Consumers Power Company

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December 22, 1981

Mr J G Keppler, Regional Director
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MIDLAND PROJECT -
MIDLAND DOCKET NOS 50-329, 50-330
UNIT NO 1, REACTOR VESSEL BROKEN ANCHOR BOLT -
FILE 0.4.9.35 SERIAL 15361

REFERENCES 1. CONSUMERS POWER LETTERS TO J G KEPPLER, SAME SUBJECT

a. SERIAL 15035 DATED NOVEMBER 23, 1981
b. SERIAL 14625 DATED DECEMBER 1, 1981

ENCLOSURE Report entitled, "Reactor Pressure Vessel Support Modification for Midland Nuclear Power Plant, Midland, Michigan, Report No 3", Revision 1, dated December 1981.

Reference 1.a was an Interim 50.55(e) report transmitting the updated technical report describing the reactor support modification, the schedule for accomplishment of that modification and the description of the analytical techniques being used, and Reference 1.b was the Final 50.55(e) report.

The two enclosures to Reference 1.a, "Reactor Pressure Vessel Support Modification for Midland Nuclear Power Plant, Midland, Michigan, Report No 3" and "Letter Report - Teledyne Engineering Services (TES) Project 5355: Expanded Criteria for Acceptability for Service of Midland Unit 1 RV Anchor Stress", were discussed in detail with the NRC Staff in Bethesda on December 2 and 3, 1981. During that meeting, the staff requested certain clarifications and supportive material.

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The enclosed report to this letter which is Revision 1 to the previous Report No 3 has been revised to incorporate Staff comments and in addition includes some minor text correction of an editorial nature. The revisions to the enclosed report are indicated in the right-hand margin.

This letter and its enclosed report is intended to comprise a complete and current package of documentation describing the design concept, the analytical techniques to be used and the completion schedule for the modification of the reactor vessel support system. Upon completion of this task, the final designs and analytical results will be reported in the FSAR.

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JWC/BFH/mo

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REACTOR PRESSURE VESSEL
SUPPORT MODIFICATION
FOR
MIDLAND NUCLEAR POWER PLANT

REPORT NO. 3, REVISION 1

DECEMBER 1981

CONSUMERS POWER COMPANY
JACKSON, MICHIGAN

REACTOR PRESSURE VESSEL

SUPPORT MODIFICATION

FOR

MIDLAND NUCLEAR POWER PLANT

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APPENDICES

LIST OF FIGURES

1.0 INTRODUCTION

Unit 1 of Consumers Power Company's Midland Plant experienced failure of three reactor vessel anchor studs several weeks after being tensioned to a nominal value of 92 ksi in their tension area. Figure 1.1 shows the location of the three failures. The anchor studs were purchased as ASTM A354 Grade BD, 2.5 inches in diameter and 7 feet, 4 inches long. There are a total of 96 anchor studs per reactor vessel in two concentric rings on each side of the reactor vessel skirt.

Investigation of the failed reactor vessel anchor studs was performed by Teledyne Engineering Services (TES) (References 1 through 5). According to the investigation, the failure was due to stress corrosion crack propagation to a point where brittle fracture took place.

Modifying the reactor vessel supporting system to include the addition of the upper lateral supports (ULS) above the reactor vessel nozzles, along with stressing the anchor studs to a reduced preload level, will provide the necessary support for the reactor vessel (RV). Two reports (See References 6 and 7) were transmitted to the NRC in July and December 1980. The first report covered the initial design criteria of the new support system including the allowable stresses. The second report covered preliminary design loads and methods of analysis. Other interim reports and responses to NRC questions have been provided and are listed in the transmittal letter for this report.

It has been determined for engineering reasons, that the gap size between the RV and the ULS should be increased from the nominal 1/32 inches previously reported to the NRC, to a gap size large enough to avoid contact between the RV and ULS during a seismic event and continue to provide the necessary lateral support for the RV from the design basis loss-of-coolant accident (LOCA).

This Report Number 3 provides the required details for both the design and the analytical methods used, and thus satisfies the commitments made by the Company to the NRC. This report supersedes both previous reports (See References 6 and 7) by presenting the previous and new material in a single document. Where differences occur in either the design or the analytical methods between this report and the two previous reports, this report takes precedence and reflects the product of studies which have been performed to both enhance the modified RV support system and to assure the Company that the final design adequately meets all safety requirements.

