SO23-411-57-3-2

It is hereby certified that the analyses described in this design report have been properly and completely reconciled with the requirements of Section III of the ASME Boiler and Pressure Vessel Code, 1989 Edition (no Addenda)

Report 35 Pages
Appendix A 5 Pages
Appendix B 22 Pages
Appendix C 7 Pages
Appendix D 9 Pages

DESIGN REPORT NO. S-PENG-DR-002, REV. 01

ADDENDUM TO THE PRESSURIZER ANALYTICAL STRESS REPORT FOR SOUTHERN CALIFORNIA EDISON SAN ONOFRE UNITS 2 AND 3

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COMBUSTION ENGINEERING, INC.
WINDSOR, CONNECTICUT

This Design Analysis is complete and verified. Management authorizes the use of its results.

Prepared By: C.L.Mendrala [signature] Date: 8/27/97
Cognizant Engineer

Checked By: J.T. Wrenn [signature] Date: 8-27-97
Independent Reviewer

Approved By: K.H. Haslinger [signature] Date: 8-28-97
Supervisor, Structural Integrity and Testing

This Design Report is certified to be in compliance with the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Nuclear Power Plant Component, 1989 Edition, up to and including the (NONE) Addenda.

Certified By [signature] B. T. Lubin P.E.
Registration No. 15253
State of Connecticut
Date 8-29-1997

VPL No.: SO23-411-57-3-2
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RECORD OF REVISIONS

Rev	Date	Pages Changed	Prepared By	Reviewed By	Approved By
00	6-25-97	Original	A.V. Bauer	C.L. Mendrala	K.H. Haslinger
01	8-21-97	4, 5, 16, 20, 24-27, 32, 33, 35 Inserted Appendix C	C.L. Mendrala	J.T. Wrenn	K.H. Haslinger

ABSTRACT

The structural integrity of the Southern California Edison, San Onofre Units 2 and 3, Mechanical Nozzle Seal Assembly (MNSA), to be installed on the side pressurizer RTD nozzle and the bottom pressurizer level nozzle, is designed and fabricated under the requirements of Reference 5.1, Project Plan No. S3-NOME-IPQP-0156, to satisfy the requirements of the ASME Code, Section III. The acceptability of the design is established by the results of the detailed structural and thermal analysis contained in this report.

All stresses and cumulative fatigue usage factors within the scope of this report are satisfactory and meet the appropriate requirements from the ASME Boiler and Pressure Vessel Code, Section III, 1989 Edition (No Addenda) (Reference 5.9).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 OBJECTIVE

The objective of this design report is to present the results of the evaluation of the Mechanical Nozzle Seal Assembly (MNSA) to be installed on the side pressurizer RTD nozzle and the bottom pressurizer level nozzle at the Southern California Edison (SCE), San Onofre Units 2 and 3.

The MNSA is a mechanical device that acts as a complete replacement of the "J" weld between an Inconel 600 instrument nozzle and the pressurizer. Its function is to prevent leakage and restrain the nozzle from ejecting in the event of a through-wall crack or weld failure of a nozzle. The potential for these events exists due to Primary Water Stress Corrosion Cracking.

The MNSA for the side pressurizer RTD nozzle and the bottom pressurizer level nozzle have similar designs and operate under the same conditions. Since the side pressurizer RTD nozzle is larger in size, the analysis for the side pressurizer RTD nozzle MNSA presented here is considered bounding. Where differences exist, specific to the component, analyses are performed.

This revision is performed to modify the methodology used in calculating the load on the bolts connecting the MNSA to the pressurizer.

1.2 ASSESSMENT OF SIGNIFICANT DESIGN CHANGES

This report presents the detailed structural and thermal analyses required to substantiate the adequacy of the design of the SCE, San Onofre Units 2 and 3 Mechanical Nozzle Seal Assembly as a replacement of the nozzle "J" weld. This analytical work encompasses the requirements set forth in Reference 5.1 and is performed in accordance with the requirements of the ABB CENO Quality Procedures Manual QPM-101 (Reference 5.2).

1.3 ANALYTICAL METHOD

Standard methods of elastic analysis were used in this evaluation. The ANSYS 5.3 finite element computer code (Reference 5.13) was used to perform the structural analysis of certain components as required. This analysis follows the requirements of the ASME Code Section III for Class 1 components and is analyzed for a 40 year life.

2.0 DESIGN INPUTS

2.1 SELECTION OF DESIGN INPUTS

2.1.1 The Mechanical Nozzle Seal Assembly is considered a pressure retaining component. The design pressure is 2500 psi and design temperature is 700°F. Operating pressure and temperature are 2?50 psi and 653°F, respectively (References 5.3, and 5.4, pg. 3). Ambient design temperature is 120°F (Reference 5.7).

2.1.2 MNSA materials, material properties and stress allowable limits are given below and are taken from References 5.8 and 5.9; Table I-1.2, Table I-2.2, Table I-5.0, and Table I-6.0.

Item	Material
Compression Collar	SA-479, Type 304
Lower Flange	SA-479, Type 304
Upper Flange	SA-479, Type 304
Top Plate	SA-479, Type 304
Hex Bolts	SA-453, Grade 660
Hex Nuts	SA-453, Grade 660
Tied Rods	SA-453, Grade 660
Socket Head Shoulder Screw	SA-453, Grade 660

Material	Allowable Stress 700°F		Thermal Expansion Coeff. (α) [X 10^{-6} in/in/°F]			Modulus of Elasticity (E) [X 10^6 psi]	
	Sm (ksi)	Sy (ksi)	120°F	200°F	653°F	70°F	700°F
SA-453, Grade 660	26.8	-	8.27	8.39	9.00	28.3	24.8
SA-479, Type 304	16.0	17.7	8.60	8.79	9.61	28.3	24.8

2.1.3 Side pressurizer RTD and bottom pressurizer level nozzles materials are taken from References 5.3, 5.5, 5.17 and 5.19. Material properties and stress allowable limits are taken from Reference 5.9; Table I-1.2, Table I-2.2, Table I-5.0, and Table I-6.0.

Component/ Material	Thermal Expansion Coeff. (α) [X 10^{-6} in/in/°F]		Modulus of Elasticity (E) [X 10^6 psi]	
	400°F	653°F	70°F	700°F
Safe End SA-182, Type 316	9.21	9.69	28.3	24.8
Safe End SA-479, Type 304	9.19	9.61	28.3	24.8
Nozzle SB-166	7.57	7.88	31.0	28.2
Thermowell - Inconel	7.57	7.88	31.0	28.2
Valve SA-182, Type 316	9.21	9.69	28.3	24.8

Pressurizer shell SA-533 Gr... B — Sm = 26.7 ksi @ 700°F
Pressurizer shell SA-533 Grade B — Sy = 43.1 ksi @ 700°F

2.1.4 The bolts and tie rods have the following dimensions (References 5.8, 5.14 and 5.19):

	Bolts [0.500-20 UNF-2A]	Tie Rods [0.375-16 UNC-2A]	
Major diameter	0.5000 in	0.3750 in	
Minor diameter	0.4405 in	0.3005 in	
Basic pitch diameter	0.4675 in	0.3344 in	
Minor area	0.1486 in^2	0.0678 in^2	
Stress area	0.1599 in^2	0.0775 in^2	
		Side RTD	Bottom level
Rod length		3.50 in	5.50 in
Effective thread length *		4.395 in [1]	4.781 in [2]
Threaded area		0.0775 in^2	0.0775 in^2
Rod area		0.1104 in^2	0.1104 in^2

where (Ref. 5.19):

(1) 4.395 in = tie rod length (9.5) - rod length (3.5) - flange thickness (0.73) - nut thickness (0.5) - free end rod length [not engaged] (0.375)

(2) 4.781 in = tie rod length (12.5) - rod length (5.5) -flange thickness (0.75) - nut thickness (0.5) - free end rod length [not engaged] (0.969)

2.1.5 Various components dimensions are taken from Reference 5.5, 5.6, 5.17 and 5.19 as indicated below (Note: Some dimensions are calculated/estimated from field measurements).

	Side Prz RTD Nozzle	Ref.	Bottom Level Nozzle	Ref.
Pressure Diameter	1.330 in	5.5/5.6	1.062 in	5.5/5.6
Length of component [1]	8.00 in	5.19	13.00 in	5.19
Length of Safe End [2]	3.70 in	5.19	5.50 in	5.19
Length of nozzle	3.00 in	5.19	2.00 in	5.19
Length of Thermowell [3]	1.3 in	5.19		
Length of Valve			5.5 in	5.17
Pressure Area = (πr^2)	1.389 in^2	5.5/5.6	0.886 in^2	5.5/5.6

Notes:

(1) From O.D. of the head

(2) Calculated from measurements

(3) Estimated from measurements

2.1.6 The Mechanical Nozzle Seal Assembly design provides for 0.065 inches of compression of the Grafoil seal (gap between Upper and Lower Flanges, Reference 5.8). Such compression of the Grafoil creates pressure of about 3,500 psi, according to Reference 5.23. It is deemed to be sufficient to seal the possible leak area on the Nozzle, because achieved pressure exceeds the design pressure of 2500 psi at design temperature of 611°F. Sealing capabilities of Grafoil were verified during the hydrostatic test at 3,125 psi and three thermal cycles from near ambient temperature to 650°F and 2,500 psi with borated water.

2.1.7 Hydrostatic test pressure conditions are not analyzed in this calculation because the seal component will not be exposed to this condition during service. Hydrostatic testing was performed as part of the seal qualification (Reference 5.10).

2.2 ASSUMPTIONS

2.2.1 If no crack is present, it is assumed that the MNSA is not loaded during normal operating conditions. The only load would be experienced if the nozzle is subjected to a 360° through-wall crack at or above the J-weld. This load would be equal to the internal pressure of the system against the area of the nozzle. This load would act against the top plate and distribute through the rest of the assembly back into the pressurizer shell. After this event occurs, the load would become cyclical from essentially zero at Cold Shutdown to its maximum at normal operating conditions.

2.2.2 A coefficient of friction of 0.30 for Grafoil on Inconel 600 is assumed. Reference 5.21, Table IV shows tests results of grafoil on stainless steel of 0.20 for a pressure of 12 psi. For this application, the load generated to compress the grafoil seal is significantly larger than 12 psi. Extrapolating the information in Reference 5.21, a factor of 0.30 is considered a reasonable assumption.

