GE Nuclear Energy

COMMONWEALTH EDISON COMPANY
DRESDEN NUCLEAR POWER PLANT
UNITS 2 AND 3
SHROUD AND SHROUD REPAIR HARDWARE ANALYSIS
VOLUME I : SHROUD REPAIR HARDWARE BACKUP CALCULATIONS

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ABSTRACT

Volumes I and II of this document provide the results of the stress analysis of the Dresden 2 and 3 and Shroud Repair Hardware, demonstrating that structural integrity is maintained when subjected to the loading and limits specified in Design Specification 25A5688.

EXECUTIVE SUMMARY

This report provides the results of the stress analysis of the Dresden Units shroud and shroud repair hardware when subjected to all applied loadings including seismic, pressure, deadweight, and thermal effects.

The shroud restraint hardware consists of four identical sets of tie rod and spring assemblies. The four sets are spaced 90° apart, beginning at 20° from vessel zero. Each set consists of the following major elements:

1. An Upper Spring, located in the reactor pressure vessel (RPV)/shroud annulus at the top guide elevation. This spring provides lateral seismic support to the shroud at the top guide elevation and transmits seismic loads from the nuclear core directly to the RPV.

2. An Upper Support Assembly, located in the annulus from the top guide elevation to the top of the shroud. This assembly provides a connection for the tie rod to the shroud top.

3. A Middle Spring, located in the annulus at the elevation of the jet pump support brackets. This spring provides lateral seismic support to the shroud, keeps the shroud from coming in contact with the jet pump support brackets during a seismic event, and restrains the tie rod movement for proper tie rod vibration characteristics.

4. A Lower Spring, located in the annulus at the core plate and shroud support region. This spring provides lateral seismic support to the shroud, transmitting core seismic loads to the RPV. In addition, this spring provides a connection for the tie rod to the shroud support plate.

5. The Tie Rod, which connects to the upper end of the top of the shroud and to the lower end of the lower spring. This component develops a thermal preload due to normal operating temperature, which in turn provides vertical clamping forces to the shroud.

The upper, middle and lower springs are optimized to transfer the lateral operational, hydrodynamic and seismic loads while meeting the stress limits.

The stress analysis of the overall core shroud was performed with the ANSYS code [Reference 1]. A three-dimensional finite element model was constructed which included the shroud from the upper flange at the shroud head joint down to the connections at the RPV. Because of the symmetrical behavior of the shroud under the applied loads, a 180° circumferential segment was modeled.

The stress analysis of the major shroud repair hardware components was performed with the COSMOSM [Reference 10] and ANSYS codes. For the smaller components, hand calculations were performed.

The load combinations and structural acceptance criteria are contained in the Design Specification [Reference 2]. The results of the stress analysis demonstrate that the shroud and shroud repair hardware meet the requirements of that specification.

The Volume I of this report is describing the analysis of the shroud repair hardware.

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SHROUD REPAIR HARDWARE

1.0 INTRODUCTION

Intergranular stress corrosion cracking (IGSCC) has been found in the core shroud welded joints of several Boiling Water Reactors. Similar cracking may also exist in the welded joints of the Dresden Units 2 and 3 Core Shroud. GENE has designed a shroud repair system that reinforces the shroud in the event that any or all of the seven shroud horizontal weld joints are cracked. The stress analysis discussed in this report demonstrates that the shroud and the shroud repair system structural integrity is maintained if any or all of these seven welded joints are cracked completely through their thickness and around their entire 360° circumference. The structural integrity of the shroud and shroud repair system is also demonstrated in the event that the shroud is uncracked and the repair system is installed.

The Volume I of this report is describing the analysis of the shroud repair hardware.

2.0 SHROUD REPAIR SYSTEM DESIGN FEATURES

The shroud repair system consists of four identical sets of tie rod and spring assemblies. The four sets are spaced at 90° intervals beginning at 20° from vessel zero. A layout of one of the tie rod and spring sets is shown in Figure 2.1.

The tie rods are thermally preloaded to provide vertical compressive clamping forces on the shroud. The magnitude of the tie rod thermal preload is greater than the net uplift forces on the shroud due to normal operating pressures and postulated Loss of Coolant Accident (LOCA) recirculation line break pressures, so that no vertical separation of shroud sections would occur in those cases if the welded joints are postulated to be completely cracked. This is not the case for postulated LOCA main steam line break uplift pressures, which are sufficient to overcome the tie rod preload and momentarily separate shroud sections.

The upper, middle, and lower springs provide a lateral seismic load path from the top guide and core plate to the RPV. The magnitude of the seismic loads in these springs is a function of their stiffness. The stiffness has been optimized to minimize the seismic loads while still meeting the stress and displacements limits. The U-shaped upper springs consists of tapered legs that flex towards each other under lateral seismic loads. The taper in these legs has been optimized to produce constant stress along their length while providing the required stiffness. For the middle spring, the flexibility of the taper beam section provides the needed lateral stiffness to keep the middle section of the shroud from coming in contact with the jet pump support brackets during a seismic event. This keeps the shroud from moving closer than 1/2-inch to the jet pump support bracket. The rigid middle section of the middle spring also provides an intermediate lateral support to the tie rod. The natural vibration frequency of the tie rod with this intermediate support is then well removed from the flow-induced forcing frequency (flow induced vibration is discussed in detail in Section 6.6). For the lower spring, the flexibility of the Y-shaped feature at the top provides the lateral stiffness property, whereas the flexibility of the straight middle section provides the axial stiffness property, which in combination with the stiffness of the tie rod and upper axial component determines the tie rod thermal preload.

The shroud geometry and location and designation of the seven shroud horizontal weld joints are shown in Figure 2.2.