REACTOR PRESSURE VESSEL

POSITION OF FAILED STUDS IN UNIT 1

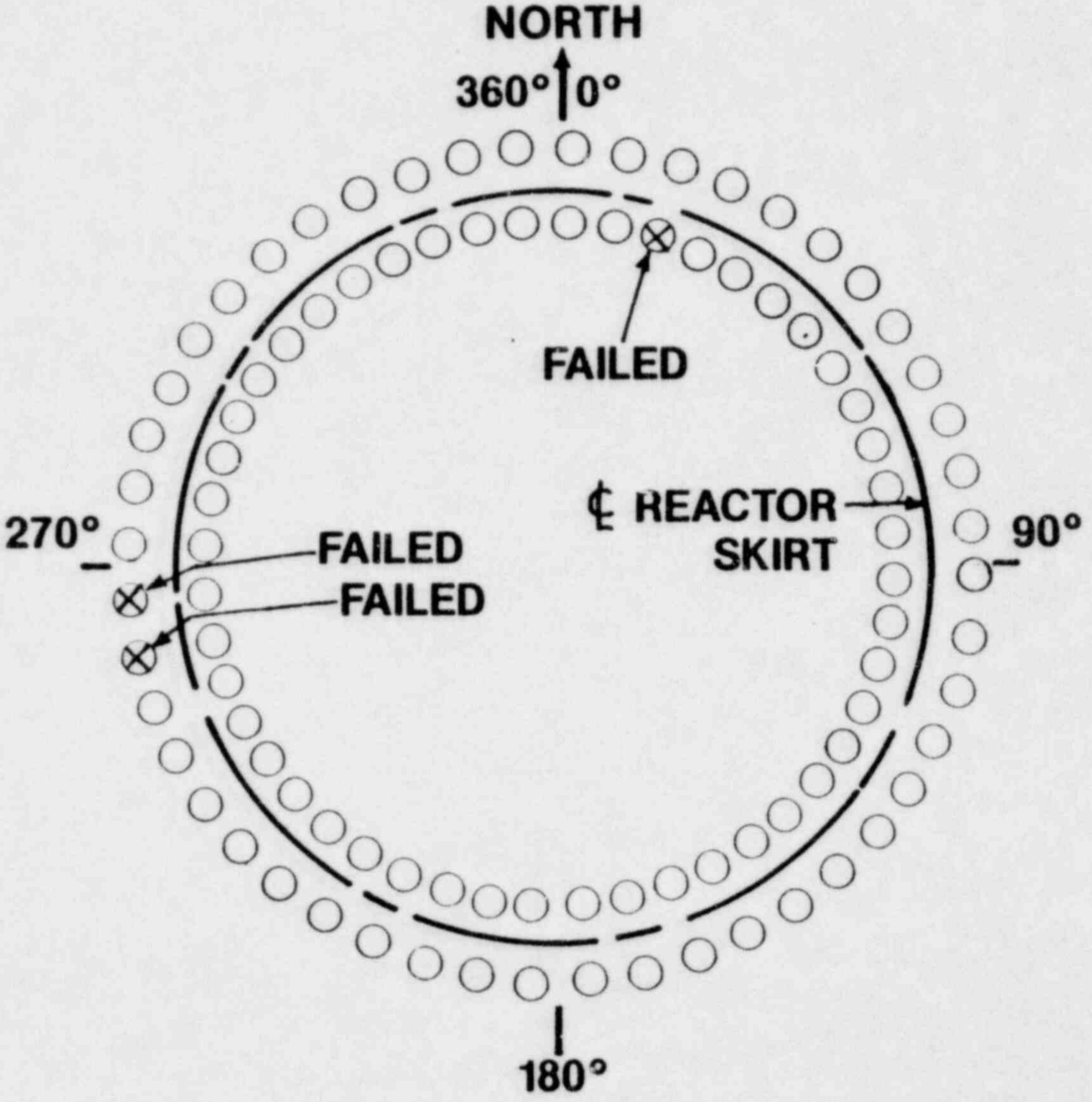


FIGURE (1.1)