3.0 ANALYSIS

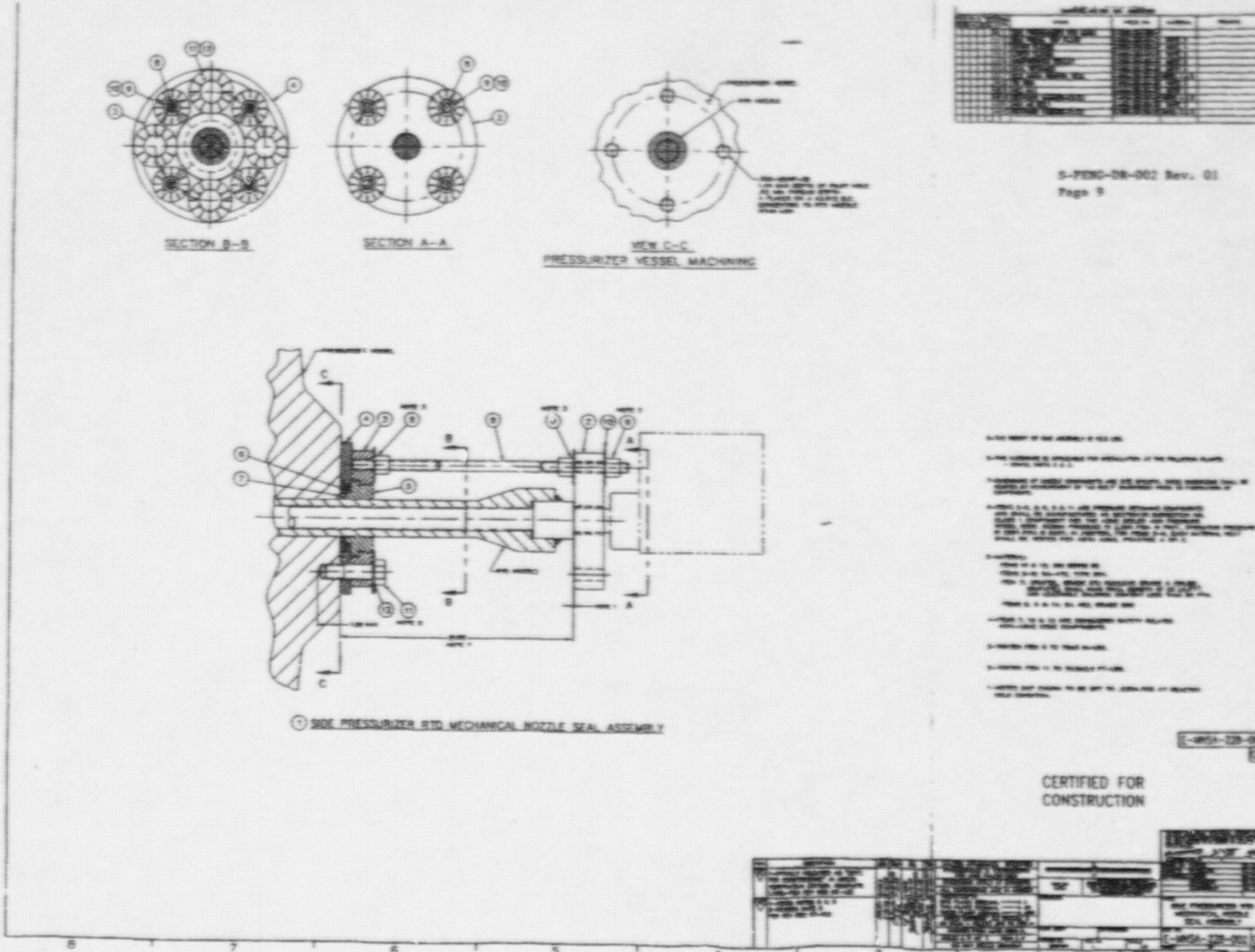
3.1 MNSA DESCRIPTION

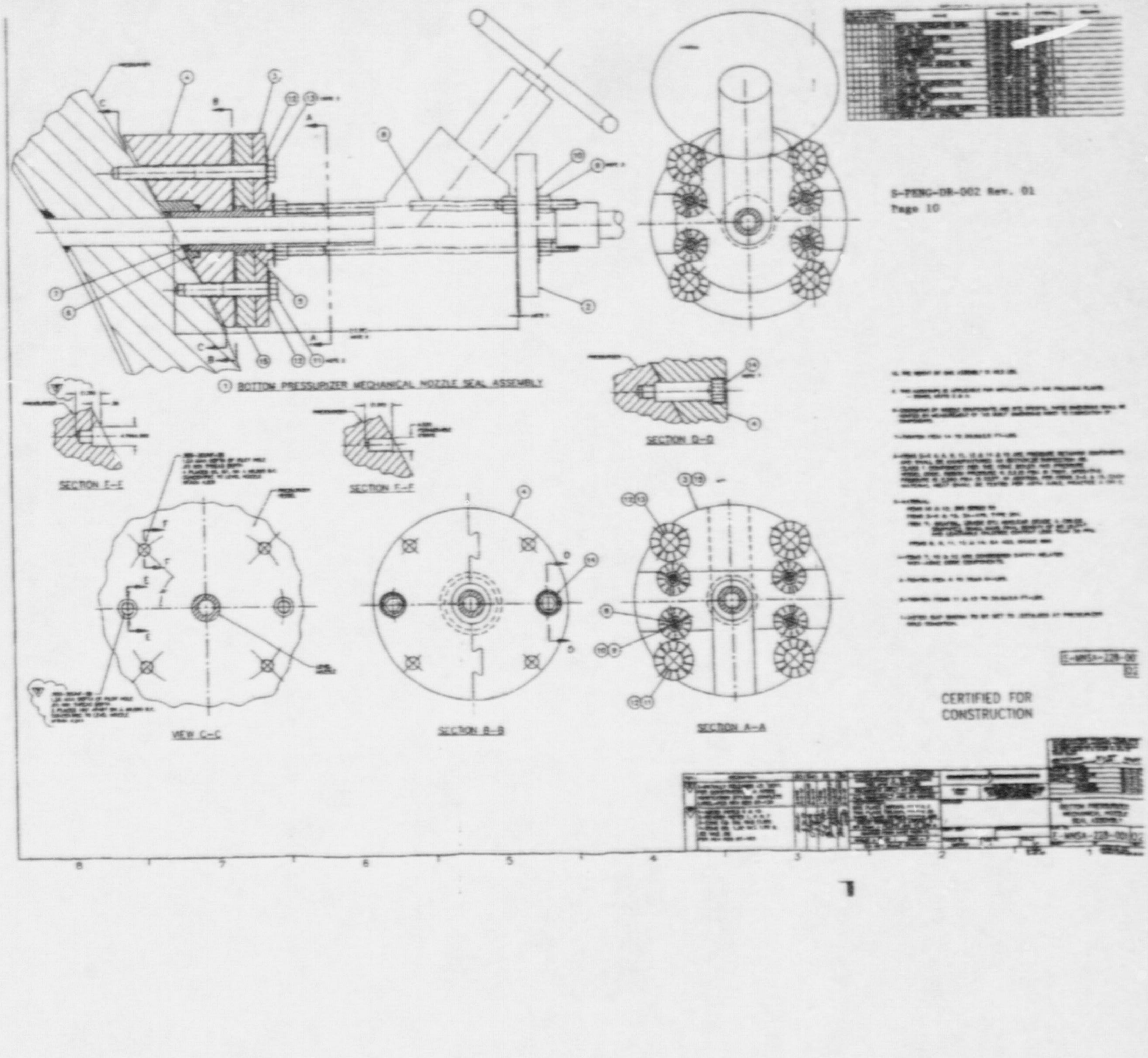
The MNSA is a mechanical device that acts as a complete replacement of the "J"weld between an Inconel 600 instrument nozzle and the pressurizer. It replaces the sealing function of the weld using a Grafoil seal compressed at the nozzle outside diameter to the outer pressurizer surface. The MNSA also replaces the weld structurally by means of threaded fasteners engaged in tapped holes in the outer pressurizer surface, and a restraining plate held in place by threaded tie rods. This feature prevents the nozzle from ejecting from the pressurizer, should the "J"weld fail or the nozzle develop a circumferential crack.

Two mechanical nozzle seal assemblies are analyzed herein. Each MNSA consists of threaded tie rods, top plate, upper flange, lower flange, compression collar, seal retainer, Grafoil seal, retainer washers, and threaded fasteners. To prevent the nozzle from ejecting, the top plate is held against the nozzle safe end by four threaded tie rods and it is fastened by hex nuts, at the top and at the bottom. The other end of the tie rods is fastened into the upper flange.

Threaded fasteners, threaded into tapped holes on the outer surface of the pressurizer, generate the force necessary to compress the Grafoil seal. To keep the seal in place and avoid leakage, the load is transferred through the threaded fasteners into the upper flange, and into the compression collar. Both the lower flange and the retainer seal act as seal retainers. Since the bottom pressurizer level nozzle is located at an angle with the horizontal, shear pins are set into the pressurizer shell to carry the shear load between the lower flange and pressurizer shell when compressing the seal.

Drawings (Reference 5.8) for the pressurizer RTD nozzle and the bottom pressurizer level nozzle (Reference 5.8) are presented in Figures 1 and 2.


SECTION B-B
SECTION A-A
VIEW C-C
PRESSURIZER VESSEL MACHINING
(1) SIDE PRESSURIZER RTD MECHANICAL NOZZLE SEAL ASSEMBLY
CERTIFIED FOR CONSTRUCTION


BOTTOM PRESSURIZER MECHANICAL NOZZLE SEAL ASSEMBLY
SECTION E-E
SECTION F-F
SECTION D-D
VIEW C-C
SECTION B-B
SECTION A-A
CERTIFIED FOR
CONSTRUCTION

3.2 LOADING CONDITIONS

3.2.1 Loading Due to Pressure

The applicable loading is due to the pressure pushing against the entire cross section of the nozzle. From Section 2.1, the pressure area of the side pressurizer RTD nozzle assembly is 1.389 in^2, and the pressure area of the bottom pressurizer level nozzle is 0.886 in^2. Therefore the loads are:

Load (side pressurizer RTD nozzle) = (2500 psi) (1.389 in^2) = 3,473 lbs
Load (bottom pressurizer level nozzle) = (2500 psi) (0.886 in^2) = 2,215 lbs

3.2.2 Loading Due to Thermal Expansion

Under operating conditions, it is assumed that the tie rods temperature increases from a reference temperature of 70°F to the ambient temperature of 120°F, and that the nozzle/thermowell/valve and the lower flange are perfect heat sources and reach the operating temperature of 653°F (Section 2.1). These conditions produce the maximum gap closure between the nozzle and the MNSA top plate. On the other hand, a more reasonable temperature distribution is selected based on engineering judgment. In this case, it is assumed that the tie rod temperature increases from a reference temperature of 70°F to 200°F, and that the nozzle/thermowell/valve, as well as the lower flange, reach the temperature of 400°F under operating conditions. These conditions produce the minimum gap closure between the nozzle/thermowell/valve and the MNSA top plate.

The thermal expansion (maximum and minimum closure gaps) due to the displacement of the nozzle is calculated as follows (Reference 5.12, pg. 53):

δ due to thermal expansion of the nozzle = L α ΔT
where: L is the length of the component (Section 2.1)
α is the thermal expansion coefficient (Section 2.1)
ΔT is the differential temperature (as applicable)

Maximum/Minimum Closure = Nozzle + Safe End + Thermowell/Valve - Tie Rods - Flanges

where: the tie rod length is determined to compare growths of equal length (not related to actual length, i.e., component length - flanges length).

<u>Side pressurizer RTD nozzle:</u>
Maximum Closure:

$(3.00 \text{ in.})(7.88 \times 10^{-6} \text{ in./in. °F})(653-70)\text{°F} +$
$(3.70 \text{ in.})(9.69 \times 10^{-6} \text{ in./in. °F})(653-70)\text{°F} +$
$(1.30 \text{ in.})(7.88 \times 10^{-6} \text{ in./in. °F})(653-70)\text{°F} -$
$(6.905 \text{ in.})(8.27 \times 10^{-6} \text{ in./in. °F})(120-70)\text{°F} -$
$(1.095 \text{ in.})(9.61 \times 10^{-6} \text{ in./in. °F})(653-70)\text{°F} = 0.03169 \text{ in.}$

Minimum Closure:

(3.00 in.) (7.57 X 10^{-6} in./in. °F) (400-70)°F +
(3.70 in.) (9.21 X 10^{-6} in./in. °F) (400-70)°F +
(1.30 in.) (7.57 X 10^{-6} in./in. °F) (400-70)°F -
(6.905 in.) (8.39 X 10^{-6} in./in. °F) (200-70)°F -
(1.095 in.) (9.19 X 10^{-6} in./in. °F) (400-70)°F = 0.01114 in.

Bottom pressurizer level nozzle:
Maximum Closure:

(2.00 in.) (7.88 X 10^{-6} in./in. °F) (653-70)°F +
(5.50 in.) (9.61 X 10^{-6} in./in. °F) (653-70)°F +
(5.50 in.) (9.69 X 10^{-6} in./in. °F) (653-70)°F -
(9.531 in.) (8.27 X 10^{-6} in./in. °F) (120-70)°F -
(3.469 in.) (9.61 X 10^{-6} in./in. °F) (653-70)°F = 0.04191 in.

Minimum Closure:

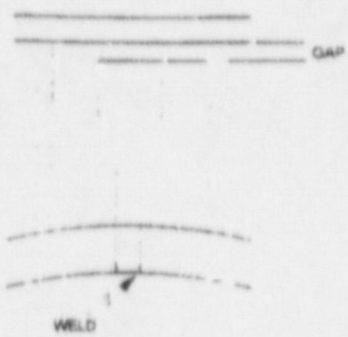
(2.00 in.) (7.57 X 10^{-6} in./in. °F) (400-70)°F +
(5.50 in.) (9.19 X 10^{-6} in./in. °F) (400-70)°F +
(5.50 in.) (9.69 X 10^{-6} in./in. °F) (400-70)°F -
(9.531 in.) (8.39 X 10^{-6} in./in. °F) (200-70)°F -
(3.469 in.) (9.19 X 10^{-6} in./in. °F) (400-70)°F = 0.01450 in.

where (Ref. 5.19) 3.469 in = (2.293 - 0.274) + 0.70 + 0.75]

A cold gap should be set to allow for free thermal expansion of the nozzle, but not to exceed the gap analyzed for in the following sections.

3.2.3 Cold gap setting for the side pressurizer RTD nozzle

A cold gap between the tie rods and the top plate should be set to account for the thermal expansion of the nozzle. If the nozzle is ejected, the impact load would produce stresses on the tie rods and top plate which need to be considered. A setting of 0.03" ± 0.005" is recommended for the side pressurizer MNSA. It is recognized that the low end of this range is less than the maximum closure obtained in the previous section. Since the ideal conditions used to obtain the maximum closure are not anticipated during operation, the 0.025" minimum gap is concluded to be acceptable. The maximum cold gap setting of 0.035" indicates that a gap of 0.035-0.01114=0.02386" can exist during normal operation. Therefore, the stresses due to the impact load are determined assuming a gap of 0.025". The stiffnesses of the tie rods and top plate are taken into consideration in the calculation of the stresses.



The total deflection due to the impact load is determined below. It is assumed that the energy at impact is converted into potential (spring) energy, and that the total displacement is equal to the amount of displacement allowed by the gap plus the deflection of the nozzle and MNSA after impact. All equations are taken from Reference 5.16, pgs. 3-17 and 3-20.

Kinetic Energy = Spring Energy

$$\frac{1}{2} m V^2 = \frac{1}{2} K \Delta x^2$$

where: $V = \sqrt{2 a s}$

$$m (a s) = \frac{1}{2} K \Delta x^2$$

where: $F = m a$

$$F s = \frac{1}{2} K \Delta x^2$$

Assuming that s = Gap + Δx, and a friction coefficient of 0.30; then $F = 0.7 F_{max}$, where F_{max} is load acting on the nozzle (3,473 lbs) then:

$$0.7F\,(Gap + \Delta x) = \frac{1}{2} K \Delta x^2$$

$$\frac{1}{2} K \Delta x^2 - 0.7F\,Gap - 0.7F\,\Delta x = 0 \qquad [3.1]$$

In order to determine the Δx, the stiffness of the tie rods and the top plate are calculated.

Stiffness of 4 Tie Rods (Section 2.0):

$$K_{rods} = 4\frac{A\,E}{l} = 4\frac{(0.1104\ in^2)(24.8\ X 10^6\ \frac{lbf}{in^2})}{3.5\ in} = 3,129,051\ \frac{lbf}{in}$$

$$K_{threaded\ rods} = 4\frac{A\,E}{l} = 4\frac{(0.0775\ in^2)(24.8\ X 10^6\ \frac{lbf}{in^2})}{4.395\ in} = 1,749,261\ \frac{lbf}{in}$$

Stiffness of the Top Plate (Section 2.0):

The equations for calculating the deflection of the top plate are found in Reference 5.11, Table 24, Case 1a:

$$y = \frac{w\,a^3}{D}(\frac{C_1\,L_9}{C_7} - L_3)$$

where:

$$D = \frac{E\,t^3}{12(1-\gamma^2)} = \frac{24.8 X 10^6\ \frac{lbf}{in^2}\ (1.0)^3\ in^3}{12\ (1-0.3^2)} = 2,271,062\ lbf$$

and C_1, C_7, L_9, and L_3 are constants, and are calculated using the equations of Reference 5.11, pgs. 332-334 where:

- a = 1.906 in
- b = 0.5 in
- r_o = 0.6650 in
- t = 1.0 in
- γ = 0.3
- E = 24.8 X 10^6 psi
- C_1 = 0.8494
- C_7 = 1.6151
- L_3 = 0.0264
- L_9 = 0.2924

Solving for the stiffness of the top plate:

$$K_{top\ plate} = -\frac{2\pi\,r_o}{\frac{a^3}{D}(\frac{C_1 L_9}{C_7} - L_3)} = 10,760,000\ \frac{lbf}{in}$$

Determination of equivalent stiffness:

$$K_{equiv} = \frac{1}{\frac{1}{K_{rod}} + \frac{1}{K_{threaded\ rod}} + \frac{1}{K_{top\ plate}}} = 1,016,100\ \frac{lbf}{in}$$

The equation [3.1] previously developed is used to solve for Δx:

$$\frac{1}{2}K\ \Delta x^2 - 0.7F\ Gap - 0.7F\ \Delta x = 0$$

Solving the quadratic equation using a load (F) of 3,473 lbs (calculated in Section 3.2.1) and a gap equal to 0.025", we have a maximum Δx value of 0.01359 in. Solving for the impact force we have:

$$Force_{impact} = K_{equiv}\ \Delta x = 1{,}016{,}100\frac{lbf}{in}(0.01359\ in) = 13{,}808\ lbf = 13.9\ kips$$

3.2.3.1 STRESS DUE TO THE IMPACT LOAD

Stress in the tie rods

From Reference 5.8: Tie Rod Diameter = 0.375 in.
Notch radius =0.040 in.
$A = (\pi)\ [0.1875 - 0.040]^2 = (\pi)\ [0.1475]^2 = 0.0683\ in^2$
Impact Force = 13.9 kips / 4 tie rods = 3.475 kips

Stress = 3.475 kips / 0.0683 in^2 = 50.88 ksi
Stress = 50.88 ksi < 2 Sm = 53.6 ksi

Shear stress in the threads (0.375-16 UNC-2A)

The tie rods pass through the top plate and are held in place with nuts at the top and at the bottom. The top nut is the only one being loaded during impact. The nuts are of the same material as the rods. Therefore, the external thread are is used.

From References 5.14 and 5.18:
As = π n Le Kn max [1/2n + 0.57735 (Es min - Kn max)] = 0.288 in^2

where:
n is number of threads per inch = 16
Le is the length of engagement (nut thickness) = 0.5 in (Ref. 5.8)
Kn max is maximum minor diameter of internal thread = 0.321 in
Es min is minimum pitch diameter of external thread = 0.3287 in
Impact Force = 13.9 kips / 4 nuts = 3.475 kips

Shear Stress = 3.475 kips / 0.288 in^2 = 12.066 ksi
Shear Stress = 12.07 ksi < 0.6 Sm = 16.08 ksi

On the other side, the tie rods thread into the Upper Flange and are locked down with lock washers. Since the Upper Flange is manufactured from a lower strength material than the tie rods, the strength of the Upper Flange thread is the critical element of this connection. Therefore:

From References 5.14 and 5.18:
As = π n Le Ds min [1/2n + 0.57735(Ds min - En max)] = 0.414 in^2

where: n is number of threads per inch = 16
Le is the length of engagement. Assume equal to 0.5 in (Ref. 5.8)
En max is maximum pitch diameter of internal thread = 0.3401 in
Ds min is minimum major diameter of external thread = 0.3643 in
Impact Force = 13.9 kips / 4 tie rods = 3.475 kips

Shear Stress = 3.475 kips / 0.414 in^2 = 8.394 ksi
Shear Stress = 8.39 ksi < 0.6 Sm = 9.6 ksi

The minimum allowable length of engagement of the tie rod into the Upper Flange may be calculated as a simple proportion:

Le_{min} = (Shear Stress / Allowable Stress) x Assumed Length of Engagement =
= (8.39/9.6) x 0.5 = 0.437 in.

Shear stress in the hex bolts (0.500-20 UNF-2A)

The effect of impact on the bolt are evaluated in Section 3.3.3.