Enclosure 10

GENE 771-85-1194, Revision 2

Dresden Units 2 & 3, Shroud Repair Seismic Analysis Backup Calculations

General Electric Nuclear Company Proprietary Information

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Enclosure 9

GENE-771-84-1194, Revision 2

Dresden Units 2 & 3, Shroud Repair Seismic Analysis

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GENE Stress Report, 25A5691, Revision 2

Pressure Vessel - Dresden Units 2 & 3

GE Nuclear Energy

25A5691 SH. NO. 1
REV. 2

REVISION STATUS SHEET

DOC TITLE PRESSURE VESSEL

LEGEND OR DESCRIPTION OF GROUPS

TYPE: STRESS REPORT

FMF: DRESDEN 2 AND 3

MPL NO: PRODUCT SUMMARY SEC. 7

THIS ITEM IS OR CONTAINS A SAFETY RELATED ITEM YES ☒ NO EQUIP CLASS P

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1	J. L. TROVATO 03/27/95	RJA	
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1.0 SCOPE

This document is the ASME Code Section III Paragraph N-142 Stress Report for the Reactor Pressure Vessel. This analysis addresses the new loads applied to the vessel as a result of the installation of the shroud stabilizers which function to replace the horizontal girth welds H1 through H7 and weld H8 in the core shroud.

2.0 APPLICABLE DOCUMENTS

2.1 General Electric Documents. The following documents form a part of this stress report to the extent specified herein.

Subject	Document Number	
a. Code Design Specification	25A5689	Rev. 1
b. Shroud Repair Hardware Design Specification	25A5688	Rev. 2
c. GE Drawing-Reactor Vessel SH-4	885D660	Rev. 8
d. GE Drawing-Vessel Loading	885D910	Rev. 6
e. GE Drawing-Detail, Support Lower	112D6664	Rev. 0
f. GE Drawing-Detail, Contact Lower	112D6667	Rev. 0
g. GE Drawing-Detail, Contact Middle	112D6681	Rev. 1
h. GE Drawing-Detail, Contact Upper	112D6666	Rev. 0
i. GE Drawing-Reactor Thermal Cycles	921D265	Rev. 1
j. GE File-Shroud Support Dresden 2	VPF # 1248-114-4	
k. GE File-RPV Stress Report for Dresden 2	VPF # 1248-436-1	
1) Report # 8 Rev. 5-Support Skirt Analysis		
2) Report # 10 Rev. 6-Brackets		
3) Report # 11 Rev. 4-Shroud Support System Analysis		
4) Report # 20-Rev. 3-Shell Analysis		
l. GE Shroud Mechanical Repairs Program Dresden 2 & 3- Seismic Analysis	GENE-771-84-1194	Rev 2
m. GE File-Shroud Support Dresden 3	VPF # 2252-131-3	
n. GE File-RPV Stress Report for Dresden 3	VPF # 2252-181-1	
1) Report # 8 Rev. 5-Support Skirt Analysis		
2) Report # 10 Rev. 6-Brackets		
3) Report # 11 Rev. 4-Shroud Support System Analysis		
4) Report # 20-Rev. 3-Shell Analysis		

2.2 Codes and Standards. The following documents of the specified issue form a part of this specification to the extent specified herein.

2.2.1 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code

a. Section III, 1963 Edition and Addenda through Summer 1964 (Dresden 2)

b. Section III, 1965 Edition and Addenda through Summer 1965 (Dresden 3)

2.2.2 Other Documents
   a. "Roark's Formulas For Stress & Strain", by W. C. Young, 6th Edition
   b. "Theory of Plates and Shells", by S. Timoshenko, 2nd Edition

3.0 GENERAL DESCRIPTION

3.1 Purpose

The purpose of the shroud stabilizers is to structurally replace all of the horizontal girth welds in the core shroud and and weld betweeen the shroud cylinder and the shroud support plate. These welds provide support for the cylindrical plate sections, and the shroud head, and prevent core bypass flow from exiting to the downcomer region. The core top guide and core support plate horizontally support the fuel assemblies and maintain the correct fuel channel spacing permitting control rod insertion.

3.2 Design Requirements

The design requirements for the shroud stabilizers were separated into two documents. The first document addressed those requirements that were not under the jurisdiction of the ASME Code (Paragraph 2.1.b). The second document addressed those requirements that were under the jurisdiction of the ASME Code (Paragraph 2.1.a).

3.3 Acceptability

This Stress Report documents the acceptability of the structural integrity requirements of the Code Design Specification defined in Paragraph 2.1.a. The original B & W stress report for Dresden 2 (2.1.k) and for Dresden 3 (2.1.n) are indentical except their VPF numbers. Therefore, any reference to 2.1.k implies reference to 2.1.n also. Where data for Dresden 2 (2.1.j) differs from Dresden 3 data (2.1.m), the most conservative of the two values are used in the calculations and are specifically indicated.

4.0 ANALYSIS

4.1 General

The Design Specification (2.1.a) defines four new design mechanical loads on the reactor pressure vessel. These loads and their point of application are shown in Figure 1 and Table 1. These loads are separated by a distance of approximately equal to 70" (See Figure 1) and therefore, can be treated as separate forces. Each of F1, F2, F3 and F4 are addressed in sections 4.2 through 4.6.

4.2 Evaluation for load F1

The force F1 is applied to the reactor pressure vessel (RPV) shell 72 inches above the shroud support plate. It is a local force applied in the radial direction by the shroud repair during a Design Basis earthquake (DBE). At this elevation the RPV shell is 6.125 inches thick minimum (page B-2-2 of 2.1.k.4).

4.2.1 Compute stresses induced in RPV due to F1 applied radially to RPV shell at approximately 72 inches above the support plate during DBE:

Use theory of plate and shells by S. Timoshenko (2.2.2.b, pg. 471)

