CFX Program, [5,6]. All transients and tests analysis are listed in Table2.-1 Figure 3.2.2-2 shows the locations of the stress class lines used in the analysis. Fatigue analysis data for class lines can be obtained from Ansys-CFX output files. Based on A-3200(b) in Appendix A of Section XI [1], K_I is calculated using linearised stress (see Table 3.2.2-1 and Fig 3.2.2-1) The maximum stresses of Level C Conditions are used to calculate K_{IC}

3.3 Flaw Growth Calculation

The method stipulated in Appendix A of Section XI, [1] for calculation of flaw growth is used in the analysis. Table 3.3-1 summarizes stress intensification factors, K_I in Level A to D Conditions when temperatures are grater that 200F (except Hydrotest conditions) The FlawEvo Program has been used for flaw growth evolution [4]

3.4 Material Fracture Toughness

K_{Ia} and K_{Ic} given in A-4200 of [1] are lower values from tests of SA-533 Gr. B Class 1, SA-508 Class 2, and SA-508 Class 3 steel provided in Figure A-4200-1 of [1], wich Figures can be used if the actual product form are not available. In this Figure, reference nil-ductility temperature RT_{NDT} is required. RT_{NDT} = 20 ^{0}F is used in this calculation.

For Level A & B, T = 200 ^{0}F is used conservatively to calculate K_{Ia} .

For the Field Hydrotest, T = 158 ^{0}F is considered as the lowest temperature.