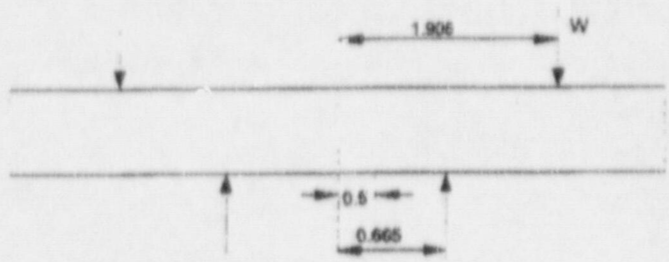
Stress in the top plate

The shear area is = π (D) t = π (1.33 in) (1.0 in) = 4.178 in^2
where: D is the diameter of the thermowell = 1.33 in (Reference 5.19)
t is the thickness of the top plate = 1.0 in (Reference 5.8)

Shear Stress = 13.9 kips / 4.178 in^2 = 3.33 ksi
Shear Stress = 3.33 ksi < 0.6 Sm = 9.6 ksi

Bending stress

FIGURE 3 RTD TOP PLATE



The impact load is distributed over the area of the top plate in contact with the nozzle. The impact load is applied at the location of the outer radius of the thermowell. From Reference 5.11, Table 24, Case 1a:

r_o = 0.6650 in (Reference 5.19)
a= 1.906 in (Reference 5.8)
b = 0.5 in (Reference 5.8)
$W = F_{impact} / (2\pi) r$ = 13.9 kips / (2 π) 0.6650 in = 3.327 kips/in
b/a = 0.2623
K_m (b/a) = 0.5676
$M = K_m W a$ = 0.5676 (3.327 kips/in) (1.906 in) = 3.599 kips-in
$\sigma = 6\ (3.599 \text{ kips-in}) / (1.0)^2 \text{ in}^2 = 21.59$ ksi

Bending Stress: σ = 21.59 ksi < 1.5 Sm = 24.0 ksi

3.2.4 Cold gap setting for the bottom pressurizer level nozzle

A cold gap between the tie rods and the top plate should be set to account for the thermal expansion of the nozzle. If the nozzle is ejected, the impact load would produce stresses on the tie rods and top plate which need to be considered. A setting of 0.037" ± 0.005" is recommended for the bottom pressurizer MNSA. It is recognized that the low end of this range is less than the maximum closure obtained in Section 3.2.2. Since the ideal conditions used to obtain the maximum closure are not anticipated during operation, the 0.032" minimum gap is concluded to be acceptable. The maximum cold gap setting of 0.042" indicates that a gap of 0.042-0.0145=0.0275" can exist during normal operation. Therefore, the stresses due to the impact load are determined assuming a gap of 0.028". The stiffnesses of the tie rods and top plate are taken into consideration in the calculation of the stresses.

Stiffness of 4 Tie Rods (Section 2.0):

$$K_{rods} = 4\frac{AE}{l} = 4\frac{(0.1104\ in^2)(24.8\ X\ 10^6\ \frac{lbf}{in^2})}{5.5\ in} = 1{,}991{,}215\ \frac{lbf}{in}$$

$$K_{threaded\ rods} = 4\frac{AE}{l} = 4\frac{(0.0775\ in^2)(24.8\ X\ 10^6\ \frac{lbf}{in^2})}{4.781\ in} = 1{,}608{,}032\ \frac{lbf}{in}$$

Stiffness of the Top Plate (Section 2.0):

The ANSYS 5.3 finite element analysis code is used to determine the stiffness of the top plate which has an irregular shape. A 3-D symmetric model of the plate is generated using the SHELL93 type element. A half symmetry model of the plate is selected for the representative finite element model. The model was restrained at the locations of the tie rods in all directions. All dimensions are taken from References 5.8 and 5.17. To simulate the impact load, a distributed load of 500 lbs was applied at the outer diameter edge, where the valve contacts the plate at a radius of 1.03 inch. Due to the model symmetry the 500 lbs load is equivalent to 1000 lbs. The maximum deflection of the top plate resulted in a value of 0.000199 inch. The output from this run is shown in Appendix B. The stiffness is determined as follows:

$K_{top\ plate}$ = F / d = 1000 lbs / 0.000199 inch = 5,025,126 lbs/in

Determination of equivalent stiffness:

$$K_{equiv} = \frac{1}{\frac{1}{K_{rod}} + \frac{1}{K_{threaded\ rod}} + \frac{1}{K_{top\ plate}}} = 755{,}810\frac{lbf}{in}$$

Equation [3.1] developed in Section 3.2.3 is used to determine the Δx:

$$\frac{1}{2}K\ \Delta x^2 - 0.7F\ Gap - 0.7F\ \Delta x = 0$$

Solving the quadratic equation using a load (F) of 2,215 lbs (calculated in Section 3.2.1) and a gap equal to 0.028", we have a maximum Δx value of 0.01296 in. Solving for the impact force we have:

$$Force_{impact} = K_{equiv}\ \Delta x$$

$$Force_{impact} = K_{equiv}\Delta x = 755{,}810\frac{lbf}{in}(0.01296\ in) = 9{,}795\ lbf = 9.8\ kips$$

3.2.4.1 STRESSES DUE TO THE IMPACT LOAD

Stress in the tie rods

From Reference 5.8: Tie Rod Diameter = 0.375 in.
Notch radius =0.040 in.

$A = (\pi)\,[0.1875 - 0.040]^2 = (\pi)\,[0.1475]^2 = 0.0683\ in^2$

Impact Force = 9.8 kips / 4 tie rods = 2.45 kips

Stress = 2.45 kips / 0.0683 in^2 = 35.87 ksi

Stress = 35.87 ksi < 2 Sm = 53.6 ksi

Shear Stress in the threads (0.375-16 UNC-2A)

The tie rods pass through the top plate and are held in place with nuts at the top and at the bottom. The top nut is the only one being loaded during impact. The nuts are of the same material as the rods. Therefore, the external thread are is used.

From References 5.16 and 5.18:

$As = \pi\ n\ Le\ Kn\ max\ [1/2n + 0.57735\ (Es\ min - Kn\ max)] = 0.288\ in^2$

where:
n is number of threads per inch = 16
Le is the length of engagement (nut thickness) = 0.5 in (Ref. 5.8)
Kn max is maximum minor diameter of internal thread = 0.321 in
Es min is minimum pitch diameter of external thread = 0.3287 in
Impact Force = 9.8 kips / 4 nuts = 2.45 kips

Shear Stress = 2.45 kips / 0.288 in^2 = 8.51 ksi

Shear Stress = 8.51 ksi < 0.6 Sm = 16.08 ksi

On the other side, the tie rods thread into the Upper Flange and are locked down with lock washers. Since the Upper Flange is manufactured from a lower strength material than the tie rods, the strength of the Upper Flange thread is a critical element of this connection. Therefore:

From References 5.16 and 5.18:

$As = \pi\ n\ Le\ Ds\ min\ [1/2n + 0.57735(Ds\ min - En\ max)] = 0.414\ in^2$

where:
n is number of threads per inch = 16
Le is the length of engagement. Assume equal to 0.5 in (Ref. 5.8)
En max is maximum pitch diameter of internal thread = 0.3401 in
Ds min is minimum major diameter of external thread = 0.3643 in
Impact Force = 9.8 kips / 4 tie rods = 2.45 kips

Shear Stress = 2.45 kips / 0.414 in^2 =5.92 ksi

Shear Stress = 5.92 ksi < 0.6 Sm = 9.6 ksi

The minimum allowable length of engagement of the tie rod into the Upper Flange may be calculated as a simple proportion:

Le_{min} = (Shear Stress / Allowable Stress) x Assumed Length of Engagement =
= (5.92/9.6) x 0.5 = 0.308 in.

Shear Stress in the hex bolts (0.500-20 UNF-2A)

The effect of impact on the bolt are evaluated in Section 3.3.3.

Stress in the top plate

The shear area is = π (D) t = π (2.06 in) (0.75 in) = 4.853 in^2

where: D is the diameter of the valve = 2.06 in (Reference 5.17)
t is the thickness of the top plate = 0.75 in (Reference 5.6)

Shear Stress = 9.8 kips / 4.853 in^2 = 2.02 ksi

Shear Stress = 2.02 ksi < 0.6 Sm = 9.6 ksi

Bending stress

The top plate finite element model developed in Section 3.2.4 was used to determine the stresses in the top plate. The effective applied load of 1000 lbs generated a maximum stress intensity of 2952 psi. Scaling this value:

2952 psi X (9820 lbs /1000 lbs) = 28,989 psi = 29.0 ksi

Bending Stress: σ = 29.0 ksi > 1.5 Sm = 24.0 ksi @ 700°F

However, this allowable is at design temperature of 700°F. This temperature is unrealistic for the top plate which is approximately 13 inches away from the pressurizer head. Therefore, considering a temperature of 300°F a more realistic temperature for this component, this value is acceptable since the allowable stress at 300°F is 30 ksi (Reference 5.9, Table I-2.2).

Bending Stress: σ = 29.0 ksi < 1.5 Sm = 30.0 ksi @ 300°F

3.3 DETERMINATION OF STRESSES - Normal Operating Conditions (after weld failure occurs)

3.3.1 Tie Rods

The following evaluation applies to both the side RTD and bottom pressurizer nozzle locations.

Three areas of the tie rods (Reference 5.8) need to be examined:

1. The notched area between the threaded area and the full thickness rod
2. The threaded/nutted connection at the top plate; and
3. The threaded/nutted connection at the upper flange.

1. At the notched area (Reference 5.8)

Tie Rod Diameter = 0.375 in.
Notch radius = 0.040 in.

$A = (\pi)[0.1875 - 0.040]^2 = (\pi)[0.1475]^2 = 0.0683 \text{ in}^2$

$P = 3.473 \text{ kips} / 4 = 0.868 \text{ kips}$

$\sigma = 0.868 \text{ kips} / 0.0683 \text{ in}^2 = \mathbf{12.71 \text{ ksi} < Sm = 26.8 \text{ ksi}}$

Since the load on the bottom pressurizer level nozzle is lower and the tie rods diameters are the same for both assemblies (Section 3.1), the above stress value is considered bounding for the bottom pressurizer level nozzle.

Fatigue Analysis

For fatigue, assuming the nozzle is cracked through and that the load cycles are from 0 to 2500 psi, the cycle on the tie rods would be from 0 to 12.71 ksi. Reference 5.9, Table I-9.1 gives a fatigue life of infinite cycles ($>10^{11}$).

2. Top Plate Connection to Tie Rods

The tie rods pass through the top plate and are held in place with nuts at the top and at the bottom. The top nut is the only one being loaded. The nuts are of the same material as the rods. Therefore, the external thread is used.

Shear stress in the threads

From References 5.16 and 5.18:

$As = \pi\, n\, Le\, Kn\, max\, [1/2n + 0.57735\, (Es\, min - Kn\, max)] = 0.288 \text{ in}^2$

where:
- n is number of threads per inch = 16
- Le is the length of engagement (nut thickness) = 0.5 in (Ref. 5.8)
- Kn max is maximum minor diameter of internal thread = 0.321 in
- Es min is minimum pitch diameter of external thread = 0.3287 in

Using the load of 3,473 lbs / 4 tie rods = 0.868 kips

Shear Stress = 0.868 kips / 0.288 in^2 = 3.014 ksi
Shear Stress = 3.01 ksi < 0.6 Sm = 16.08 ksi

3. Upper Flange Connection to Tie Rods

The tie Rods thread into the Upper Flange and are locked down with lock washers. The Upper flange is manufactured from the lower strength material, consequently, the strength of the upper flange thread is the critical element in the connection, hence:

From References 5.16 and 5.18:

$As = \pi \, n \, Le \, Ds \, min \, [1/2n + 0.57735(Ds \, min - En \, max)] = 0.414 \, in^2$

where:
n is number of threads per inch = 16
Le is the length of engagement. Assume equal to 0.5 in (Ref. 5.8)
En max is maximum pitch diameter of internal thread = 0.3401 in
Ds min is minimum major diameter of external thread = 0.3643 in

Using the load of 3,473 lbs / 4 tie rods = 0.868 kips
Shear Stress = 0.868 kips / 0.414 in^2 = 2.097 ksi
Shear Stress = 2.10 ksi < 0.6 Sm = 9.6 ksi

This stress value is bounding with respect to the bottom pressurizer level nozzle since the lowest engagement length value (0.5 inch) is used and thread sizes are the same.

3.3.2 Top Plate

Side pressurizer RTD nozzle

Shear stress

The top plate will become loaded and the shear force will be equal to 3.473 kips. Shear stress is proportional to that calculated in Section 3.2.3.1. Hence:

τ = 3.33 ksi (3.473 kips) / 13.9 ksi = 0.832 ksi
τ = 0.832 ksi < 0.6 Sm = 9.6 ksi

Bending in the Top Plate

Likewise, the bending stress is proportional to that calculated due to the impact load in Section 3.2.3.1. The bending stress is:

σ = 21.59 ksi (3.473 kips) / 13.9 ksi = 5.394 ksi

Bending Stress: σ = 5.39 ksi < 1.5 Sm = 24.0 ksi

Bottom pressurizer level nozzle:

Shear stress

The top plate will become loaded and the shear force will be equal to 2.215 kips. The shear stress is proportional to that calculated in Section 3.2.4.1. Hence:

τ = 2.02 ksi (2.215 kips) / 9.8 ksi = 0.457 ksi

τ = 0.457 ksi < 0.6 Sm = 9.6 ksi

Bending stress:

Using the top plate finite element model developed in Section 3.2.4.1 to determine the stiffness, a stress value of 2952 psi is scaled for the applied load of 2,215 psi under normal operating conditions as follows

2,952 psi X (2,215 lbs / 1000 lbs) = 6539 psi = 6.54 ksi

Bending Stress: σ = 6.54 ksi < 1.5 Sm = 24.0 ksi

3.3.3 Bolt Stresses

Design Sizing

Four (4) 0.500-20 UNF-2A hex head bolts hold the assembly to the Pressurizer. Under normal operating loading, the load would pass from the top plate to the tie rods, to the top flange to the hex head bolts. The same loads applied to the tie rods may be applied to the bolts. The loading applied is for the side pressurizer location and envelopes the bottom pressurizer location.

Stress Area = 0.1599 in^2 (Section 2.1)
P = 3.473 kips / 4 = 0.868 kips

σ = 0.868 kips / 0.1599 in^2

σ = 5.43 ksi < Sm = 26.8 ksi

Bolt Pre-load

The bolts for both MNSA locations are being pre-loaded to 30 ft-lbs (Reference 5.8). To determine the load in each bolt, the following equation is used (Reference 5.15, pg. 302):

$T = 0.2\,F\,d$; hence $F = T / 0.2\,d$

where: T is the applied torque = 360 in-lbs
d is the nominal major bolt diameter = 0.50 in. (Section 2.1)

Therefore, F = (360 in-pounds) / (0.20) (0.50 in) = 3.600 kips. This is greater than the loading which occurs during normal operation, 3.473 kips / 4 = 0.868 kips. As a result, only the preload condition is analyzed for the bolting.

The total pre-load of 4 (3.600 kips) = 14.400 kips

Maximum Bolt Load

Due to the flexibility in the design of flanged connection between the MNSA and the pressurizer, the impact load during ejection of the nozzle will increase the load on the bolts. The stiffness of the flange relative to the stiffness of the bolts will determine what percentage of the impact load will be transmitted to the bolts. The total load on the bolt can be expessed by (Reference 5.24):

$$\text{Fmax} = \text{Preload} + \left(\frac{K_{bolt}}{K_{bolt} + K_{flange}}\right)\text{F}_{impact}$$

The stiffness of the components is calculated in the Appendix C and shows the maximum bolt load to be:

Side pressurizer RTD nozzle

$$\text{Fmax} = 3.6 + \left(\frac{9584338}{9584338 + 3842170}\right)\frac{13.9}{4} = 6.08 \text{ kips}$$

Bottom pressurizer level nozzle:

$$\text{Fmax} = 3.6 + \left(\frac{3971477}{3971477 + 1279191}\right)\frac{9.8}{4} = 5.45 \text{ kips}$$

The maximum bolt load, 6.08 kips, is used to evaluate the stresses in the bolt. The loads on the side pressure RTD nozzle are limiting and will be used to represent both MNSA locations.