R_i=125.5" Inside radius of RPV

h = 6.125" Thickness of RPV shell exclusive of cladding

$\alpha = 125.5 + 6.125/2 = 128.563$" mean radius

$$\beta = \left(\frac{3(1-\nu^2)}{\alpha^2 h^2}\right)^{1/4}$$

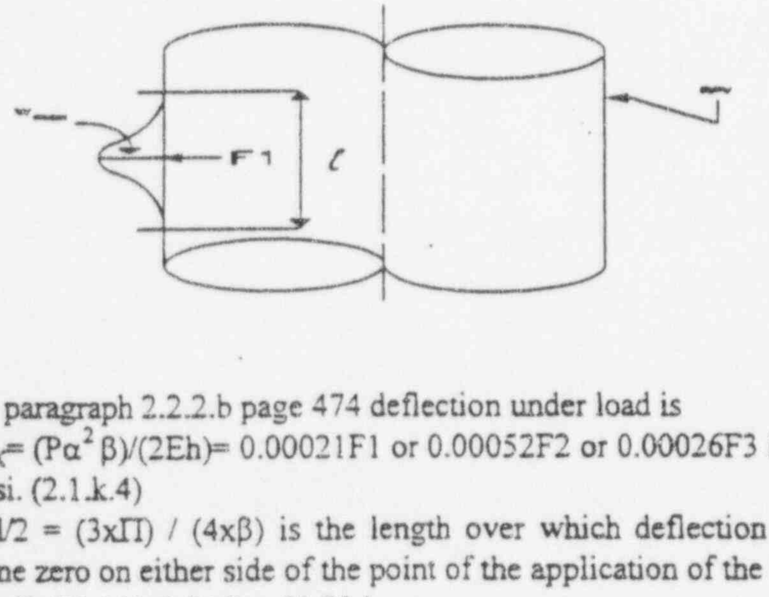
$\nu = 0.30$ Poisson's ratio (2.1.k.4)

$\beta = 0.046$

$M_{Max} = P/4\beta$ and $P = F1/2l$

where l is contact width of upper contact plate, 5" for F1 & 2" for F2 & 4" for F3 (2.1.f through 2.1.h).

M_{MAX} =0.543F1 or 1.358F2 & 0.679F3 k-in/in.



From paragraph 2.2.2.b page 474 deflection under load is

$W_{MAX} = (P\alpha^2\beta)/(2Eh)$= 0.00021F1 or 0.00052F2 or 0.00026F3 in. since E = 29.4 x 10^3 ksi. (2.1.k.4)

And l/2 = (3xΠ) / (4xβ) is the length over which deflection due to radial load become zero on either side of the point of the application of the load.

l/2 = (3xΠ) / (4x0.046) = 51.22 in.

$\sigma_1 = \sigma_l$ = Longitudinal Stress

$\sigma_2 = \sigma_t$ = Tangential Stress

Pm = Primary membrane stress intensity

Pl = Primary local membrane stress intensity

Pb = Primary bending stress intensity

$\sigma_1 = \sigma_l = 6M_{MAX}/h^2 = 0.087\ F1$ or $0.218\ F2$ or $0.109\ F3$ ksi

$\sigma_2 = \sigma_t = 6\ \nu\ M_{MAX}/h^2 + E\ Wmax / \alpha = 0.074\ F1$ or $0.186\ F2$ or $0.093\ F3$ ksi

4.2.2 For Faulted condition F1 = 190 kips. the maximum value of Pl stress intensity due to this load is negligible and the maximum value of Pb stress intensity due to this load is = 0.087 x 190 =16.53 ksi. These stress intensities occur directly under the point of load application.

4.2.3 The existing primary local membrane stress intensities in the shell per the original Stress Report (Paragraph 2.1.k.4, Page B-19-2) are 12.8 ksi (Pl) and also (Pl + Pb).

4.2.4 The new value of Pl is same as original value of 12.8 ksi. The new value of (Pl + Pb) can be conservatively calculated as 12.8 + 16.53 = 29.33 ksi.

4.2.5 The allowable value of primary membrane Pm stress intensity is Sm, which equals 26.7 ksi. and the allowable value of primary local (Pl) plus primary bending (Pl + Pb) stress intensity is 1.5Sm, which equals 40 ksi. (paragraph 2.1.k.4).

4.2.6 The Emergency load F1 is almost same as (only 4 kips. less) Faulted load F1 and thus the new value of (Pl + Pb) is 28.98 ksi. which is below the allowable of 1.5Sm = 40 ksi. per 2.1.k.4.

4.2.7 Primary stress intensity (Pb) for normal / upset condition F1 = 93 kips = 0.087 x 93 = 8.09 ksi. and the primary local stress intensity (Pl) is negligible. The existing Pl and (Pl + Pb) are 12.8 ksi. The new Pl = 12.8 ksi while new (Pl + Pb) = 12.8 + 8.09 = 20.89 ksi. < 40 ksi (1.5Sm).

4.3. <u>Evaluation for load F2</u>

Stresses in RPV due to Faulted condition F2 = 24 kips applied at approximately 188 inches above the shroud support plate can be obtained by scaling from values obtained for F1 = 190 kips. and using the lower contact plate width of 2 inches as value of "ℓ".

$\sigma_1 = 5.23$ ksi. And $\sigma_2 = 4.46$ ksi.

4.3.1 The maximum value of Pl stress intensity due to this load is negligible and the maximum value of Pb is 5.23 ksi. These stress intensities occur directly under the point of load application.

4.3.2 The existing primary local membrane stress intensities in the shell per the original Stress Report (Page B-19-2 of 2.1.k.4) is 12.8 ksi. for (Pl) and (Pl +Pb).

4.3.3 The new value of Pl is conservatively same as existing value of 12.8 ksi. The new value of Pl + Pb can be conservatively calculated as 12.8 + 5.23 = 18.03 ksi.

4.3.4 The faulted allowable value of primary membrane stress intensity is Sm, which equals 26.7 ksi. and the allowable value of primary local (Pl) and the primary plus bending (Pl + Pb) stress intensity is 1.5Sm, which equals 40 ksi. per 2.1.k.4.

4.3.5 The Emergency load F2 is same as Faulted load F2 and thus the new value of (Pl + Pb) is 18.03 ksi. which is below the allowable of 1.5Sm = 40 ksi. per 2.1.k.4.

4.3.6 Since the faulted stress intensities (Pl) and (Pl + Pb) are below the upset conditions allowable of 40 ksi., the primary stress intensity for normal / upset condition F2 = 12 kips. is satisfied by inspection as the F2 in upset conditions is lower than F2 of the DBE condition.

4.4 <u>Evaluation for load F3</u>

Stresses in RPV due to Faulted condition F3 = 140 kips applied at approximately 244 inches above the shroud support plate, can be obtained by scaling from values obtained for F1 = 190 kips. and using the lower contact plate width of 4 inches as value of "l".
$\sigma_1 = 15.26$ ksi. and $\sigma_2 = 12.97$ ksi.

4.4.1 The maximum value of Pl Stress intensity due to this load is negligible and the maximum value of Pb is 15.26 ksi. These stress intensities occur directly under the point of load application.