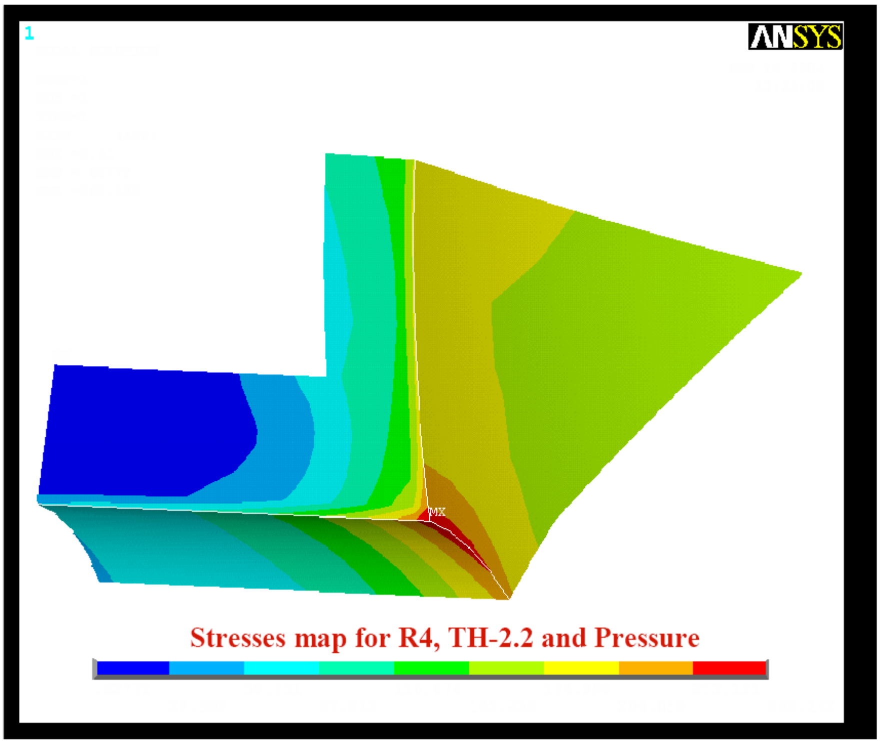

Figure 3.2.2-1. Stresses map for R4 Nozzle

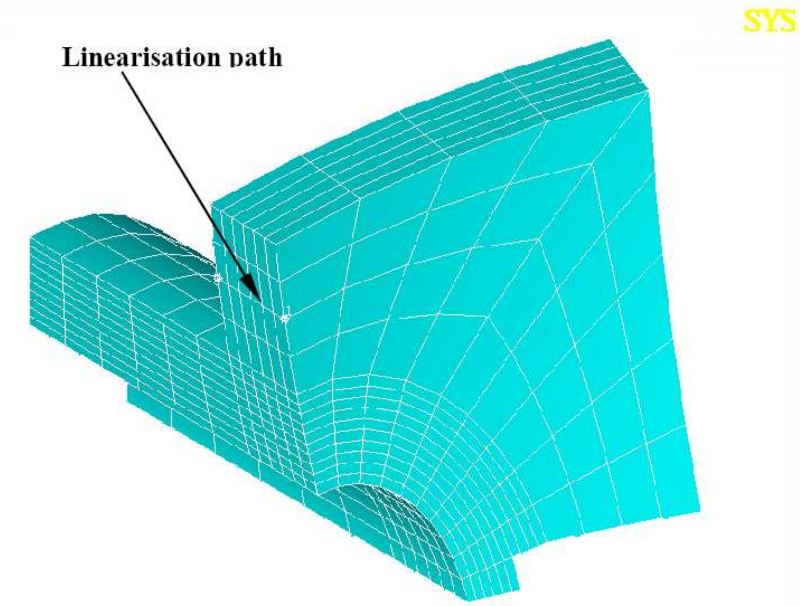

Figure 3.2.2-2. Path definition for R4 Nozzle

Table 3.2.2-1. Normal Conditions Stress Data (Summary)

INSIDE NODE = 14619 OUTSIDE NODE = 14722

** MEMBRANE **

SX	SY	SZ	SXY	SYZ	SXZ	
1.907	57.99	104.3	-12.1	9.56E-02	7.70E-02	
S1	S2	S3	SINT	SEQV		
104.3	60.49	-0.592	104.9	91.22		

** BENDING ** I=INSIDEC=CENTERO=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-3.917	-82.61	-74.9	14.96	-0.1226	7.66E-2
C	0	0	0	0	0	0
O	3.917	82.61	74.9	-14.96	0.1226	-7.66E-2
	S1	S2	S3	SINT	SEQV	
I	-1.17	-74.9	-85.36	84.19	79.48	
C	0	0	0	0	0	
O	85.36	74.9	1.17	84.19	79.48	

Table 3.3-1. Flaw Growth Analysis for Combined Flow for Level A, B,C,D & Hydrotest,[]

CONCLUZIE FISURA: **STABILA**						
Level A/B/C/D						
	K_{Ia}				196.0402	
	K_{ia_200F}				61.99335	
	CRITERIU DE ACCEPTARE			K_I	<	K_{ia_200F}
				13.43		61.99335
Hydro Test						
	K_{Ia}				66.49872	
	$K_{ia\_\_100F}$				21.02874	
	CRITERIU DE ACCEPTARE			K_I	<	K_{ia_158}
				11.04		21.02874
Level C						
	K_{IC}		Fig A-4200-1		200	
	K_{iC_100F}				141.4214	
	CRITERIU DE ACCEPTARE			K_I	<	K_{ia_200F}
				11		141.4214
Conclusion: **The combined flaw meets the req. stipulated in IWB-3600**						

3.5 Conclusions

Results from the analyses are summarized in following table.

Table 3.-4. Summary of Results for Flaw Assessments

Weld	**Transient**	**K_I** (ksi*sqrt(in))	**Acceptance criteria**(ksi*sqrt(in))	**Temp. Evaluated**
	Level A&B	13.43	62	200 ^{0}F(93 ^{0}C)
PZX	Level C&D	11	141	200 ^{0}F(93 ^{0}C)
	Hydrotest	12	21	158 ^{0}F(70 ^{0}C)

From the analyses, it has been shown that all the flaw are stable and growths of the flaws over the specified service cycles and transients are small. It is concluded that the indications found at these weld locations during the inaugural inspection are acceptable for service without repair with the following restrictions

- The minimum temperature required for hydrotest under a pressure of 2030 psi (14.MPa) for the Pressurizer is 158 ^{0}F(70 ^{0}C)

4. References

1. ASME Code, Section XI, RULES FOR Inspection of Nuclear Power Plant Components, 2001 Edition
2. Cernavoda 2 Design Manual
3. MT Cernavoda 2 UT Report 82-MT-33324-IIUT-039, Pressurizer Weld PZ39
4. FlawEvo Program, Versiunea 2, CITON/ACD
5. Ansys-CFX Program, Ver. 11.0
6. U2 Pressurizer Stress Analysis, Doc.no. 2-2-33324-1-1-AT1 Rev. 0