Tensile Stress

Stress due to the maximum bolt load is

Stress = 6.08 kips / 0.1599 in^2 = **38.02 ksi**

Stress = **38.02 ksi < 2 Sm = 53.6 ksi.**

Shear stress in the threads (0.500-20 UNF-2A/2B)

The bolts thread into the pressurizer and are locked down with lock washers. Since the pressurizer is manufactured from a lower strength material than the bolts, both external and internal threads must be checked. Therefore:

Bolt thread

From References 5.16 and 5.18:

$$As = \pi\ n\ Le\ Kn\ max\ [1/2n + 0.57735(Es\ min - Kn\ max)] = 0.4\ in^2$$

where:

n is number of threads per inch = 20
Le is the length of engagement. Assume equal to 0.5 in
Kn max is maximum minor diameter of internal thread = 0.457 in
Es min is minimum pitch diameter of external thread = 0.4619 in
Maximum bolt load = 6.08 kips

Shear Stress = 6.08 kips / 0.4 in^2 = 15.20 ksi

Shear Stress = 15.20 ksi < 0.6 Sm = 16.08 ksi

Pressurizer thread

From References 5.16 and 5.18:

$$A_s = \pi\, n\, L_e\, D_{s\,min}\,[1/2n + 0.57735(D_{s\,min} - E_{n\,max})] = 0.541\ in^2$$

where:
n is number of threads per inch = 20
Le is the length of engagement. Assume, Le = 0.5 in
En max is maximum pitch diameter of internal thread = 0.4731 in
Ds min is minimum major diameter of external thread = 0.4906 in
Max Bolt load = 6.08 kips

Shear Stress = 6.08 kips / 0.541 in^2 = 11.24 ksi
Shear Stress = 11.24 ksi < 0.6 Sm =0.6 (26.7 ksi)= 16.02 ksi

The minimum allowable length of engagement of the hex head bolt into the pressurizer may be calculated as a simple proportion; based on the bolt threads.

$L_{e\,min}$ = (Shear Stress / Allowable Stress) x Assumed Length of Engagement =
= (15.20/16.08) x 0.5 = 0.47 in.

Stresses due to thermal expansion

The thermal expansion of the upper flange and the lower flange could produce stresses in the bolts. Both the upper and lower flanges are of the same material, SA-479 Type 304. The thermal expansion is determined below. Dimensions for the upper and lower flanges are taken from Reference 5.8.

Side pressurizer nozzle

Upper flange thickness = 0.73 in.
Lower flange thickness = 0.365 in.

Expansion = (0.73+0.365) in. (9.61 X 10^{-6} in/in/°F)(653-70)°F = 0.00613 in.

It is assumed that the bolt growth occurs over the bolts length that is in contact with the clamp assembly. The thermal expansion of the bolts is:

Expansion = (1.095 in.) (9.00X 10^{-6} in/in/°F)(653-70)°F = 0.00574 in.

Therefore, the stress in the bolt:

Stress = $\Delta\delta\, E / L$ = [(0.00613- 0.00574) 24.8 X 10^6 psi] / 1.095 in.
Stress = 8.83 ksi

Bottom pressurizer nozzle:

Upper flange thickness (top)= 0.75 in.
Upper flange thickness (bottom)= 0.70 in.
Lower flange maximum thickness = 4.186 in.
Total thickness = 5.636 in.

$$\text{Expansion} = (5.636 \text{ in.})\ (9.61 \times 10^{-6} \text{ in/in/°F})(653\text{-}70)\text{°F} = 0.03158 \text{ in.}$$

It is assumed that the bolt growth occurs over the bolts length that is in contact with the clamp assembly, then the thermal expansion of the bolts is:

$$\text{Expansion} = (5.636 \text{ in.})\ (9.00 \times 10^{-6} \text{ in/in/°F})(653\text{-}70)\text{°F} = 0.02957 \text{ in.}$$

Therefore, the stress in the bolt:

$$\text{Stress} = \Delta\delta\ E / L = [(0.03158 - 0.02957)\ 24.8 \times 10^{6} \text{ psi}] / 5.636 \text{ in.}$$
Stress = 8.84 ksi

The maximum thermal stress from the two locations is added to the Maximum Bolt Load to determine the fatigue of the bolt. This evaluation is conservatively applied to both locations.

Primary + Secondary = Max bolt load + Thermal
Primary + Secondary = 38.02 + 8.84 = 46.86 < 3 Sm = 80.4 ksi

Fatigue Usage Factor

For a maximum primary plus secondary stress of 46.86 ksi, a stress fatigue usage factor is calculated. Using a stress concentration factor of 4 (Reference 5.9, Section NB-3232.3) and a Modulus of Elasticity ratio, $E_{curve} / E_{material} = 30.0/24.8 = 1.2097$, the alternating stress intensity, S_{alt} is calculated to be:

$$S_{alt} = 4\ [\ S_{max} / 2\ (E_{curve} / E_{material})] = 4\ [23.43 \text{ ksi}\ (1.2097)] = 113.4 \text{ ksi}$$

The number of allowable cycles, N_{allow}, was determined using Figure I-9-4 of Reference 5.9 for a component with a maximum stress less than 2.7 Sm. This transient is evaluated for 500 cycles of heatups and cooldowns (Reference 5.3, pg. A-454), therefore:

U = 500 / 783 = 0.639
U = 0.639 < 1.0

3.3.4 Shear Pins - Bottom pressurizer level nozzle

The bottom pressurizer level nozzle is located at an angle with the MNSA. Shear pins are installed through the lower flange to resist slippage of the MNSA with respect to the pressurizer shell. The total load bolt preload of 14.4 kips results in shear on the two pins:

Shear Stress

Diameter of shear pins (Reference 5.8) = 0.76 in

A pins = $(\pi/4)\ (D)^2 = (\pi/4)\ (0.76)^2 = 0.4536\ in^2$
$P = 14.4$ kips (cos 27°30') / 2 = 6.386 kips (Reference 5.8)
$\tau =$ 6.386 kips / 0.4536 in^2 = **14.08 ksi**
$\tau =$ 14.08 ksi < 0.6 Sm = 16.08 ksi

Bearing Stress

Diameter of hole (Reference 5.8) = 0.766 in
in contact thickness (Reference 5.8)= 0.766 (tan 27°30') + 0.38= 0.778

$A = D\,t = (0.766\ in.)\ (0.778\ in.) = 0.5959\ in^2$
$P = 14.4$ kips (cos 27°30') / 2 = 6.386 kips (Reference 5.8)
σ_b = 6.386 kips / 0.5959 in^2 = **10.71 ksi**

For the pins:

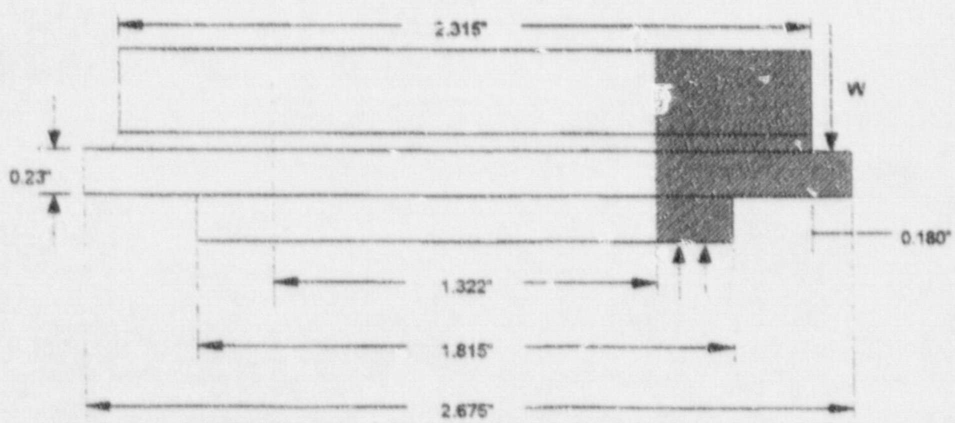
σ_b = 10.71 ksi < Sm = 26.8 ksi (vs Sy not in the Code)

For the pressurizer:

σ_b = 10.71 ksi < Sy = 43.1 ksi

3.3.5 Compression Collar

FIGURE 4 COMPRESSION COLLAR



Side pressurizer RTD nozzle:

The bolt preload, 14.4 kips, acts as a shear force on the surface 0.180 inch inboard of the 2.675 diameter. See Figure 4.

The shear area is equal to $(\pi)(D)(t) = (\pi)(2.315\ in)\ (0.23\ in) = 1.672\ in^2$

Therefore, the shear stress through the section

Shear Stress $\tau = 14.4\ kips / 1.672\ in^2 = 8.61\ ksi$

Shear Stress τ = 8.61 ksi < 0.6 Sm = 9.6 ksi

Bearing stress

The bolt preload, 14.4 kips, acts also as a bearing force on the surface between the outside diameter of the compression collar and the inside diameter of the upper flange.

The bearing area = $(\pi/4)(D^2_{comp\ collar} - d^2_{upper\ flange}) = (\pi/4)(2.675^2 - 2.318)\ in = 1.40\ in^2$

Therefore, the bearing stress is:

Bearing Stress = $14.4\ kips / 1.40\ in^2 = 10.286\ ksi$

Bearing **Stress = 10.3 ksi < Sy = 17.7 ksi**

Bottom pressurizer level nozzle

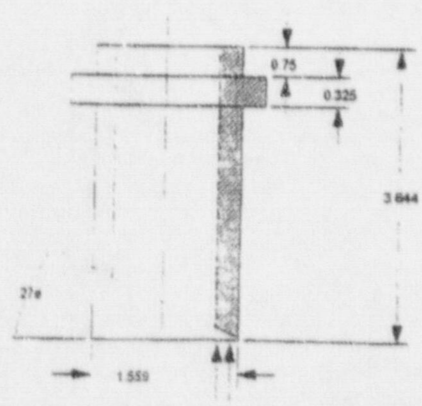
The shear area is equal to $(\pi)(D)(t) = (\pi)(1.559\ in)\ (0.325\ in) = 1.592\ in^2$

Therefore, the shear stress through the section

Shear Stress $\tau = 14.4\ kips / 1.592\ in^2$

Shear Stress τ = 9.05 ksi < 0.6 Sm = 9.6 ksi

FIGURE 5 BOTTOM PRESSURIZER COMPRESSION COLLAR



Bearing stress

The bearing area = $(\pi/4)(D^2_{comp\ collar} - d^2_{upper\ flange}) = (\pi/4)(1.919^2 - 1.562^2)$ in = 0.976 in^2

Therefore, the bearing stress is:

Bearing Stress = 14.4 kips / 0.976 in^2 = 14.75 ksi

Bearing Stress = 14.75 ksi < Sy = 17.7 ksi

3.3.6 Stresses in the Upper Flange

Side Pressurizer RTD nozzle

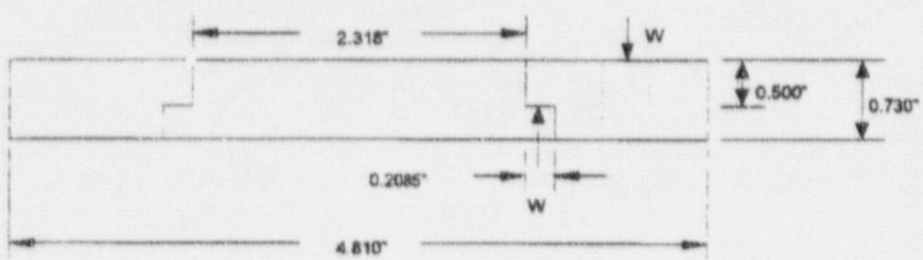
The load is the same as defined above for the Compression Collar, i.e., 14.4 kips. The shear area is equal to $(\pi)(D)(t) = (\pi)(2.735)(0.50) = 4.296$ in^2 (Reference 5.8)

Therefore, the shear stress through the section:

Shear Stress τ = 14.4 kips / 4.296 in^2 = 3.35 ksi

Shear Stress τ = 3.35 ksi < 0.6 Sm = 9.6 ksi

FIGURE 6 RTD UPPER FLANGE



Due to the proximity of the bolts and support surface, bending stresses are small and are neglected.

Bottom pressurizer level nozzle

The load is the same as defined above for the Compression Collar, i.e., 14.4 kips. The shear area is equal to $(\pi)(D)(t) = (\pi)(1.936\ in)(0.375\ in) = 2.281$ in^2 (Reference 5.8).

Therefore, the shear stress through the section:

Shear Stress τ = 14.4 kips / 2.281 in^2 = 6.31 ksi

Shear Stress τ = 6.31 ksi < 0.6 Sm = 9.6 ksi

Likewise, due to the nature of the loading, there are no bending stress in this component.

3.4 SEISMIC LOADS

Seismic loads are not considered within the scope of this analysis. A seismic qualification test program will be performed which will address the impact of seismic loads in the MNSA. (Reference 5.20).

4.0 SUMMARY OF RESULTS

All stresses are satisfactory and meet the appropriate allowable limits set forth in Section III of the ASME Boiler and Pressure Vessel Code (Reference 5.9).

The results presented below were determined using the assumptions defined and justified in Section 2.0. There are no additional contingencies or assumptions that are applicable to these resutls.

4.1 SIDE PRESSURIZER RTD NOZZLE

Results of this analysis due to the impact load are summarized below:

Component	Stress	Calculated Stress(ksi)	Allowable Stress (ksi)
Tie Rods - notch	Tensile	50.88	53.60
Tie Rods - thread	Shear	12.07	16.08
Upper flange - thread	Shear	8.39	9.6
Top Plate	Shear	3.33	9.6
	Bending	21.59	24.0

Tie rods minimum length of engagement = 0.437 inch.
Hex Bolts minimum length of engagement into the pressurizer at preload = 0.47 inch.

Results of this analysis under normal operating conditions are summarized below:

Condition	Stress	Calculated Stress(ksi)	Allowable Stress (ksi)	Usage Factor
Tie Rods - notch	Tensile	12.71	26.8	0.0
Tie Rods - thread	Shear	3.01	16.08	0.0
0.50-20 UNF Bolts	Design Sizing	5.43	26.8	N/A
	Tensile(Preload)	38.02	53.6	N/A
	Primary + Secondary	46.86	80.4	0.639
Bolts thread	Shear(Preload)	15.20	16.08	N/A
Pressurizer thread	Shear(Preload)	11.24	16.02	N/A
Top Plate	Shear	0.832	9.6	N/A
	Bending	5.39	24.0	N/A
Compression	Shear	8.61	9.6	0.0
Collar	Bearing	10.3	17.7	N/A
Upper Flange - thread	Thread Shear	2.10	9.6	0.0
	Shear	3.35	9.6	0.0

4.2 BOTTOM PRESSURIZER LEVEL NOZZLE

Results of this analysis due to the impact load are summarized below:

Component	Stress	Calculated Stress (ksi)	Allowable Stress (ksi)
Tie Rods - notch	Tensile	35.87	53.6
Tie Rods - thread	Shear	8.51	16.08
Upper Flange -thread	Shear	5.92	9.6
Top Plate	Shear	2.02	9.6
	Bending	29.0	24.0 @ 700°F
		29.0	30.0 @ 300°F

Tie rods minimum length of engagement = 0.308 inch
Hex Bolts minimum length of engagement into the pressurizer at preload = 0.47 inch.