4.4.2 The existing primary membrane stress intensities in the shell per the original Stress Report (Page B-19-2 of 2.1.k.4) is 12.8 ksi., for (Pl) and (Pl + Pb).

4.4.3 The new value of Pl is conservatively same as existing value of 12.8 ksi. The new value of (Pl + Pb) can be conservatively calculated as 12.8 +15.26 = 28.06 ksi.

4.4.4 The faulted allowable value of primary membrane stress intensity is Sm, which equals 26.7 ksi. and the allowable value of primary local (Pl) and the primary plus bending (Pl + Pb) stress intensity is 1.5Sm, which equals 40 ksi. per 2.1.k.4.

4.4.5 The Emergency load F3 is almost same as Faulted load F3 (only 6 kips less) and thus the new value of (Pl + Pb) is 26.79 ksi. which is below the allowable of 1.5Sm = 40 ksi. per 2.1.k.4.

4.4.6 Since the faulted stress intensities (Pl) and (Pl + Pb) are below the upset conditions allowable of 40 ksi., the primary stress intensity for normal / upset condition F3 = 67 kips. is satisfied by inspection as the F3 in upset conditions is lower than F3 of the faulted condition.

4.5 Evaluation of load F4 For RPV Shell

The force F4 is applied to vertical plate at 4.25 inches (2.1.e) from the inside surface of the RPV shell (this results in moment arm of 4.25 + 6.125 / 2 = 7.31" at RPV shell center line). The value of F4 is 339 kips. for Faulted and Emergency, and 123 kips. for Normal / Upset conditions, all without thermal preload, for primary stress evaluation. Additionally Normal / Upset condition is also evaluated for primary plus secondary stress intensities ranges along with fatigue using F4 of 194 kips per 2.1.a.

4.5.1 Formulas for Stress Intensity for F4 @ Shell

Apply F4 as vertical load and it will transfer as axial load V = F4 kips and moment of 7.31 F4 k-in. This load V = F4 kips. and moment 7.31F4 k-in. will be assumed to be resisted by the width of RPV shell equal to the width (b = 13.5"), of the lower support plate (paragraph 2.1.e).

Using analysis methods for edge loads for m_o (para. I-233 of 2.2.1.a) and direct membrane stress as P/t, the stresses in shell are as follows:

$$\sigma_\ell = 6\,m_o/t^2 + P/t,$$

$$\sigma_t = \frac{EW_o}{R_m} + 6\nu\frac{m_o}{t^2}$$

where

m_o = End moment = 7.31 F4/13.5 k-in/in;
t = Thickness of shell = 6.125";
P = F4/13.5 kips/in;
E = Young's Modulus = 29.4×10^3 ksi.;
R_m = Vessel Mean Radius = 128.563 in.;
ν = Poisson's ratio = 0.30;
W_o = Deflection at edge (calculated below).

Using para. I-232(2) of 2.2.1.a, the limiting value of $W_o = m_o / 2\beta^2 D$, where $D = Et^3/12(1-\nu^2)$, $\beta = \sqrt[4]{\frac{3(1-\nu^2)}{R_m^2 t^2}}$ and substituting values of D, β in terms of E, t, R_m, the expression for σ_t can be simplified as $\sigma_t = \frac{6m_o}{t^2}\left(\nu + \sqrt{\frac{1-\nu^2}{3}}\right)$. And with

$\nu = 0.30$ $\sigma_t = \frac{6m_o}{t^2}(0.85)$.

Further, since t = 6.125", the final σ_ℓ = 0.099F4 ksi., σ_t = 0.074F4 ksi.

These σ_ℓ,σ_t stresses will be used to calculate the stress intensity by principal stress difference formulas. Since shear stress is zero, the principal stresses are $\sigma_1 = \sigma_\ell$; $\sigma_2 = \sigma_t$. Primary stress intensity is maximum of σ_1, σ_2 or $\sigma_1 - \sigma_2$.

4.5.2 Evaluation For Faulted Condition

Primary local membrane plus bending (Pl + Pb) stress intensity for faulted condition F4 = 339 kips. are as follows:

$\sigma_\ell = \sigma_1 = 0.099 \times 339 = 33.56$ ksi. And $\sigma_t = \sigma_2 = 0.074 \times 339 = 25.09$ ksi.

Thus the maximum primary stress intensity (Pl + Pb) = 33.56 ksi

From page B-19-3 of original stress report (2.1.k.4) the existing maximum primary local membrane (Pl) & also (Pl + Pb) stress in tangential direction is 12.8 ksi. and 6.4 ksi. in longitudinal direction. And as the major stresses due to F4 are Pb, i.e.; while Pl = 0.012F4 = 4.07 ksi., Pb is 0.087F4 = 29.49 ksi. out of a total (Pl + Pb) of 33.56 ksi. And the new values will be as follows:

Pl = 6.4 + 4.07 = 10.47 ksi. OR 12.8 ksi.

Pl + Pb = 6.4 + 33.56 = 39.96 ksi. OR 12.8 + 25.09 = 37.89 ksi.

The allowable Pl and Pl + Pb stress intensity is 1.5Sm = 40 ksi. in the original stress report (2.1.k.4).

4.5.3 Evaluation For Emergency Condition

Primary local membrane plus bending stress intensity (Pl + Pb) and primary local membrane stress intensity (Pl) for emergency conditions and the allowable of the original stress report is same in both conditions.

4.5.4 Evaluation For Normal / Upset Conditions

Normal / upset conditions evaluations required for primary, primary plus secondary, and peak stress intensities per 2.2.1.a are shown in this section.

4.5.4.1 Primary stress intensity evaluation is required for F4 = 123 kips. which will give Pl + Pb = 0.099 x 123 = 12.18 ksi. and Pl = 0.012 x 123 = 1.47 ksi.
The existing primary stress intensity at this location for operating condition is Pl = 12.8 ksi. and Pl + Pb = 12.8 ksi. (page B-19-3 of 2.1.k.4). Thus the new value of Pl + Pb at this location is

Pl + Pb = 12.8 + 12.18 and Pl = 12.8 + 1.47
= 24.98 ksi < $1.5S_m$ = 40 ksi. = 14.27 ksi. < Sm = 26.7 ksi.