2.0 DESCRIPTION OF THE SUPPORT SYSTEM MODIFICATIONS

The brackets that were originally provided to support the cavity annular shield plugs at the top of the RV have been reinforced to also serve as the ULS, to partially resist the RV overturning moment from the design basis loss of coolant accident (LOCA), thus reducing the stresses in the anchor studs. As can be noted from Figure 2.1, the brackets are located opposite the RV between the head flange and the nozzle belt. There are 12 brackets in each reactor cavity, and they are approximately equally spaced as shown in Figure 2.2. All but four of the brackets are radially oriented with respect to the RV and the remaining four are oriented in the East-West direction. The brackets are welded to embedments in the wall as shown in Figures 2.3 and 2.4, for the radially and the East-West oriented brackets, respectively. The brackets are made of a material originally purchased as ASTM A516 steel however some of the A516 material 1 1/2 and 1 1/4 inch thick plates were not normalized. The impact properties of the material indicate that it is acceptable for use as a material purchased as impact specified ASTM A516. The embeded plates are made of ASTM A36 steel. Details of the embedments are shown in Figure 2.5. The ULS will have stainless steel shim packs permanently mounted at their ends to provide the required gap between the brackets and the RV as shown in Figures 2.3 and 2.4. The contact surface area of the ULS shim pack is 5 x 12 inches and has been machined to a surface roughness of 250. Opposite the ULS shim pack on the RV surface, a corresponding contact surface has been machined flat for an area of 8 x 13.5 inches with a surface roughness of 250 or better. With the RV at a temperature of about 70°F, a gap of 15/32 (0.469) inches will be set between the ULS and the RV. During normal operation at 100% power, this gap will be 0.121 inches. This gap has been determined to insure that the RV will only contact the ULS in the event of the design basis LOCA at 100% power operation. Further details as to how the gap size was determined are presented in the subsequent sections.

The modification to the RV skirt flange support consists of reducing anchor studs prestressing load from the intended 75 ksi to only 5 ksi as discussed in Section 8. The 5 ksi prestress value reduces to 1.5 ksi during the normal operating conditions as a result of increased anchor stud temperatures and other losses. The anchor studs alone will resist overturning moments and uplift forces from all loads on the reactor except those from the design basis LOCA. The ULS will partially function to resist the design basis LOCA overturning moments on the studs by limiting the RV displacement. Shear forces and torsional moments at the RV skirt flange support are transferred to the concrete pedestal by the shear pins between the RV skirt flange and the sole plate and the shear lugs welded to the bottom surface of the sole plate. Details of the RV skirt flange support are shown in Figures 2.6, 2.7 and 2.8.