Results of this analysis under normal operating conditions are summarized below:

Condition	Stress	Calculated Stress(ksi)	Allowable Stress (ksi)	Usage Factor
Tie Rods at notch area	Sizing	12.71	26.8	0.0
Tie Rods thread	Shear	3.01	16.08	0.0
0.50-20 UNF Bolts	Design Sizing	5.43	26.8	N/A
	Tensile(Preload)	38.02	53.6	N/A
	Primary + Secondary	46.86	80.4	0.639
Bolts thread	Shear(Preload)	15.20	16.08	N/A
Pressurizer thread	Shear(Preload)	11.24	16.02	N/A
Shear Pins	Shear	14.08	16.08	0.0
	Bearing	10.71	26.8	N/A
Pin-Pressurizer	Bearing	10.71	43.1	N/A
Top Plate	Shear	0.457	9.6	0.0
	Bending	6.54	24.0	N/A
Compression	Shear	9.05	9.6	0.0
Collar	Bearing	14.75	17.7	N/A
Upper Flange	Thread Shear	2.10	9.6	N/A
	Shear	6.31	9.6	0.0

5.0 REFERENCES

5.1 ABB Project Plan No. S3-NOME-IPQP-0156, "MNSA Design Analysis," Revision 00, June 1997.

5.2 ABB Combustion Engineering Nuclear Operations Quality Procedures Manual QPM-101, Latest Revision.

5.3 "Analytical Report for Southern California Edison San Onofre Unit No. 2 Pressurizer," Report No. CENC-1275, September 1976.

5.4 "Analytical Report for Southern California Edison San Onofre Unit No. 3 Pressurizer," Report No. CENC-1276, September 1977.

5.5 ABB CE Drawing E234-987, Revision 5, "Nozzle Details San Onofre II, 96 inch I.D. Pressurizer."

5.6 ABB CE Drawing E235-127, Revision 3, "Nozzle Details San Onofre III, 96 inch I.D. Pressurizer."

5.7 "Design Specification for the Mechanical Nozzle Seal Assembly (MNSA) San Onofre Units 2 & 3;" Specification No. S3-NOME-SP-0049, Revision 01.

5.8 ABB Drawing No.
   1. E-MNSA-228-001, Revision 02, "Bottom Pressurizer Mechanical Nozzle Seal Assembly"
   2. E-MNSA-228-002, Revision 02, "Side Pressurizer RTD Mechanical Nozzle Seal Assembly"
   3. E-MNSA-228-004, Revision 02, "Mechanical Nozzle Seal Assembly"

5.9 American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, 1989 Edition (No Addenda).

5.10 "Test Report for MNSA Hydrostatic and Thermal Cycle Tests," Test Report No. TR-PENG-042, Rev.00.

5.11 "Formulas for Stress and Strain," Raymond J. Roark and Warren C. Young, Fifth Edition, 1975, McGraw-Hill.

5.12 "Mechanics of Materials," Beer and Johnson, McGraw-Hill Inc., 1981.

5.13 ANSYS Engineering Analysis System computer code, Revision 5.3.

5.14 "Machinery's Handbook," 22nd Edition, H. H. Ryffel, Editor, Industrial Press, Inc., New York, June 1986.

5.15 "Fundamental of Machine Component Design," R.C. Juvinall, John Wiley & Sons, Inc., 1983.

5.16 "Marks' Standard Handbook for Mechanical Engineers, " E.A. Avallone and T. Baumeister III, Ninth Edition, McGraw Hill.

5.17 Rockwell-Edward Hemavalve Drawing No. ACD 31620853.

5.18 ANSI Standards for Threads, Appendix B, B1.1, 1982.

5.19 Inter-office Correspondence from J. Tursi to A. Bauer and C. Mendrala, "SONGS MNSA Design Input for Pressurizer MNSA Design Report", Letter No. NOME-97-0430, dated 6-25-97.

5.20 "Seismic Qualification of the San Onofre MNSA Clamps for Pressurizer Instrumentation Nozzle and RTD Hot Leg Nozzles, " Report No. TR-PENG-033, Rev. 00.

5.21 Union Carbide Grafoil, "Engineering Design Manual, " Volume One, Sheet and Laminatea Products, by R.A. Howard.

5.22 Mini-specification SO23-411-57, Revision A, "RCS Mechanical Nozzle Seal Assemblies, San Onofre Nuclear Generating Station Units 2 and 3," April 21, 1997.

5.23 "Test Report for Verification Testing of RTD Nozzle Seal Assembly", Report No. TR-PENG-012, Rev. 00, February 95.

5.24 "Baltimore Asymmetric LOCA Analysis for Upper Flange, Gird Beams, and CEA Shrouds", Analysis Number 8067-640-73, July 1980.

APPENDIX A

CODE DATE RECONCILIATION

Construction Code Date Reconciliation for SCE Mechanical Nozzle Seal Assemblies (MNSA)

The purpose of this reconciliation is to demonstrate fulfillment of the requirements for use of a later edition of the Construction Code for SCE's Mechanical Nozzle Seal Assembly. This is intended to allow the use of ABB Combustion Engineering's Mechanical Nozzle Seal Assembly, which was built to a later Code edition, at SCE.

In accordance with Southern California Edison Company (SCE) Specification No. S023-411-57, Rev. A (Reference 5.22), and San Onofre Units II and III Pressurizer Design Specification No. 01370-PE-130, Rev. 09, the Original Construction Code associated with Design and Procurement for the Mechanical Nozzle Seal Assembly is the 1971 Edition through Summer Addenda (hereinafter referred to as the Original Code). The Original Construction Code associated with the Installation is assumed to be the same as for Design and Procurement. The ASME Section XI program at SCE is governed by the 1989 Edition, No Addenda (hereinafter referred to as the Section XI Code). The Construction Code used for the Mechanical Nozzle Seal Assembly project is the 1989 Edition, No Addenda, of the ASME Code, Section III (hereinafter referred to as the Replacement Code).

The SCE Mechanical Nozzle Seal Assembly Project involves both Repair and Replacement activities in accordance with the Section XI Code. Article IWA-4120 states that Repairs may be performed in accordance with later editions of the Construction Code, or Section III, either in its entirety or portions thereof. The Replacement Code is therefore acceptable for the Repair activities, which includes Installation.

The Original Construction Code for Design and Procurement is the 1971 Edition of the ASME Code as noted above. The Section XI Code (Article IWA-7210) specifies that Replacements shall meet the requirements of the edition of the Construction Code to which the original component or part was constructed, unless the following alternative is adopted (Article IWA-7210 (c)):

"(c) Alternatively, replacements may meet all or portions of the requirements of later editions of the Construction Code, provided that the following requirements are met.

(1) The requirements affecting the design, fabrication, and examination of the replacement are reconciled with the Owner's Specification.

(2) Mechanical interfaces, fits and tolerances that provide satisfactory performance are not changed by the later edition of the Construction Code.

(3) Modified or alerted designs are reconciled with the Owner's Specification (Reference 5.22) through the Stress Analysis Report, Design Report, or other suitable method which demonstrates the satisfactory use for the specified design and operating conditions, whichever is applicable.

(4) Materials are compatible with the installation and system requirements."

These four requirements are addressed individually in Paragraphs (1) through (4), below:

1. Requirement

"(1) The requirements affecting the design, fabrication, and examination of the replacement are reconciled with the Owner's Specification (Reference 5.22)."

Discussion

The Owner has specified the Original Construction Code as the 1971 Edition, through Summer Addenda, of the ASME Boiler and Pressure Vessel Code, ABB Combustion Engineering Nuclear Operations, acting as the Owner's Agent, prepared a design specification for the Mechanical Nozzle Seal Assembly in accordance with the Owner's Reference 5.22, namely Design Specification for the Mechanical Nozzle Seal Assembly, Specification No. S3-NOME-SP-0049, Revision 00.

The Design requirements, as specified in the Owner's Specification (Reference 5.22) and Pressurizer Specification for ASME Code Class 1 components, are per Article NB-3000 of the Original Code. The fabrication and Installation requirements are per Article NB-4000 of the Original Code. And, the Examination requirements are per Article NB-5000 of the Original Code. Similar Articles specify the Design, Fabrication and Installation, and Examination requirements of the Replacement Code. The corresponding Articles for Design, Fabrication and Installation, and Examination requirements of the Replacement Code are Articles NB-3000, NB-4000, and NB-5000, respectively.

An itemized comparison of each of the requirements of Design, Fabrication and Examination (called Inspection in the original Code) for the Original Code and the Replacement Code is provided below:

Design

The basic design requirements defined in Article NB-3000 of the Original Code are incorporated in Article NB-3000 in general, and in particular Article NB-3200 of the Replacement Code. Between 1971 and 1989 many more design criteria, categories and definitions were added to the Replacement Code, resulting in a more comprehensive Design Code. Thus, the significant differences between the two Design Code editions are the volume of written material and the editorial/acronym changes.

Overall, it can be observed that the Replacement Code is more prescriptive concerning vessel design than is the Original Code. It is therefore concluded that, with respect to Design, the Replacement Code is reconciled to the Owner's Specification.

Fabrication and Installation

The intent of the Fabrication and Installation requirements defined in Article NB-4000 of the Original Code are also evident in Article NB-4000 of the Replacement Code. Similar to the Design requirement reconciliation described above, the Fabrication and Installation requirements defined in Article NB-4000 of the Original Code lack the depth associated with those of Article NB-4000 of the Replacement Code. Once again the original intent of the Original Code is maintained in the Replacement Code, but with a significant increase in breadth of material content. Additionally, the nuclear industry (including the Nuclear Regulatory Commission) acceptance of the Replacement Code requirements is evidence that it provides the same level of safety, if not greater, than the Original Code.

Examination

Similar to the Fabrication and Installation requirements, the intent of the Examination requirements defined in Article NB-5000 of the Original Code and Article NB-5000 of the

Replacement Code are essentially the same. The Examination requirements defined in Article NB-5000 of the Original Code lack the depth associated with those of Article NB-5000 of the Replacement Code in terms of the examination procedures and techniques. Once again the original intent of the Original Code is maintained in the Replacement Code, but with a significant increase in the technical area and most significant changes in the acceptance standards.

The acceptance criteria in the Replacement Code may seem less stringent at first glance, but further examination proves the Replacement Code is at least equivalent to the Original Code. Additionally the nuclear industry (including the Nuclear Regulatory Commission) acceptance of the Replacement Code requirements is evidence that is provides the same level of safety, if not greater, than the Original Code.

Overall, it can be observed that the Replacement Code is more prescriptive concerning vessel examination than is the Original Code. It is therefore concluded that, with respect to Examination, the Replacement Code is reconciled to the Owner's Specification.

2. Requirement

"(2) Mechanical interfaces, fits, and tolerances that provide satisfactory performance are not changed by the later edition of the Construction Code."

Discussion

The relevant interfaces, fits, and tolerances are associated with the seal between the Split Packing (Grafoil) of the Assembly and the Mechanical Nozzle. The Mechanical Nozzle Seal Assembly acts as a replacement pressure boundary, instead of the nozzle to pressurizer weld. The Mechanical Nozzle Seal Assembly is installed over the interface between the Mechanical Nozzle and Pressurizer O.D., and requires no modification of the Mechanical Nozzle for installation.

In summary, the interfaces, fits, and tolerances that provide satisfactory performance are evaluated in the Mechanical Nozzle Seal Assembly design report and consequently are in accordance with the Replacement Code.

3. Requirement

"(3) Modified or alerted designs are reconciled with the Owner's Specification (Reference 5.22) through the Stress Analysis Report, Design Report, or other suitable method which demonstrates the satisfactory use for the specified design and operating conditions, whichever is applicable."

Discussion

This Design Report has been prepared and demonstrates that the modified design is satisfactory for use for the design and operating conditions specified in S3-NOME-SP-0049 and the Owner's Specification (Reference 5.22).

4. Requirement

"(4) Materials are compatible with the installation and system requirements."

Discussion

The SCE Mechanical Nozzle Seal Assembly is fabricated from SA-479 Type 304 austenitic stainless steel, and SA-453 Grade 660 high alloy, high temperature bolting material, which are compatible with the Mechanical Nozzle material (consistent of SA-182 Type 316 stainless steel for Safe End, and SB-166 (Inconel) for the Nozzle). The Original Code does not have any material specification for SA-479 Type 304 austenitic stainless steel or SA-453 Grade 660 high alloy, high temperature bolting material, therefore no comparison can be made between the Original Code and the Replacement Code.

Because the Replacement Code has been accepted by the nuclear industry (including the Nuclear Regulatory Commission) and the Assembly's materials are similar in composition to the Mechanical Nozzle material, it is evidence that the Mechanical Nozzle Seal Assemhly material, SA-479 Type 304 and SA-453 Grade 660, is acceptable for use as designated by the Owner's Specification. It is therefore concluded that, with respect to Material, the Replacement Code is reconciled to the Owner's Specification.

Conclusion

It has been shown in the preceding paragraphs that the Replacement Code requirements are at least as prescriptive or more prescriptive than those of the Original Code. Therefore, it can be concluded that the requirements concerning the Construction Code date change for the SCE Mechanical Nozzle Seal Assembly are satisfied.

APPENDIX B

ANSYS OUTPUT

Executing /ansys53/bin/hp700/ansys.e53

```
*------------------------------------------------*
|                                                |
| WELCOME TO THE ANSYS PROGRAM                   |
|                                                |
*------------------------------------------------*



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*                                *
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*                                *
```