4.5.4.2 The primary plus secondary stress intensity for upset condition load F4 = 194 kips is performed for all 120 cycles including the blow down transient as follows (at RPV shell):
Conservatively the primary plus secondary intensity stress range for 120 cycles is Sn = 0.099 x 194 = 19.21 ksi. The existing value of same primary plus secondary stress intensity range is 20.4 ksi. (page B-16-1 of 2.1.k.4). Thus the new value of S_n = 20.4 + 19.21 = 39.61 ksi. < $3S_m$ = 80 ksi.

4.5.4.3 Fatigue, i.e., peak stress intensity range, evaluation for 120 cycles F4 is as follows:

$S_a = K_e x \frac{S_n}{2}$ Since $S_n < 3 S_m$, $K_e = 1.0$

And there is no stress concentration factor per page B-14-1 of 2.1.k.4

S_a = 22.55 (existing S_a, page B-18-2 of 2.1.k.4) + 19.21 / 2 = 32.15 ksi.

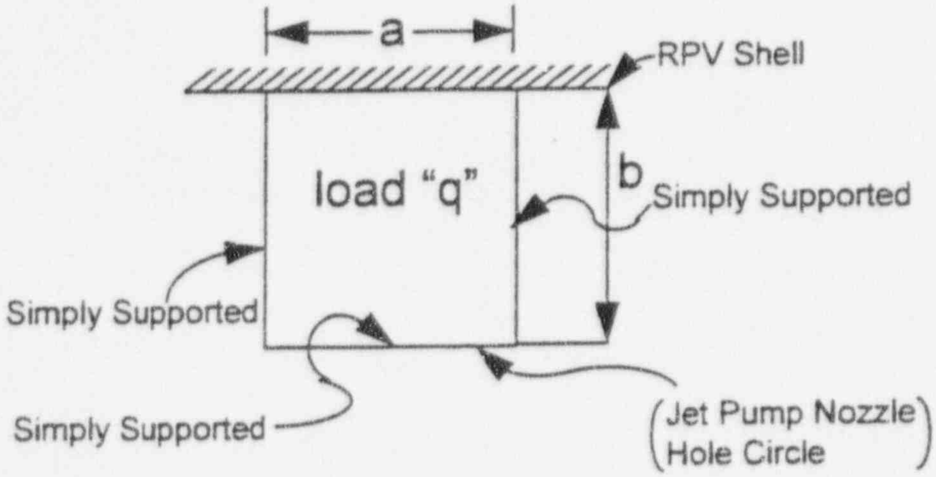
N_{all} = 20000 (Figure N-415(A) of 2.2.1.a)

Usage Factor = UF = 120 / 20000 = 0.006 < 1.0

4.6 Evaluation of RPV Shell and Baffle Plate Junction for F4 Load

4.6.1 Evaluation for Weld H8 Uncracked condition

Due to the support afforded by jet pump nozzles to the baffle plate, the load F4 will be essentially distributed over a rectangular plate between RPV shell and jet pump nozzle hole circle with the width equal to the width of the lower support plate as shown below:



where

a = Width of horizontal lower support plate (2.1.e) = 13.5";

b = Distance (radial) between shell inside radius (=125.5") and jet pump nozzle hole circle radius = 226 / 2 = 113" (per 2.1.j and 2.1.m) = 12.5";

q = Distributed load = F4 / 13.5 x 12.5 = 0.006F4 ksi.

Using formulas for middle of fixed edge moments (for uniformly loaded plate with one edge fixed, other three edges simple supported) from Timoshenko (2.2.2.b, page 241), the moment $\bar{M}y = d_2 q l^2$ (symbols per 2.2.2.b). Further, since b / a = 0.907 d_2 = 0.0916 from Table 52 of 2.2.2.b. And since l = 12.5" (smaller of a = 13.5" or b = 12.5"),

$\bar{M}y = 0.0916 \times 0.006F4 \times (12.5)^2 = 0.0859F4$ in-kips/in.

Further the bending stress $\sigma_b = 6\ \bar{M}y / t^2$ and with t = 2.063" (thickness of baffle plate per 2.1.j), the bending stress value is

$\sigma_b = 0.0859F4 x\ 6 / (2.063)^2 = 0.1211F4$ ksi

And shear stress τ = F4 /Area = (F4 / (Perimeter x 't'))

$\tau = \{F4 / [(2) \times (12.5 + 13.5) \times (2.063)]\} = 0.0093F4$ ksi.

Principal stress $\sigma_1 = 0.1211F4 / 2 + \{(0.1211F4 / 2)^2 + (\tau)^2\}^{1/2} = 0.1218F4$ ksi.

$\sigma_2 = 0.1211F4 / 2 - \{(0.1211F4 / 2)^2 + (\tau)^2\}^{1/2} = -0.0007F4$ ksi.

The maximum stress intensity = ($\sigma_1 - \sigma_2$) = 0.1225F4 ksi.

4.6.1.1 Evaluation for Faulted Condition

Primary local membrane plus bending (Pl + Pb) stress intensity for faulted conditions F4 = 339 kips. are as follows:
Thus the maximum primary stress intensity (Pl + Pb) = 0.1225 x 339 = 41.5 ksi
The maximum primary membrane plus bending stress intensity at this location from the existing stress analysis (2.1.k.3 page B-16-7) is 0.5 ksi. Therefore, the new maximum primary membrane plus bending (Pl + Pb) stress intensity is = 0.5 + 41.5 = 42 ksi. which is less than faulted allowable of 3Sm = 80 ksi for carbon steel (vessel material) and also less than the 3Sm = 70 ksi for Inconel (baffle plate material).

4.6.1.2 Evaluation for Emergency Condition

Primary local membrane plus bending stress intensity (Pl + Pb) for the Emergency condition F4 = 339 kips. is equal to 0.1225 x 339 = 41.5 ksi. Thus new Pl + Pb = 0.5 + 41.5 = 42 ksi. which is less than emergency condition allowable of 2.25Sm = 60 ksi for carbon steel (vessel material) and also less than the 2.25Sm = 52.5 ksi for Inconel (baffle plate material).