REACTOR PRESSURE VESSEL
ELEVATION

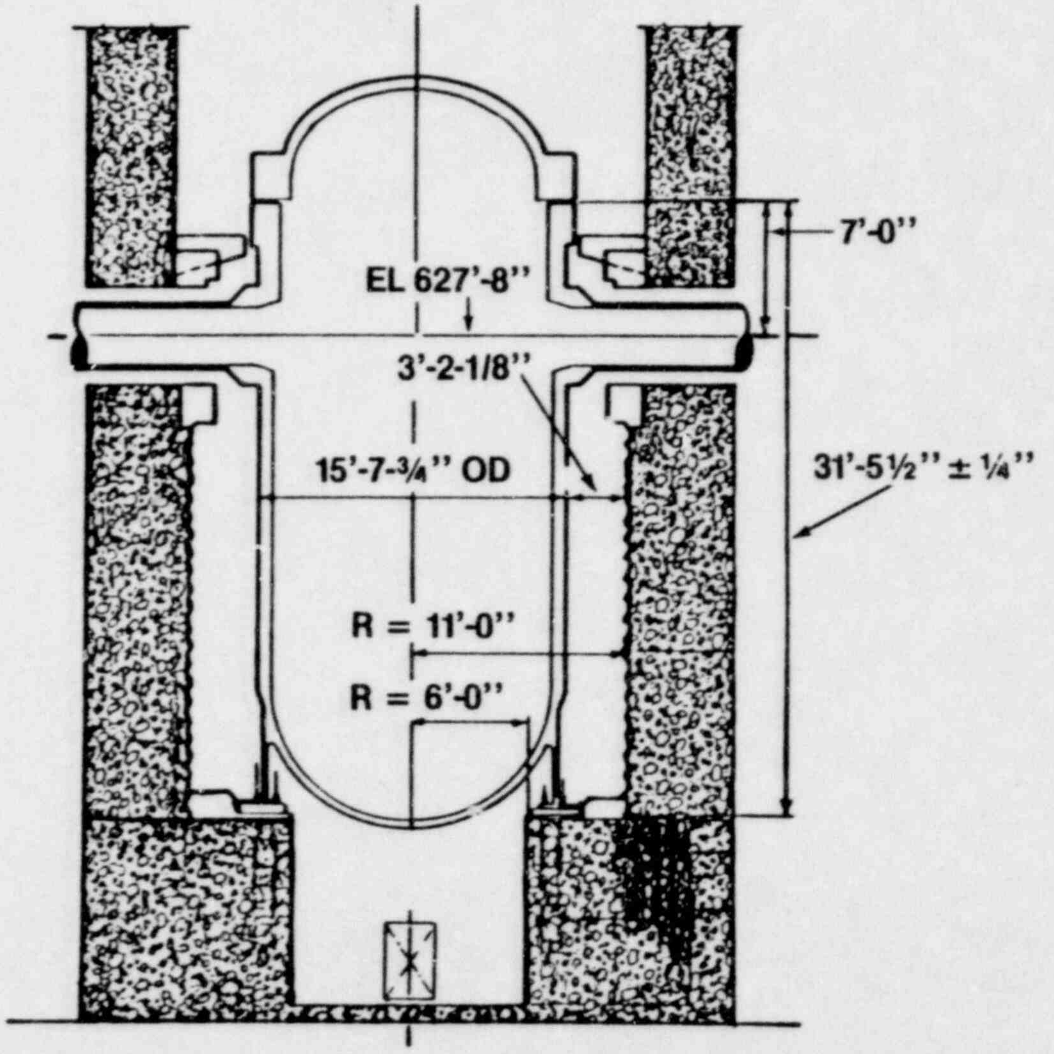


FIGURE (2.1)