****

ANSYS/Mechanical

AFTER YOU HAVE READ AND UNDERSTOOD THE PREVIOUS NOTICES.
PRESS <CR> OR <ENTER> TO CONTINUE

```
     ***** ANSYS COMMAND LINE ARGUMENTS *****
 INITIAL JOBNAME          = file
 MEMORY REQUESTED (MB)    =    64.0
 GRAPHICS DEVICE REQUESTED = X11
 START-UP FILE MODE       = READ
 GRAPHICAL ENTRY          = YES
 DATABASE SIZE REQUESTED (MB) =   16

*** NOTE ***                        CP=      2.590   TIME= 13:16:11
There are no parameters and no abbreviations defined.

10158-961227      VERSION=HP 9000/700     RELEASE= 5.3     UP071096
FOR SUPPORT CALL L. L. Beaudreau   PHONE 860-285-3991     FAX 860-285-2901
CURRENT JOBNAME=file  13:16:11  JUN 18. 1997 CP=      2.590


/SHOW SET WITH DRIVER NAME= X11     , RASTER MODE, GRAPHIC PLANES =  8

RUN SETUP PROCEDURE FROM FILE= /ansys53/docu/start.ans


/INPUT FILE= menust.tmp  LINE=      0

/INPUT FILE= /ansys53/docu/start.ans  LINE=      0

ABBREVIATION= VED_EDIT  /SYS,/opt/ved/bin/ved &

ABBREVIATION= ANSYSWEB  DELETED.

ACTIVATING THE GRAPHICAL USER INTERFACE (GUI).  PLEASE WAIT...

/INPUT FILE= plate2.inp  LINE=      0

CURRENT JOBNAME REDEFINED AS pl2

***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.3     *****
ANSYS/Mechanical
10158-961227      VERSION=HP 9000/700   13:16:49  JUN 18. 1997 CP=      3.590
FOR SUPPORT CALL L. L. Beaudreau  PHONE 860-285-3991     FAX 860-285-2901
```

```
***** ANSYS ANALYSIS DEFINITION (PREP7) *****

ENTER /SHOW,DEVICE-NAME  TO ENABLE GRAPHIC DISPLAY
ENTER FINISH             TO LEAVE PREP7
PRINTOUT KEY SET TO /GOPR (USE /NOPR TO SUPPRESS)

TITLE=
SCE MNSA non-standard plate


PARAMETER R1    =  0.8900000

PARAMETER R2    =  1.030000

PARAMETER R3    =  2.375000

PARAMETER R4    =  2.750000

PARAMETER TH    =  0.7500000

*** PROPERTY TEMPERATURE TABLE    NUM. TEMPS=  6 ***
SLOC=  1    100.0000     200.0000     300.0000
            400.0000     500.0000     600.0000

PROPERTY TABLE ALPX  MAT=  1  NUM. POINTS=  6
SLOC=  1    0.8550000E-05 0.8790000E-05 0.9000000E-05 0.9190000E-05
            0.9370000E-05 0.9530000E-05

PROPERTY TABLE EX    MAT=  1  NUM. POINTS=  6
SLOC=  1    0.2810000E+08 0.2760000E+08 0.2700000E+08 0.2650000E+08
            0.2580000E+08 0.2530000E+08

REFERENCE TEMPERATURE=  70.000  (TUNIF=  70.000)

AREA NUMBERING KEY =  1

LINE NUMBERING KEY =  1
XYZ TRIAD DISPLAY SET TO LEFT BOTTOM

ELEMENT TYPE     1 IS SHELL93     8-NODE STRUCTURAL SHELL
 KEYOPT(1-12)=   0 0 0   0 0 0   0 0 0   0 0 0

CURRENT NODAL DOF SET IS  UX    UY    UZ    ROTX  ROTY  ROTZ
 THREE-DIMENSIONAL MODEL

REAL CONSTANT SET      1  ITEMS     1 TO     6
  0.75000     0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

FOR ELEMENT TYPE(S) ALLOWING MULTIPLE SHAPES:
```

```
PRODUCE ALL QUADRILATERAL OR BRICK ELEMENTS. (MAPPED)

DEFAULT ELEMENT DIVISIONS PER LINE BASED ON ELEMENT SIZE = 0.300

KEYPOINT    1 X,Y,Z= 0.000000E+00 0.000000E+00 1.00000     IN CSYS= 0

KEYPOINT    2 X,Y,Z= 0.000000E+00 0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT    3 X,Y,Z= 0.890000     0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT    4 X,Y,Z= 1.03000      0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT    5 X,Y,Z= 2.37500      0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT    6 X,Y,Z= 2.75000      0.000000E+00 0.000000E+00 IN CSYS= 0

LINE CONNECTS KEYPOINTS    2    3
 LINE NO.=    1 KP1=    2 TAN1= -1.0000  0.0000  0.0000
              KP2=    3 TAN2=  1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS    3    4
 LINE NO.=    2 KP1=    3 TAN1= -1.0000  0.0000  0.0000
              KP2=    4 TAN2=  1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS    4    5
 LINE NO.=    3 KP1=    4 TAN1= -1.0000  0.0000  0.0000
              KP2=    5 TAN2=  1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS    5    6
 LINE NO.=    4 KP1=    5 TAN1= -1.0000  0.0000  0.0000
              KP2=    6 TAN2=  1.0000  0.0000  0.0000

ROTATE LINES    1.   2.   3.   4.
   ABOUT THE AXIS DEFINED BY KEYPOINTS    1    2
  DEGREES OF ARC=  -69.00  NUMBER OF SEGMENTS=  1

ROTATE LINES    5.   6.   7.   8.
   ABOUT THE AXIS DEFINED BY KEYPOINTS    1    2
  DEGREES OF ARC=  -21.00  NUMBER OF SEGMENTS=  1

ROTATE LINES    13.  14.  15.  16.
   ABOUT THE AXIS DEFINED BY KEYPOINTS    1    2
  DEGREES OF ARC=  -21.00  NUMBER OF SEGMENTS=  1

ROTATE LINES    21.  22.  23.  24.
   ABOUT THE AXIS DEFINED BY KEYPOINTS    1    2
  DEGREES OF ARC=  -69.00  NUMBER OF SEGMENTS=  1

DELETE SELECTED AREAS FROM    1 TO    5 BY    4
```

```
  DELETED    2 AREAS

KEYPOINT    50  X,Y,Z=  3.75000     0.000000E+00 0.000000E+00 IN CSYS= 0

LINE CONNECTS KEYPOINTS     2   50
 LINE NO.=   37 KP1=     2 TAN1=  -1.0000  0.0000  0.0000
          KP2=    50 TAN2=   1.0000  0.0000  0.0000

*GET know_l  FROM LINE ITEM=NUM MAX  VALUE= 37.0000000

DRAG LINES:
  13.
   ALONG LINES
  37.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= back.db
 FOR POSSIBLE RESUME FROM THIS POINT

GENERATE     2 TOTAL SETS OF AREAS
 SET IS FROM     1 TO     1 IN STEPS OF     1
 DX,DY,DZ=  0.000E+00  0.000E+00  0.000E+00      CSYS= 0

SUBTRACT AREAS

   AREA NUMBERS TO BE OPERATED ON =       2
   AREAS OPERATED ON WILL BE DELETED
   AREA NUMBERS TO BE SUBTRACTED  =       5
   AREAS SUBTRACTED WILL BE DELETED
   OUTPUT AREAS =    17

GENERATE     2 TOTAL SETS OF AREAS
 SET IS FROM     1 TO     1 IN STEPS OF     1
 DX,DY,DZ=  0.000E+00  0.000E+00  0.000E+00      CSYS= 0

SUBTRACT AREAS

   AREA NUMBERS TO BE OPERATED ON =       3
   AREAS OPERATED ON WILL BE DELETED
   AREA NUMBERS TO BE SUBTRACTED  =       2
   AREAS SUBTRACTED WILL BE DELETED
   OUTPUT AREAS =    5

GENERATE     2 TOTAL SETS OF AREAS
 SET IS FROM     1 TO     1 IN STEPS OF     1
 DX,DY,DZ=  0.000E+00  0.000E+00  0.000E+00      CSYS= 0

SUBTRACT AREAS

   AREA NUMBERS TO BE OPERATED ON =       4
   AREAS OPERATED ON WILL BE DELETED
```

AREA NUMBERS TO BE SUBTRACTED = 2
AREAS SUBTRACTED WILL BE DELETED
OUTPUT AREAS = 3

SUBTRACT AREAS

AREA NUMBERS TO BE OPERATED ON = 6
AREAS OPERATED ON WILL BE DELETED
AREA NUMBERS TO BE SUBTRACTED = 1
AREAS SUBTRACTED WILL BE DELETED
OUTPUT AREAS = 2

*** NOTE *** CP= 4.940 TIME= 15:16:55
NEW BACKUP FILE NAME= back.dbb.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= back.db
FOR POSSIBLE RESUME FROM THIS POINT

DELETE SELECTED AREAS FROM 9 TO 13 BY 4

DELETED 2 AREAS

MERGE COINCIDENT NODES WITHIN TOLERANCE OF 0.10000E-03

MERGE IDENTICAL MATERIALS WITHIN TOLERANCE OF 0.10000E-06

MERGE IDENTICAL ELEMENT TYPES

MERGE IDENTICAL REAL CONSTANT SETS WITHIN TOLERANCE OF 0.10000E-06

MERGE IDENTICAL ELEMENTS

MERGE IDENTICAL COUPLED DOF SETS

MERGE IDENTICAL CONSTRAINT EQUATIONS WITHIN TOLERANCE OF 0.10000E-06

MERGE COINCIDENT KEYPOINTS WITHIN TOLERANCE OF 0.10000E-03
KEYPOINT 4 USED FOR KEYPOINT(S) 29
KEYPOINT 28 USED FOR KEYPOINT(S) 32
KEYPOINT 30 USED FOR KEYPOINT(S) 31
LINE 2 USED FOR LINE(S) 45
LINE 41 USED FOR LINE(S) 44
LINE 43 USED FOR LINE(S) 46

GENERATE NODES AND ELEMENTS IN ALL SELECTED AREAS

** Meshing of area 2 in progress **
** Meshing of area 2 completed ** 40 elements.

** Meshing of area 3 in progress **

** Meshing of area 3 completed ** 20 elements.

** Meshing of area 5 in progress **
** Meshing of area 5 completed ** 60 elements.

** Meshing of area 7 in progress **
** Meshing of area 7 completed ** 24 elements.

** Meshing of area 8 in progress **
** Meshing of area 8 completed ** 8 elements.

** Meshing of area 10 in progress **
** Meshing of area 10 completed ** 40 elements.

** Meshing of area 11 in progress **
** Meshing of area 11 completed ** 24 elements.

** Meshing of area 12 in progress **
** Meshing of area 12 completed ** 8 elements.

** Meshing of area 14 in progress **
** Meshing of area 14 completed ** 120 elements.

** Meshing of area 15 in progress **
** Meshing of area 15 completed ** 72 elements.

** Meshing of area 16 in progress **
** Meshing of area 16 completed ** 24 elements.

** Meshing of area 17 in progress **
** Meshing of area 17 completed ** 75 elements.

```
NUMBER OF AREAS MESHED      =    12
MAXIMUM NODE NUMBER         =  1632
MAXIMUM ELEMENT NUMBER      =   515

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE       0 TO        0 STEP        1

    0  VOLUMES (OF      0  DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE       1 TO       17 STEP        1

   12  AREAS (OF    12  DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE       1 TO       49 STEP        1
```

```
 36  LINES (OF   36  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE        1 TO       50 STEP        1

  24  KEYPOINTS (OF    24  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE        1 TO      515 STEP        1

 515  ELEMENTS (OF   515  DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE        1 TO     1632 STEP        1

 1632  NODES (OF   1632  DEFINED) SELECTED BY  NSEL  COMMAND.

*** NOTE ***                    CP=     6.090   TIME= 13:16:59
DELETED BACKUP FILE NAME= back.dbb.

*** NOTE ***                    CP=     6.130   TIME= 13:16:59
NEW BACKUP FILE NAME= back.dbb.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= back.db
 FOR POSSIBLE RESUME FROM THIS POINT

SELECT       FOR ITEM=LINE COMPONENT=
 IN RANGE       30 TO       33 STEP        1

   4  LINES (OF    36  DEFINED) SELECTED BY LSEL  COMMAND.

ALSO SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE        3 TO       25 STEP       22

   6  LINES (OF    36  DEFINED) SELECTED BY LSEL COMMAND.

ALSO SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE       47 TO       49 STEP        1

   9  LINES (OF    36  DEFINED) SELECTED BY LSEL COMMAND.

SELECT      ALL NODES (INTERIOR TO LINE, AND AT KEYPOINTS)
      RELATED TO SELECTED LINE SET.

  113  NODES (OF  1632  DEFINED) SELECTED FROM
    9 SELECTED LINES BY NSLL COMMAND.

SYMMETRY CONSTRAINTS FOR COORDINATE SYSTEM  0 IN DIRECTION   Y
ON SURFACE DEFINED BY ALL SELECTED NODES
```

```
*** NOTE ***                    CP=     6.460   TIME= 13:17:00
Nodes on symmetry surfaces are rotated into coordinate system 0.

TOTAL SPECIFIED CONSTRAINTS=  339

SELECT      FOR ITEM=KP   COMPONENT=
 IN RANGE       9 TO       17 STEP       8

    2  KEYPOINTS (OF      24  DEFINED) SELECTED BY  KSEL  COMMAND.

SELECT      NODES ASSOCIATED WITH SELECTED KEYPOINTS

    2  NODES (OF   1632  DEFINED) SELECTED FROM
    2 SELECTED KEYPOINTS BY  NSLK  COMMAND.

SPECIFIED CONSTRAINT UX   FOR SELECTED NODES       1 TO    1632 BY       1
REAL= 0.000000000E+00  IMAG= 0.000000000E+00
ADDITIONAL DOFS=  UY    UZ    ROTX  ROTY  ROTZ

SELECT ALL ENTITIES OF TYPE= ALL   AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE       0 TO        0 STEP       1

    0  VOLUMES (OF       0  DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE       1 TO       17 STEP       1

   12  AREAS (OF     12  DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE       1 TO       49 STEP       1

   36  LINES (OF     36  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE       1 TO       50 STEP       1

   24  KEYPOINTS (OF      24  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE       1 TO      515 STEP       1

  515  ELEMENTS (OF    515  DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE       1 TO     1632 STEP       1
```

1632 NODES (OF 1632 DEFINED) SELECTED BY NSEL COMMAND.

***** ROUTINE COMPLETED ***** CP = 6.570

***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS

PRINT ALL ITEMS WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 26 TO 34 STEP 8

2 LINES (OF 36 DEFINED) SELECTED BY LSEL COMMAND.

ALSO SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 18 TO 43 STEP 25

4 LINES (OF 36 DEFINED) SELECTED BY LSEL COMMAND.

SELECT ALL NODES (INTERIOR TO LINE, AND AT KEYPOINTS)
RELATED TO SELECTED LINE SET.

61 NODES (OF 1632 DEFINED) SELECTED FROM
4 SELECTED LINES BY NSLL COMMAND.

*GET nnum FROM NODE ITEM=COUN VALUE= 61.0000000

SPECIFIED NODAL LOAD FZ FOR SELECTED NODES 1 TO 1632 BY 1
REAL= -8.19672131 IMAG= 0.000000000E+00

SELECT ALL ENTITIES OF TYPE= ALL AND BELOW

ALL SELECT FOR ITEM=VOLU COMPONENT=
IN RANGE 0 TO 0 STEP 1

0 VOLUMES (OF 0 DEFINED) SELECTED BY VSEL COMMAND.

ALL SELECT FOR ITEM=AREA COMPONENT=
IN RANGE 1 TO 17 STEP 1

```
  12  AREAS (OF    12  DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE        1 TO      49 STEP        1

  36  LINES (OF    36  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE        1 TO      50 STEP        1

  24  KEYPOINTS (OF     24  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE        1 TO     515 STEP        1

 515  ELEMENTS (OF    515  DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE        1 TO    1632 STEP        1

1632  NODES (OF   1632  DEFINED) SELECTED BY  NSEL  COMMAND.

***** ANSYS SOLVE   COMMAND *****

            S O L U T I O N   O P T I O N S

  PROBLEM DIMENSIONALITY..............3-D
  DEGREES OF FREEDOM.......UX   UY   UZ   ROTX ROTY ROTZ
  ANALYSIS TYPE ..................STATIC (STEADY-STATE)

*** NOTE ***                    CP=      6.800   TIME= 13:17:02
Present time 0 is less than or equal to the previous time.
 Time will default to 1.

*** NOTE ***                    CP=      6.800   TIME= 13:17:02
Results printout suppressed for interactive execute.
** Reordering still in progress **
** Reordering still in progress **

            L O A D   S T E P   O P T I O N S

  LOAD STEP NUMBER.................        1
  TIME AT END OF THE LOAD STEP..........  1.0000
  NUMBER OF SUBSTEPS.................        1
  STEP CHANGE BOUNDARY CONDITIONS .........   NO
  PRINT OUTPUT CONTROLS
    ITEM     FREQUENCY   COMPONENT
    ALL       NONE
  DATABASE OUTPUT CONTROLS
    ITEM     FREQUENCY   COMPONENT
```

ALL ALL

Range of element maximum matrix coefficients in global coordinates
Maximum= 727897419 at element 61.
Minimum= 36366047.2 at element 409.

*** ELEMENT MATRIX FORMULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 515 SHELL93 1.520 0.003
Time at end of element matrix formulation CP= 8.8200001.
Solution Preparation Element= 10 Cum. Iter.= 1 CP= 9.040
Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Solution Preparation Element= 210 Cum. Iter.= 1 CP= 9.380
Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Solution Preparation Element= 510 Cum. Iter.= 1 CP= 9.900
Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.

Estimated number of active DOF= 9441.
Maximum wavefront= 257.

Equation Solution Element= 460 Cum. Iter.= 1 CP= 14.910
Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Time at end of matrix triangularization CP= 15.3100003.
Equation solver maximum pivot= 257025034 at node 254 UY.
Equation solver minimum pivot= 1.530889572E-02 at node 1455 ROTZ.