4.6.1.3 Evaluation for Normal / Upset Conditions

4.6.1.3.1 Evaluation for Primary Stress Intensity

Primary stress intensity evaluation for upset conditions is required for F4 = 123 kips. which will give Pl + Pb value of 0.1225 x 123 = 15.06 ksi.
The existing primary stress intensity for operating conditions is 9.6 ksi (page B-16-7 of 2.1.k.3). Thus the new value of Pl + Pb at this location is
Pl + Pb = 9.6 + 15.06
= 24.66 ksi. < 1.5Sm = 40 ksi for cabon steel, the vessel material
< 1.5Sm = 35 ksi for Inconel, the baffle plate material

4.6.1.3.2 Evaluation for Primary plus Secondary Stress Intensity

The primary plus secondary stress intensity range for upset condition F4 = 194 kips is performed for all 281 loading cycles including the blow-down transient as follows (at junction of baffle plate and RPV shell):

Conservatively the highest primary plus secondary stress intensity range is for 10 cycles of loss of feed water pump transient and is equal to Sn = 0.1225 x 194 = 23.77 ksi The existing value of the same primary plus secondary stress intensity range is 67.2 ksi. (page C-16-7 of 2.1.k.3). Thus the new value of Sn

= 67.2 + 23.77 = 90.97 ksi. > 3Sm = 70 ksi. (conservatively, for Inconel, the baffle plate material)

4.6.1.3.3 Evaluation for Fatigue

Fatigue, i.e., peak stress intensity range, for these 10 cycles is Sp = 88.8 (Existing) + 1.64 x 23.77 = 127.78 ksi. where 1.64 is the bending stress concentration factor as used in the original stress report, pg. B-17-2.
Sa = Ke x Sp / 2. and since Sn > 3 Sm,
Ke = 1.0 + [(1/n - 1) / (m - 1)] { (Sn / 3Sm) - 1} = 1.6
Sa = 102.22 ksi.
Na = 550 (Figure N-415(A) of 2.2.1.a)
Usage Factor = UF = 10 / 550 = 0.018
Similarly calculating the usage factor for remaining 271 cycles, the cumulative usage factor is 0.141 << 1.0, and thus is well below the code limit.

4.6.2 Evaluation for Weld H8 Cracked condition

A finite element model using computer program ANSYS was analyzed for this condition. The results are summarized in this subsection.

4.6.2.1 Evaluation for Faulted Condition

Primary local membrane plus bending (Pl + Pb) stress intensity for faulted conditions F4 = 339 kips is 59.17 ksi. which is less than faulted allowable of 3Sm = 70 ksi. for Inconel (baffle plate material) as well as 3Sm = 80 ksi. for carbon steel (RPV shell material).

4.6.2.2 Evaluation for Emergency Condition

Primary local membrane plus bending stress intensity (Pl + Pb) for the Emergency condition F4 = 339 kips is 38.27 ksi which is less than 2.25Sm = 52.5 ksi. for Inconel (baffle plate material).as well as 2.25Sm = 60 ksi. for carbon steel (RPV shell material).

4.6.2.3 Evaluation for Normal / Upset Conditions

4.6.2.3.1 Evaluation for Primary Stress Intensity

Primary local membrane plus bending stress intensity (Pl + Pb) for the Emergency condition F4 = 123 kips is 22.43 ksi which is less than 1.5Sm = 35 ksi. for Inconel (baffle plate material).as well as 1.5Sm = 40 ksi. for carbon steel (RPV shell material).

4.6.2.3.2 Evaluation for Primary plus Secondary Stress Intensity

The primary plus secondary stress intensity range for upset condition F4 = 194 kips is performed for all 281 loading cycles including the blow-down transient at junction of baffle plate and RPV shell.

Conservatively the highest primary plus secondary stress intensity range is for all 281 cycles is Sn = 44.36 ksi < 3Sm = 70 ksi (conservatively, for baffle plate material).

4.6.2.3.3 Evaluation for Fatigue

Fatigue, i.e., peak stress intensity range, for all 281 cycles is Sp = 1.64 x 44.36 = 72.76 ksi where 1.64 is the bending stress concentration factor as used in the original stress report, pg. B-17-2.
Sa = Ke x Sp / 2. and since Sn < 3 Sm, Ke = 1.0
Sa = 36.38 ksi
Na = 11000 (Figure N-415(A) of 2.2.1.a)
Usage Factor = UF = 281 / 11000 = 0.026 < 1.0

4.7 Summary

Evaluation for Dresden Unit 2 & 3 for F1, F2, F3, F4 and their effects on all Code requirements are satisfied as documented in sections 4.1 through 4.6. All of the stress intensities due to the new design mechanical loads F1, F2, F3, and F4 satisfy the allowable stress intensities of the original Code of Construction (Paragraph 2.2.1.a for Dresden 2 and Paragraph 2.2.1.b for Dresden 3).

4.8 Evaluation of RPV Stabilizer Brackets

The new seismic load on the RPV stabilizer bracket location (F7) is 1120 kips. in DBE and 550 kips. in OBE. These when conservatively converted into individual bracket loads result in individual bracket loads of 275 kips. in OBE and 560 kips. in DBE. These loads are greater than the RPV stabilizer bracket seismic loading of 246 kips per document 2.1.d. Thus the effect of F7 (as a result of shroud stabilizer modification) on RPV is reevaluated using the existing analysis (2.1.k.2). The results of these re-evaluations (GENE-771-77-1194) show that the stress intensities at shell junction as well as the maximum stresses in the bracket legs are below their respective allowable. The highest stress intensity (including local stresses) in the shell junction is 42.83 ksi. which is below the allowable of 80 ksi.

4.9 Evaluation of RPV Skirt

The new seismic shear and overturning moment on the base of RPV skirt are F5 and M5. The maximum of these values are F5 = 1100 kips and M5 = 25220 kip-ft in Upset conditions while in Faulted conditions they are F5 = 2220 kips. & M5 = 50870 kip-ft (Emergency condition values are slightly lower than Faulted condition values). These values are not the same as the seismic values of H = 870.72 kips and M = 25,200 kip-ft used in the original skirt stress analysis report (page B-19-3 of 2.1.k.1).