REACTOR PRESSURE VESSEL
UPPER LATERAL SUPPORT PLAN

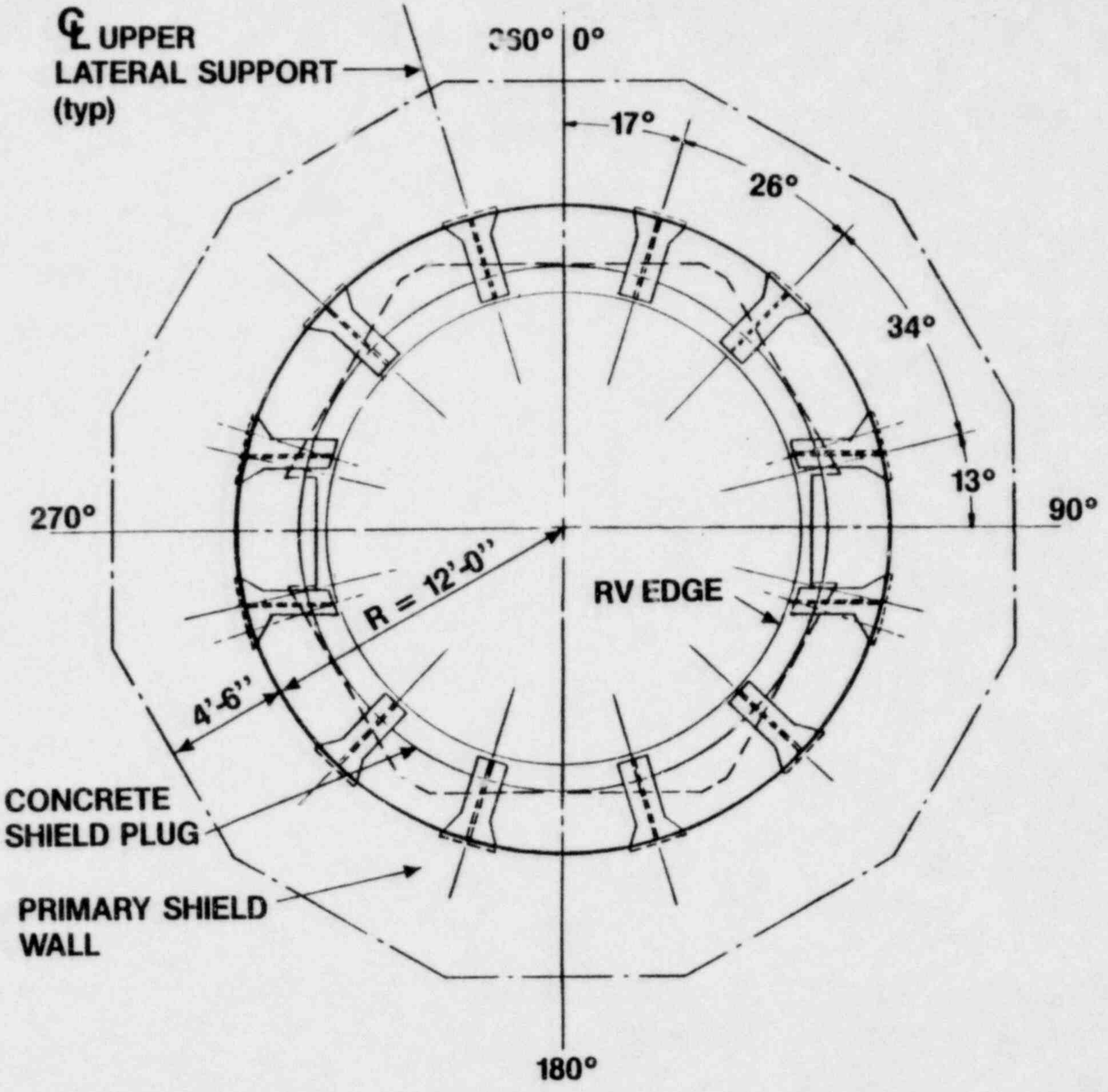
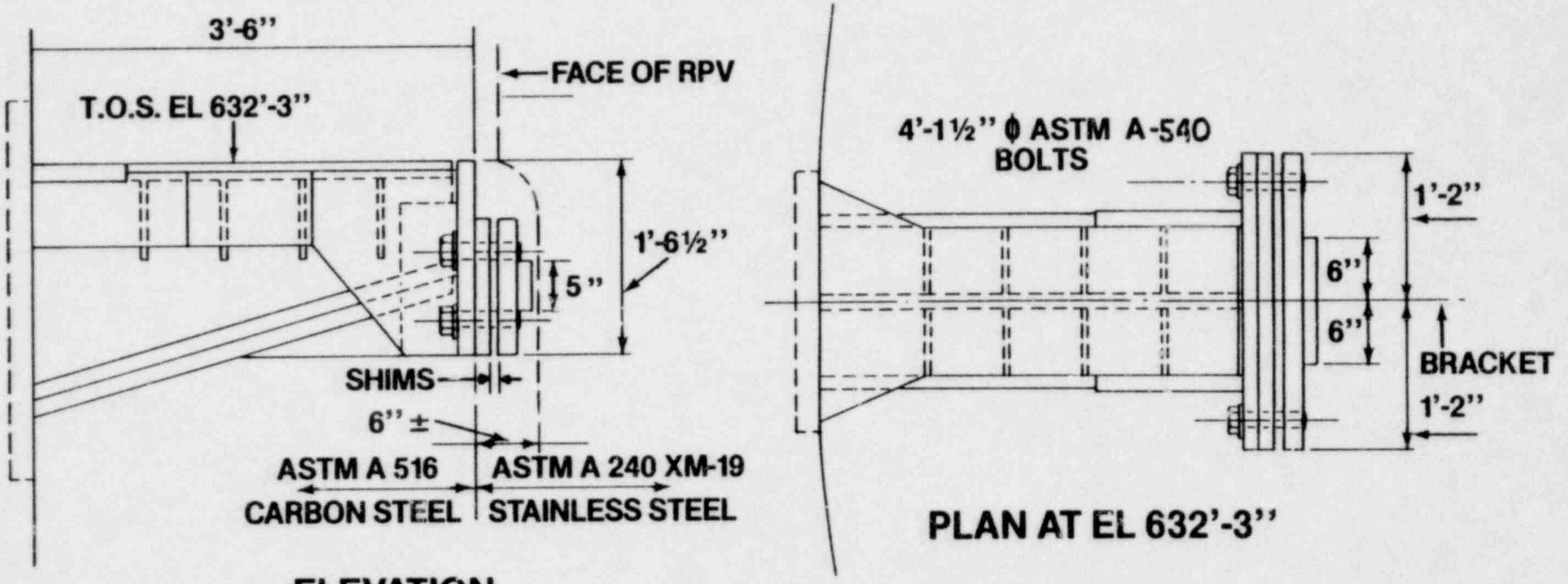


FIGURE (2.2)