*** ELEMENT RESULT CALCULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 515 SHELL93 1.250 0.002

*** NODAL LOAD CALCULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 515 SHELL93 0.110 0.000
*** LOAD STEP 1 SUBSTEP 1 COMPLETED. CUM ITER = 1
*** TIME = 1.00000 TIME INC = 1.00000 NEW TRIANG MATRIX

*** PROBLEM STATISTICS
ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 9441
R.M.S. WAVEFRONT SIZE = 232.6

*** ANSYS BINARY FILE STATISTICS
BUFFER SIZE USED= 4096
9.859 MB WRITTEN ON ELEMENT MATRIX FILE: pl2.emat

1.219 MB WRITTEN ON ELEMENT SAVED DATA FILE: pl2.esav
17.031 MB WRITTEN ON TRIANGULARIZED MATRIX FILE: pl2.tri
1.313 MB WRITTEN ON RESULTS FILE: pl2.rst

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 17.750

***** ANSYS RESULTS INTERPRETATION (POST1) *****

ENTER /SHOW,DEVICE-NAME TO ENABLE GRAPHIC DISPLAY
ENTER FINISH TO LEAVE POST1

USE LOAD STEP 1 SUBSTEP 0 FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP= 1 SUBSTEP= 1 CUMULATIVE ITERATION= 1
TIME/FREQUENCY= 1.0000
TITLE= SCE MNSA non-standard plate

SELECT FOR ITEM=U COMPONENT=Z BETWEEN-0.20000E-03 AND -0.19000E-03
KABS= 0. TOLERANCE= 0.100000E-12

133 NODES (OF 1632 DEFINED) SELECTED BY NSEL COMMAND.

PRINT U NODAL SOLUTION PER NODE

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
746	-0.19928E-03
762	-0.19121E-03
763	-0.19297E-03
764	-0.19454E-03
765	-0.19592E-03
766	-0.19707E-03
767	-0.19801E-03
768	-0.19870E-03
769	-0.19913E-03
770	-0.19576E-03

771 -0.19902E-03
772 -0.19876E-03
773 -0.19852E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
774	-0.19828E-03
775	-0.19805E-03
776	-0.19783E-03
777	-0.19762E-03
778	-0.19741E-03
779	-0.19722E-03
780	-0.19703E-03
781	-0.19684E-03
782	-0.19667E-03
783	-0.19650E-03
784	-0.19634E-03
785	-0.19619E-03
786	-0.19606E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
787	-0.19591E-03
788	-0.19578E-03
789	-0.19577E-03
807	-0.19085E-03
808	-0.19200E-03
809	-0.19321E-03
810	-0.19394E-03
811	-0.19471E-03
812	-0.19514E-03
1018	-0.19101E-03
1019	-0.19081E-03
1020	-0.19062E-03

1021 -0.19043E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1022	-0.19024E-03
1023	-0.19005E-03
1037	-0.19255E-03
1038	-0.19214E-03
1039	-0.19175E-03
1040	-0.19137E-03
1041	-0.19100E-03
1042	-0.19064E-03
1043	-0.19030E-03
1046	-0.19432E-03
1047	-0.19410E-03
1048	-0.19388E-03
1049	-0.19367E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1050	-0.19346E-03
1051	-0.19326E-03
1052	-0.19306E-03
1053	-0.19286E-03
1054	-0.19267E-03
1055	-0.19249E-03
1056	-0.19230E-03
1057	-0.19212E-03
1058	-0.19194E-03
1059	-0.19177E-03
1060	-0.19160E-03
1061	-0.19143E-03
1062	-0.19125E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1063	-0.19107E-03
1064	-0.19096E-03
1065	-0.19545E-03
1066	-0.19500E-03
1067	-0.19458E-03
1068	-0.19417E-03
1069	-0.19378E-03
1070	-0.19341E-03
1071	-0.19305E-03
1072	-0.19270E-03
1073	-0.19238E-03
1074	-0.19683E-03
1075	-0.19659E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1076	-0.19635E-03
1077	-0.19613E-03
1078	-0.19590E-03
1079	-0.19569E-03
1080	-0.19548E-03
1081	-0.19527E-03
1082	-0.19507E-03
1083	-0.19487E-03
1084	-0.19468E-03
1085	-0.19449E-03
1086	-0.19431E-03
1087	-0.19413E-03
1088	-0.19396E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1089	-0.19379E-03
1090	-0.19360E-03
1091	-0.19342E-03
1092	-0.19331E-03
1093	-0.19751E-03
1094	-0.19703E-03
1095	-0.19658E-03
1096	-0.19616E-03
1097	-0.19575E-03
1098	-0.19537E-03
1099	-0.19500E-03
1100	-0.19464E-03
1101	-0.19432E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1102	-0.19844E-03
1103	-0.19819E-03
1104	-0.19795E-03
1105	-0.19771E-03
1106	-0.19748E-03
1107	-0.19726E-03
1108	-0.19704E-03
1109	-0.19683E-03
1110	-0.19662E-03
1111	-0.19642E-03
1112	-0.19623E-03
1113	-0.19604E-03
1114	-0.19585E-03

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

```
NODE     UZ
1115 -0.19566E-03
1116 -0.19548E-03
1117 -0.19531E-03
1118 -0.19511E-03
1119 -0.19492E-03
1120 -0.19482E-03
1121 -0.19862E-03
1122 -0.19813E-03
1123 -0.19768E-03
1124 -0.19726E-03
1125 -0.19686E-03
1126 -0.19649E-03
1127 -0.19615E-03
```

SCE MNSA non-standard plate

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

```
NODE     UZ
1128 -0.19582E-03
1129 -0.19552E-03
1131 -0.19044E-03
```

MAXIMUM ABSOLUTE VALUES
NODE 746
VALUE -0.19928E-03

SELECT ALL ENTITIES OF TYPE= ALL AND BELOW

ALL SELECT FOR ITEM=VOLU COMPONENT=
IN RANGE 0 TO 0 STEP 1

0 VOLUMES (OF 0 DEFINED) SELECTED BY VSEL COMMAND.

ALL SELECT FOR ITEM=AREA COMPONENT=
IN RANGE 1 TO 17 STEP 1

12 AREAS (OF 12 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 49 STEP 1

36 LINES (OF 36 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT FOR ITEM=KP COMPONENT=
IN RANGE 1 TO 50 STEP 1

24 KEYPOINTS (OF 24 DEFINED) SELECTED BY KSEL COMMAND.

ALL SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 1 TO 515 STEP 1

515 ELEMENTS (OF 515 DEFINED) SELECTED BY ESEL COMMAND.

ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 1632 STEP 1

1632 NODES (OF 1632 DEFINED) SELECTED BY NSEL COMMAND.

SELECT FOR ITEM=S COMPONENT=INT BETWEEN 2500.0 AND 0.12677E+31
KABS= 0. TOLERANCE= 0.250000E-04

17 NODES (OF 1632 DEFINED) SELECTED BY NSEL COMMAND.

PRINT S NODAL SOLUTION PER NODE

SCE MNSA non-standard plate

***** POST1 NODAL STRESS LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0
SHELL NODAL RESULTS ARE AT TOP

NODE	S1	S2	S3	SINT	SEQV
235	2084.4	1587.0	-504.27	2588.7	2379.3
522	2356.9	781.79	-150.19	2507.1	2194.9
748	2418.8	636.66	-252.71	2671.5	2356.3
750	2437.6	514.27	-378.81	2816.4	2492.9
752	2404.1	412.55	-513.76	2917.8	2582.4
754	2311.4	326.67	-641.01	2952.4	2607.0
756	2156.7	252.73	-744.69	2901.4	2553.2
758	1941.7	188.54	-810.94	2752.7	2413.5
760	1673.3	133.29	-828.40	2501.7	2185.7
823	2328.9	647.63	-211.86	2540.8	2238.4
851	2329.0	529.38	-316.57	2645.6	2340.2
879	2281.8	428.05	-429.54	2711.3	2400.3
881	2172.9	444.16	-358.13	2531.0	2240.3
907	2181.5	340.94	-537.35	2718.9	2403.3

```
SCE MNSA non-standard plate

 ***** POST1 NODAL STRESS LISTING *****

 LOAD STEP=    1  SUBSTEP=    1
  TIME=   1.0000     LOAD CASE=  0
 SHELL NODAL RESULTS ARE AT TOP

  NODE    S1         S2         S3         SINT       SEQV
   909  2065.6     356.58    -448.21     2513.8     2223.5
 [illegible]35  2026.1     265.38    -626.45     2652.6     2337.9
 [illegible]  1817.8     199.71    -684.51     2502.3     2197.9

MINIMUM VALUES
NODE       760        760        760        760        760
VALUE   1673.3     133.29    -828.40     2501.7     2185.7

MAXIMUM VALUES
NODE       750        235        522        754        754
VALUE   2437.6     1587.0    -150.19     2952.4     2607.0

SCE MNSA non-standard plate

 ***** POST1 NODAL STRESS LISTING *****

 LOAD STEP=    1  SUBSTEP=    1
  TIME=   1.0000     LOAD CASE=  0
 SHELL NODAL RESULTS ARE AT TOP

  NODE    S1         S2         S3         SINT       SEQV
***** ESTIMATED BOUNDS CONSIDERING THE EFFECT OF DISCRETIZATION ERROR *****

MINIMUM VALUES
NODE       760        750        235        235        235
VALUE   1671.9     131.88    -885.57     2207.4     1998.0

MAXIMUM VALUES
NODE       235        235        235        235        235
VALUE   2465.7     1968.3    -122.97     2970.0     2760.6
***************************************************************************

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE       0 TO        0 STEP        1

    0  VOLUMES (OF       0  DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
```

```
IN RANGE       1 TO       17 STEP        1

  12  AREAS (OF    12  DEFINED) SELECTED BY ASEL COMMAND

ALL SELECT   FOR ITEM=LINE COMPONENT=
IN RANGE       1 TO       49 STEP        1

  36  LINES (OF    36  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
IN RANGE       1 TO       50 STEP        1

  24  KEYPOINTS (OF    24  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
IN RANGE       1 TO      515 STEP        1

  515  ELEMENTS (OF    515  DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
IN RANGE       1 TO     1632 STEP        1

 1632  NODES (OF   1632  DEFINED) SELECTED BY  NSEL  COMMAND.

EXIT THE ANSYS POST1 DATABASE PROCESSOR


***** ROUTINE COMPLETED *****  CP =       18.830
```

APPENDIX C

STIFFNESS OF FLANGED CONNECTION

C.1 Objective

This appendix calculates the stiffness of the components in the flanged connection between the MNSA and the pressurizer. E(.h MNSA location has a different stiffness..

C.2 Side Pressurizer RTD Nozzle

Stiffness of Hex Head Bolts:

The stiffness of the bolts is calulated using the same methods described for the tie rods in Section 3.2.3 of the main text. Dimensions are taken from Reference 5.8.

$$K_{bolts} = 4\frac{A\,E}{l} = 4\frac{(0.1599\ in^2)(24.8\ X\,10^6\ \frac{lbf}{in^2})}{1.655\,in} = 9{,}584{,}338\ \frac{lbf}{in}$$

where: A = cross section of bolt, Section 2.1.4
l = effective length of bolt,
= thread engagement + lower flange + upper flange + washer
= 0.5 + 0.365 + 0.73 + 0.06 = 1.655 inch

Stiffness of Overall Flange:

The side pressurizer MNSA has two components which represent the flanged connection to the pressurizer, the upper flange and the compression collar. The stiffness of each of these compoents is calculated using the same method described for the top plate in Section 3.2.3 of the main text.

Upper flange:

The following equations are found in Reference 5.11, Table 24, Case 1a. All dimensionse are taken from Reference 5.8.

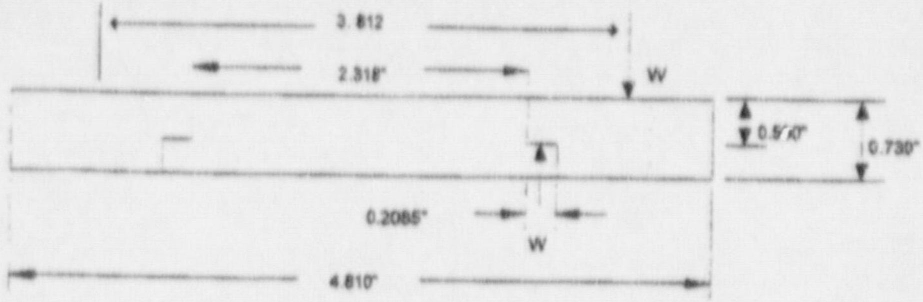
$$y = \frac{w\,a^3}{D}\left(\frac{C_1\,L_9}{C_7} - L_3\right)$$

where:

$$D = \frac{E\,t^3}{12(1-\gamma^2)} = \frac{24.8\,X\,10^6\ \frac{lbf}{in^2}(0.73)^3\,in^3}{12\,(1-0.3^2)} = 883{,}482\ lbf$$

C_1, C_7, L_9, and L_3 are constants, and are calculated using the equations of Reference 5.11, pgs. 332-334 using the following dimensions. Since the flange does not have a rectangular cross section, the dimensions are selected to produces the lowest flange stiffness.

RTD UPPER FLANGE



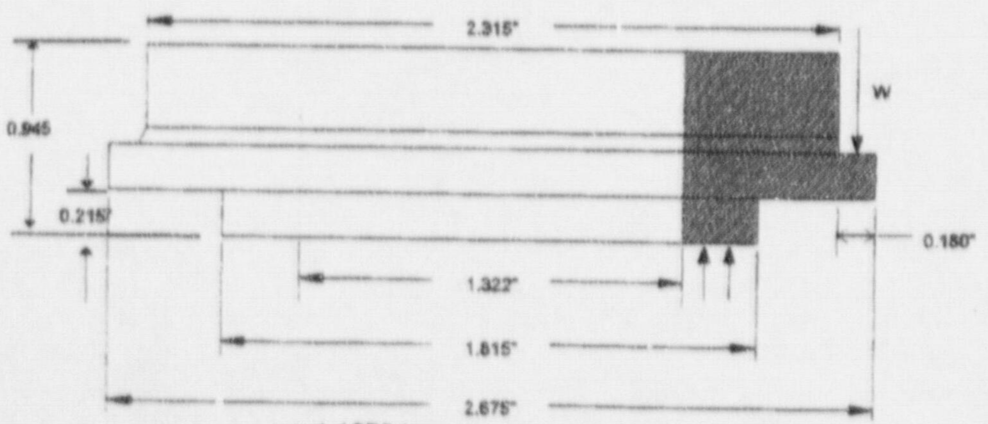
a = outer radius, 1.906 in
b = inner radius, 1.263 in
r_o = radius of applied load, 1.263 in
t = thickness, 0.73 in
γ = Poisson's ratio, 0.3
E = elastic modulus, 24.8 X 10^6 psi
C_1 = 0.3254
C_7 = 0.3851
L_3 = 0.0052
L_9 = 0.2423

Solving for the stiffness of the upper flange:

$$K_{\text{upper flange}} = \frac{w}{y} = \frac{2\pi r_o}{\frac{a^3}{D}\left(\frac{C_1 L_9}{C_7} - L_3\right)} = 5{,}074{,}435 \frac{lbf}{in}$$

Compresion Collar:

COMPRESSION COLLAR



a = 1.1575 in
b = 0.661 in
r_o = 0.784 in
t = 0.73 in

$\nu = 0.3$
$E = 24.8 \times 10^6$ psi
$C_1 = 0.4145$
$C_7 = 0.5369$
$L_3 = 0.0046$
$L_9 = 0.2357$

$$D = \frac{E\,t^3}{12(1-\gamma^2)} = \frac{24.8X10^6 \,\frac{lbf}{in^2}(0.73)^3\, in^3}{12(1-03^2)} = 883{,}482\ lbf$$

$$K_{collar} = \frac{w}{y} = \frac{2\pi\, r_o}{\frac{a^3}{D}\left(\frac{C_1 L_9}{C_7} - L_3\right)} = 15{,}821{,}942\,\frac{lbf}{in}$$

Determination of equivalent flange stiffness:

These components act in series against the bolt. The effective stiffness of the two components is calculated below.

$$K_{flange} = \frac{1}{\frac{1}{K_{flange}} + \frac{1}{K_{collar}}} = 3{,}842{,}170\,\frac{lbf}{in}$$

C.3 Bottom Pressurizer Level Nozzle

Stiffness of Hex Head Bolts:

The stiffness of the bolts is calulated using the same methods described for the tie rods in Section 3.2.3 of the main text.

$$K_{bolts} = 4\frac{A\,E}{l} = 4\frac{(0.1599\ in^2)(24.8\,X\,10^6\ \frac{lbf}{in^2})}{3.994\ in} = 3{,}971{,}477\ \frac{lbf}{in}$$

where: A = cross section of bolt, Section 2.1.4
l = effective length of bolt.
= thread engagement + average lower flange + upper flange (top) + upper flange (bottom)+ washer
= 0.5 +[4.186 - 7.5 /2* tan(27.5°)] + 0.5 + 0.7 + 0.06 = 3.994

Stiffness of Overall Flange:

The side pressurizer MNSA has three components which represent the flanged connection to the pressurizer, the upper flange (top), upper flange (bottom) and the compression collar. The stiffness of each flange is calculated using the same method described for the upper flange of the side pressurizer MNSA. The compression collar is tall and narrow and therefore considered to have only axial stiffness.