The bending moments in the original analysis & the present analysis are of the same nature, but have different numerical values. The original bending moments were calculated based on the seismic horizontal design acceleration coefficient of 0.4g and taking the summation of the moments of the horizontal seismic loads located at the center of gravity (C. G.'s) of each load causing the overturning moments. This was given in Table G of GE drawing 885D910 (2.1.d) for the original analysis. In the present analysis the bending moments are taken directly from the dynamic analysis of the seismic model. The details are available in GENE-771-84-1194 (2.1.l). This analysis was performed using time-history methodology.

The original seismic axial load was based on a vertical acceleration coefficient (= 0.08g OBE) multiplied by the total downward load. This axial load has not been changed in the present analysis even though the vertical acceleration coefficient is 0.067g in OBE per Dresden UFSAR The present analysis(GENE-771-77-1194) also documents the qualification of RPV skirt for DBE seismic while original analysis was performed for only OBE earthquake.

Therefore, the RPV skirt stresses are re-evaluated using the analysis of the existing stress report # 8. The results of these re-evaluations (GENE-771-77-1194) show that the maximum stresses in the skirt are below their respective allowable. The highest direct and shear stress in the skirt are 26.87 ksi. & 13.53 ksi. which are below the allowable of 40 ksi. and 16 ksi. respectively.

4.10 Evaluation of Shroud Support System

The new seismic shears and overturning moments on the base of shroud support are F6 and M6. The maximum (envelope of cracked and uncracked shroud) of these values are F6 = 520 kips and M6 = 10820 kip-ft in Upset conditions while in Emergency and Faulted conditions they are F6 = 1090 kips and M6 = 23080 kip-ft. These values are not the same as the seismic values of H = 945 kips and M = 6000 kip-ft used in the original stress analysis report (page B-11-1 of 2.1.k.3). Additionally there is an axial load on the support legs due to tie-rod attachment at the top of the shroud. Therefore, the stresses in shroud support system are re-evaluated using the analysis of the existing stress report # 11. The results of these re evaluations (GENE-771-77-1194) show that the maximum stresses in the shroud support system are below their respective allowable. The highest primary stress intensity is 32.53 ksi which is below the allowable of 52.5 ksi. The highest usage factor is (at the junction of support leg and RPV shell) 0.07 < 1.0. Thus the shroud support system meets all code allowable.

The shroud support legs were checked for buckling in the original stress report for dead weight plus OBE loads (2.1.k.3) with factor of safety of 1.97 against yield stress. In the present analysis, the load on support legs is same in both weld H8 uncracked and cracked. Therefore, only one check for buckling is performed in the present analysis. This check for buckling is performed (GENE-771-77-1194) under vertical & horizontal seismic loadings. The factors of safety for buckling under various conditions ranges from a low value of 1.2 based on short column theory & 4.2 based on long column theory (Faulted and Emergency condition) to a high value of 13.8 based on short column theory & 82.3 based on long column theory (Normal condition). Thus the support legs are adequetely supported against buckling failure.

5.0 Certification

Based on the best of my knowledge and belief, it is hereby certified that the analysis documented in this Stress Report satisfies the requirements of ASME Boiler and Pressure Vessel Code Section III, 1963 Edition with Addenda through Summer 1964 (Dresden 2) & 1965 Edition with Addenda through Summer 1965 (Dresden 3) and Design Specification listed in Paragraph 2.1.a. This certification is provided as required by Paragraph N-142 of said Section III.

Signature: AHerlekar Date: 5/12/95

License Number: C23562 State: California

AROON SADASHIV HERLEKAR
C 23562

Table 1 - ADDITIONAL DESIGN MECHANICAL LOADS

Force	Normal/Upset	Emergency	Faulted	Remarks
F1	93 kips	186 kips	190 kips	Primary Stress Only
F2	12 kips	23 kips	24 kips	Primary Stress Only
F3	67 kips	134 kips	140 kips	Primary Stress Only
F4	123 kips	339 kips	339 kips	Primary Stress Only(Note 3)
	194 Kips	-	-	Pl+Pb+Q+F Stresses Only
F7	550 kips	1100 kips	1120 kips	RPV Stabilizer Bracket Seismic load
F5	1100 kips	2210 kips	2220 kips	Seismic Shear @ RPV skirt
M5	25220 K-ft	50440 K-ft	50870 K-ft	Seismic Moment @ RPV skirt
M6	10820 K-ft	23080 K-ft	23080 K-ft	Seismic Moment @ Shroud Support
F6	520 kips	1090 kips	1090 kips	Seismic Shear @ Shroud Support

NOTES

1)F1, F2, F3 are discrete loads applied over a small area. At any one point in time, F1, F2, F3 are each applied to one location. At any one point in time, F4 is applied to 4 tie rod locations locations 90° apart for the installation of four shroud stabilizer assemblies. The load F4 shown is maximum and applies to one of any two tie rods 180 degrees apart, while the remaining three tie rods have loads lower than F4 values shown above.

2)The stress intensities shall meet the stress allowable of the ASME Code, Section III, for the load combinations defined by the Dresden UFSAR. Faulted and Emergency load combinations shall meet the stress allowable as defined by the Dresden UFSAR for the reactor pressure vessel.

3) Loads F1, F2, F3, F4 to be used in the primary stress evaluation are from document 2.1.a. Loads F5, F6, F7, M5 & M6 are taken from 2.1.b

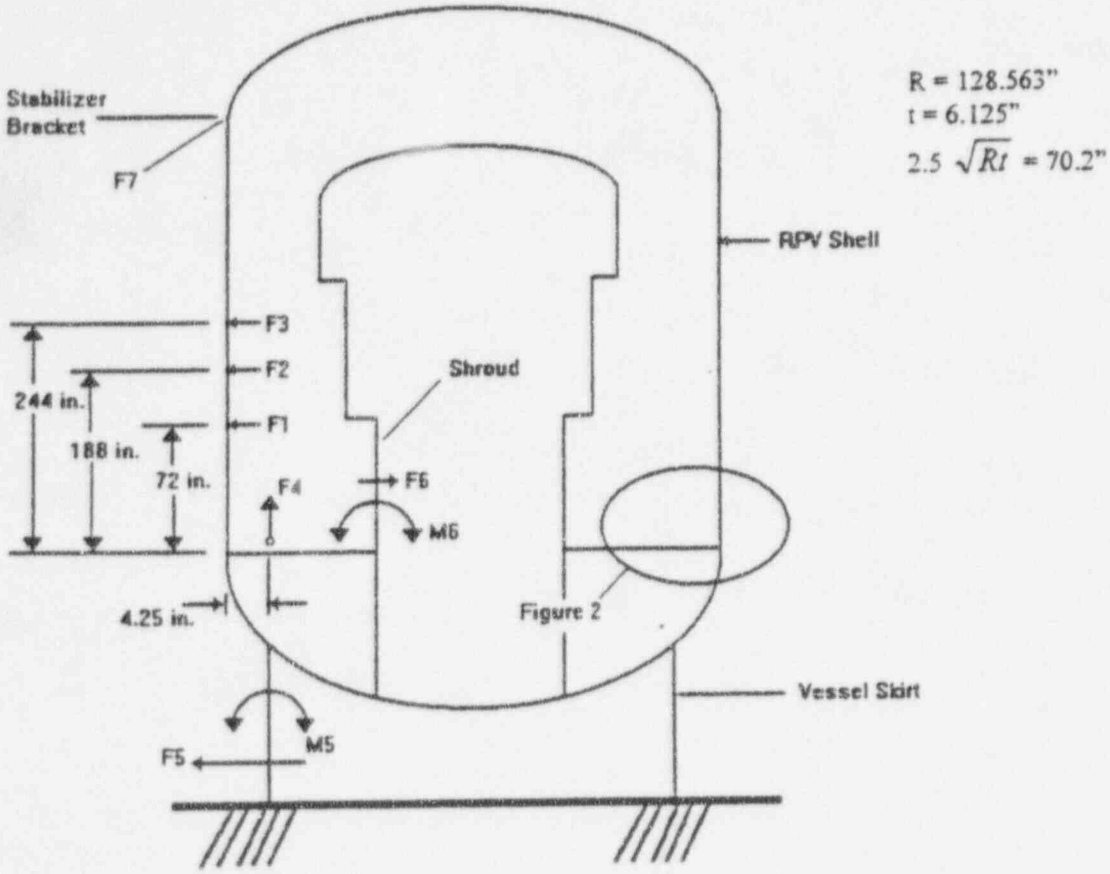


FIGURE 1. APPLICATION OF DESIGN MECHANICAL LOADS

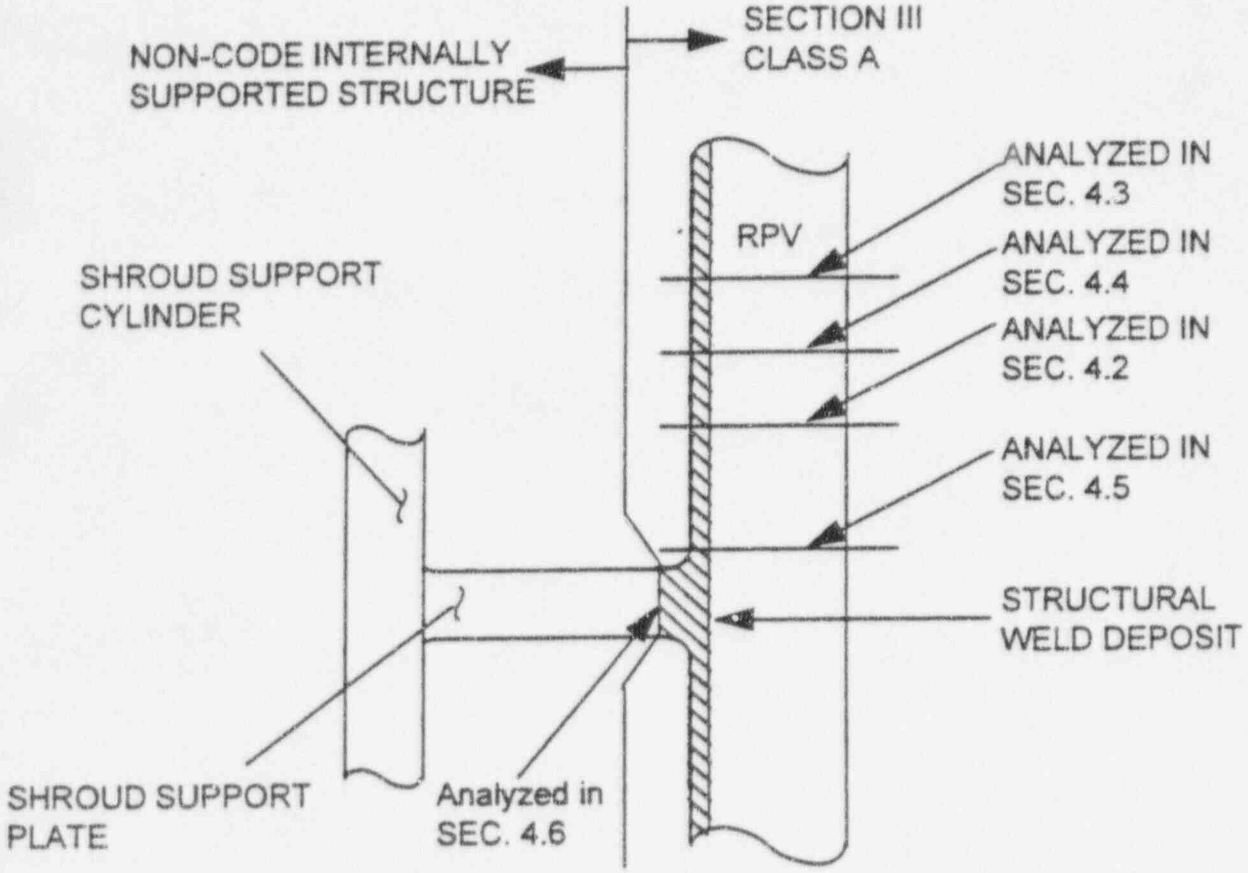


FIGURE 2. BOUNDARY OF ASME CODE JURISDICTION

Enclosure 12

GENE 771-77-1194, Revision 2

Shroud Repairs Program for Dresden Units 2 & 3 Back-up Calculations for RPV Stress Report No: 25A5691

General Electric Nuclear Company Proprietary Information

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