Upper flange (top):

The following equations are found in Reference 5.11, Table 24, Case 1a. All dimensionse are taken from Reference 5.8.

a = outer radius, 3.25 in
b = inner radius, 1.156 in
r_o = radius of applied load, 1.156 in
t = thickness, 0.5 in
γ = Poisson's ratio, 0.3
E = elastic modulus, 24.8 X 10^6 psi
C_1 = 0.6687
C_7 = 1.1174
L_3 = 0.0259
L_9 = 0.2934

$$D = \frac{E\,t^3}{12(1-\gamma^2)} = \frac{24.8\,X 10^6\ \frac{lbf}{in^2}(0.5)^3\,in^3}{12(1-0.3^2)} = 283{,}883\ lbf$$

Solving for the stiffness of the upper flange, top:

$$K_{upper,top} = \frac{w}{y} = \frac{2\pi r_o}{\frac{a^3}{D}\left(\frac{C_1 L_9}{C_7} - L_3\right)} = 401{,}286\,\frac{lbf}{in}$$

Upper flange (bottom):

The following equations are found in Reference 5.11, Table 24, Case 1a. All dimensionse are taken from Reference 5.8.

a = outer radius, 3.25 in
b = inner radius, 0.781 in
r_0 = radius of applied load, 0.968 in
t = thickness, 0.7 in
γ = Poisson's ratio, 0.3
E = elastic modulus, 24.8 X 10^6 psi
C_1 = 0.9089
C_7 = 1.7841
L_3 = 0.0303
L_9 = 0.2819

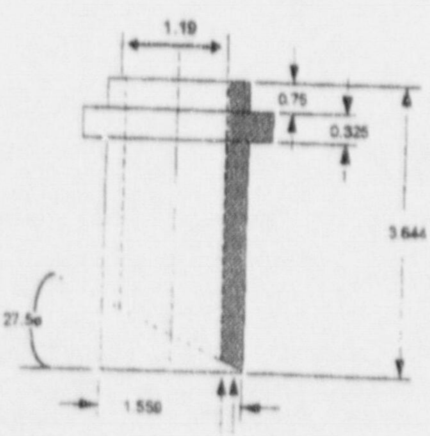
$$D = \frac{E\,t^3}{12(1-\gamma^2)} = \frac{24.8\,X10^6\,\frac{lbf}{in^2}(0.7)^3\,in^3}{12\,(1-0.3^2)} = 778{,}974\ lbf$$

Solving for the stiffness of the upper flange, bottom:

$$K_{upper,bot} = \frac{w}{y} = \frac{2\pi r_o}{\frac{a^3}{D}\left(\frac{C_1 L_9}{C_7} - L_3\right)} = 1{,}217{,}462\,\frac{lbf}{in}$$

Compresion Collar:

BOTTOM PRESSURIZER COMPRESSION COLLAR



$$K_{collars} = \frac{A\,E}{l} = \frac{(0.7967\ in^2)(24.8\ X\ 10^6\ \frac{lbf}{in^2})}{3.24\ in} = 6{,}098{,}198\ \frac{lbf}{in}$$

where: A = cross section of collar, $\pi/4*(1.559^2 - 1.19^2) = 0.7967\ in^2$
l = average effective length,
= [3.644 + (3.644-1.559*tan27.5°)] / 2 = 3.24 in

Determination of equivalent flange stiffness:

The three flanges act in parallel with the bolts. The overall flange and the compression collar act in series with the bolt. The effective stiffness of the components is calculated below.

$$K_{flange} = \frac{1}{\frac{1}{(K_{upper.top} + K_{upper.bot})} + \frac{1}{K_{collar}}} = 1{,}279{,}191\ \frac{lbf}{in}$$

APPENDIX D

QUALITY ASSURANCE FORMS

DESIGN REPORT REVIEW CHECKLIST

Instructions: The Independent Reviewer is to complete this checklist for each Design Report. This checklist may be incorporated into the Design Report or maintained separate.

Title: Addendum to the Pressurizer Analytical Stress Report for Southern California Edison San Onofre Units 2 And 3

Document Number: S-PENG-DR-002 **Revision Number:** 01

	Yes	N/A
1. Have all drawings been prepared and independently reviewed in accordance with QP 3.7?	☑	☐
2. Are Checklists for the Design Analysis (QP 3.4) and Drawing (QP 3.7) review attached to the Design Report or on file with the CEO as quality records?	☑	☐
3. Have the analyses been separately prepared and independently reviewed in accordance with QP 3.4? ; or	☐	☑
4. Is the analyses to be independently reviewed in conjunction with the compilation and verification of the design report?	☑	☐
5. Have all applicable TCRs, DCRs, NCRs, etc. been listed and reconciled in the Design Report?	☐	☑
6. Are all applicable drawings and analyses used for design and construction in agreement with, and identified and described in the Design Report?	☑	☐
7. Are the correct revision levels of all design output documents listed?	☑	☐
8. Have provisions been made for a copy of the Owner's Review of the Design Report to be attached to the Design Report?	☐	☑
9. Does the Design Report contain sufficient details and references to permit certification by a Registered Professional Engineer (RPE)?	☑	☐
10. Is the Design Report in accordance with the format requirements of the procedure?	☑	☐

Comments (if any)

Checklist completed by:

Independent Reviewer J.T. Wrenn (Printed Name) J. T. Wrenn (Signature) 8-27-97 (Date)

Verification Plan

Title: Addendum to the Pressurizer Analytical Stress Report for Southern California Edison San Onofre Units 2 And 3

Document Number: **S-PENG-DR-002** Revision Number: 01

Instructions: Describe the method(s) of verification to be employed, i.e., Design Review, Alternate Analysis, Qualification Testing, a combination of these or an alternative. The Design Analysis Verification Checklist is to be used for all Design Analyses. Other elements to consider in formulating the plan are: methods for checking calculations; comparison of results with similar analyses, etc.

Description of Verification Method:

Method of verification is design review; including:

- Verify that appropriate analytical methods were used correctly,
- Verify that all technical parameters associated with the analytical methods were correctly selected from traceable sources,
- Review numerical calculations for accuracy.

Verification Plan prepared by:	Approved by:
J.T. Wrenn [signature]	K. H. Haslinger [signature]
Independent Reviewer printed name and signature	Management approver printed name and signature

Design Analysis Verification Checklist

(Page 1 of 4)

Instructions: The Independent Reviewer is to complete this checklist for each analysis and it is to be incorporated into the completed analysis. If a major topic area (generally unnumbered, bold face type such as **Use of Computer Software**) is not applicable, then N/A next to the topic may be checked and the check boxes for all items under it may be left blank. Where there is no check box under N/A (not applicable) for a numbered item, such a response is generally inappropriate. If N/A is checked in such a situation, document the basis at the end of this checklist in the Comments section.

Title: Addendum to the Pressurizer Analytical Stress Report for Southern California Edison San Onofre Units 2 And 3

Document Number: S-PENG-DR-002 **Revision Number:** 01

	Yes	N/A
Overall Assessment		
1. Are the results/conclusions correct and appropriate for their intended use?	☑	
2. Are all limitations and contingencies on the results/conclusions documented?	☑	
Assignment of Cognizant Engineers, Independent Reviewers and Mentors		
1. Have Cognizant Engineers, Independent Reviewers and Mentors, if applicable, been assigned and approved by management?	☑	
2. If there are multiple Cognizant Engineers, has their scope been documented?	☐	☑
3. If there are multiple Independent Reviewers, has their scope been documented?	☐	☑
4. If there will be multiple Management Approvers, has their scope been documented?	☐	☑
5. If an Independent Reviewer is the supervisor has the appropriate level of approval been documented?	☐	☑
Use of Computer Software		☐
For software which has been validated under QP 3.13:		☐
1. Is the software applicable for this analysis?	☑	
2. If there are significant changes in the mode of software use, has the Program Manager(s) been consulted and have they initialed the approvals section of the Design Analysis In-Process Approvals form?	☐	☑
For software which has not been validated under QP 3.13:		☑
1. Is the computer type, program name and revision identification documented?	☐	
2. Is the documentation sufficient for the Independent Reviewer to concur that the software is appropriate for the analysis?	☐	
3. Is the documentation sufficient for the Independent Reviewer to concur that the results are correct?	☐	
4. If the documentation is incorporated by reference, is there assurance that the software actually used is identical to that in the reference?	☐	
5. If spreadsheets have been used, is the documentation sufficient for the Independent Reviewer to concur that the results are correct?	☐	

Design Analysis Contents	Yes	N/A
Objective of the Design Analysis		
1 Has information necessary to define the task been included or referenced?	☑	
2 Has the reason why the analysis is being performed or revised been documented?	☑	
3. Has the applicability and intended use of the results been documented?	☑	
Assessment of Significant Design Changes		
1. Have significant design-related changes that might impact this analysis been considered?	☑	
2. If any such changes have been identified, have they been adequately addressed?	☐	☑
Analytical Techniques (Methods)		
I. Are the analytical techniques (methods) described in sufficient detail to judge their appropriateness?	☑	
II. Have analytical techniques incorporated by reference to generic analyses, lead plant analyses or previous cycle analyses been previously verified?	☐	☑
III. For modifications or departures from previously approved analytical techniques or Conventional Engineering Analysis Procedures (QP 3.19):	☐	☑
A. Are they documented and justified?	☐	☐
B. Have they been approved by Management initialing the Design Analysis In-Process Approvals form?	☐	☐
IV. If superseded approved analytical techniques or Engineering Analysis Procedures are used, is their use justified and approved?	☐	☑
V. Does the date of issue of referenced approved procedures or Engineering Analysis Procedures predate their use in this analysis?	☐	☑
Selection of Design Inputs		
1. Are the design inputs documented?	☑	
2. Are the design inputs correctly selected and traceable to their source?	☑	
3. Are references as direct as possible to the original source or documents containing collection/tabulations of inputs?	☑	
4. Is the reference notation appropriately specific to the information utilized?	☑	
5. Are the bases for selection of all design inputs documented?	☑	
6. Is the verification status of design inputs transmitted from customer is appropriate and documented?	☐	☑
7. Is the verification status of design inputs transmitted from ABB CENS appropriate and documented?	☑	☐
8. Is the use of customer-controlled sources such as Tech Specs, UFSARs, etc. authorized, and does the authorization specify amendment level, revision number, etc.?	☐	☑
Assumptions		
1. If there are no assumptions, is this documented?	☐	☑
2 Are all assumptions identified and justified?	☑	☐
3. Are assumptions which must be cleared by CENO or the customer listed on a Contingencies and Assumptions form?	☐	☑
4 Is a process in place which assures that assumptions which must be cleared by the customer will be included in transmittals to the customer?	☐	☑

Design Analysis Verification Checklist

(Page 3 of 4)

Results/conclusions	Yes	N/A
1. Are all results contained in or referenced in the Results/Conclusion section?	☑	
2. Are all limitations on the results/conclusions and their applicability documented in this section?	☑	
3. Are all contingencies on the results that must be cleared listed in the results/conclusion section and on a Contingencies and Assumptions form?	☐	☑
4. Is a process in place which assures that those contingencies which are the customer's responsibility to clear will be included in transmittals to the customer?	☐	☑
5. Has a comparison of the results with those of a previous cycle or similar analysis been made and significant differences explained?	☐	☑
Other Elements		
1. Have applicable Codes (e.g. ASME Code) and standards been appropriately referenced and applied?	☑	☐
2. Is the information from relevant literature searches/background data adequately documented and referenced?	☑	☐
3. Are hand calculations correct and appropriately documented?	☑	☐
4. Is all applicable computer output and input included?	☑	☐
5. Is all computer software used identified by name and revision identification?	☑	☐
6. Are all microfiche envelopes identified with the analysis number and number of sheets?	☐	☑
7. Are all files on CD-ROM identified by the path name?	☐	☑
8. Are all computer disks identified with the analysis number?	☐	☑
References		
1. Are all references used to perform the analysis listed?	☑	
2. Are the references as direct as possible and appropriate to the source?	☑	
3. Is the reference citation specific to the information utilized, including revision level or date of issue, and where appropriate, identification of the location of the information in the reference, such as page, table or paragraph number?	☑	
Form/Format		
1. Is the document legible, reproducible and in a form suitable for filing and retrieving as a Quality Record?	☑	
2. Are all pages identified with the document number, including revision number?	☑	
3. Do all pages have a unique page number?	☑	
4. Have all changes been authenticated by the initials and date of both the Cognizant Engineer, Independent Reviewer and, if required, by Management?	☐	N/A [initials]
For a revision to a completed analysis		☐
1. Where practical have changes and additions been identified by mechanisms such as vertical lines etc.?	☑	
2. Where practical have deletions been identified by mechanisms such as strike outs etc.?	☐	N/A [initials]
3. Have indications of changes in previous revisions been removed?	☑	
4. Has a Record of Revisions page been added or revised, and does it contain the extent of the revision?	☑	
5. Does the distribution of the revision include those on the distribution of the previous revision?	☑	

Design Analysis Verification Checklist

(Page 4 of 4)

	Yes	N/A
For a "complete revision":		☐
1. Have the title and document number been preserved without change?	☑	
2. Has the revision number been incremented by one?	☑	
For a "page change package":		☑
1. Are pages numbered in accordance with the original analysis?	☐	
2. Are instructions provided for the insertion and deletion of revised pages?	☐	
3. Has a new Title Page been prepared with the Package Contents reflecting the change package?	☐	
4. Has the original Title Page been retained to preserve the approval record?	☐	
5. Has a new Design Analysis In-Process Approvals form been prepared?	☐	
6. Has the original Design Analysis In-Process Approvals form been retained to preserve the approval record?	☐	

Comments (if any)

Independent Reviewer's Comments				
Comment Number	Reviewer's Comment	Response Required?	Author's Response	Response Accepted?
	NONE			

Checklist completed by:

Independent Reviewer: J.T. Wrenn (Printed Name) — [signature] (Signature) — 8-27-97 (Date)

Design Report Review Certificate

This Design Report has been reviewed by the undersigned in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Nuclear Power Plant Component, 1989 Edition, no Addenda, and to the best of the reviewer's knowledge and belief is based upon the Design, Service, and Testing Loadings stated in the design specification.

Stress Report Vendor: CE Nuclear Operations
Report No. S-PENG-DR-002 — Revision: 01 — Date: 8/29/97

Design Specification: 01370-PE-130 — Revision: 09 — Date: 12-16-93

Design Specification: S3-NOME-SP-0049 — Revision: 01 — Date: 6-24-97

Plant Owner: Southern California Edison
San Onofre II & III

Designee: Combustion Engineering, Inc.
ABB Combustion Engineering Nuclear Operations
Windsor, Connecticut

Certified by: Karl H. Haslinger (Name) — Professional Engineer (Title) — 8/29/97 (Date)

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