REACTOR PRESSURE VESSEL
UPPER LATERAL SUPPORT BRACKET DETAIL (Typical 8)

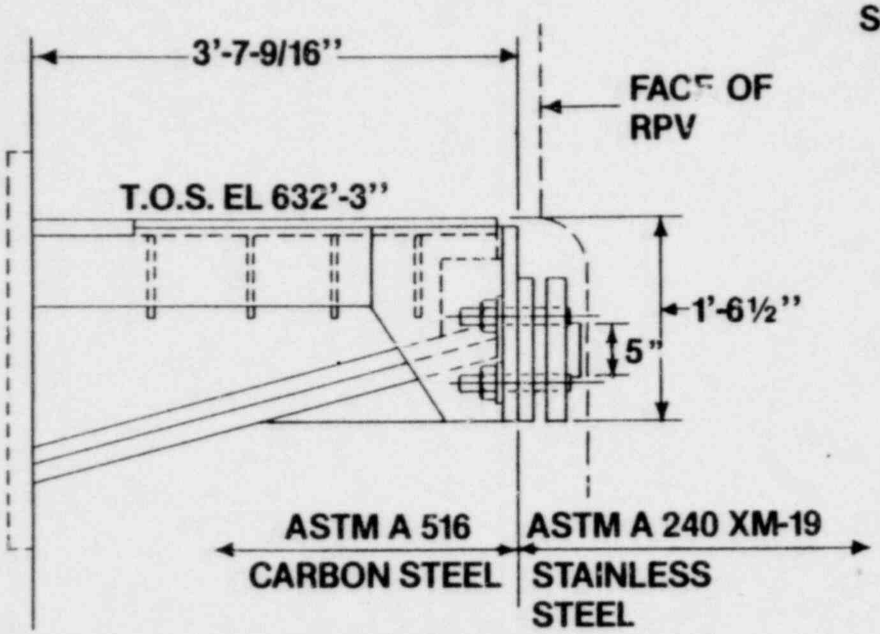


ELEVATION

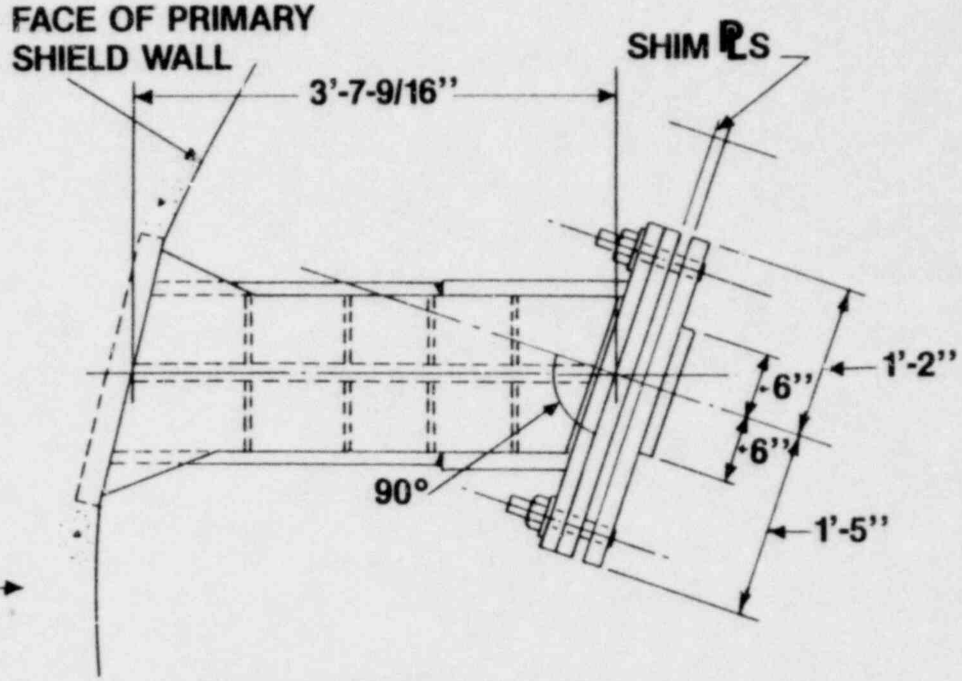
PLAN AT EL 632'-3"

FIGURE (2.3)

REACTOR PRESSURE VESSEL
UPPER LATERAL SUPPORT BRACKET DETAIL(Typical 4)



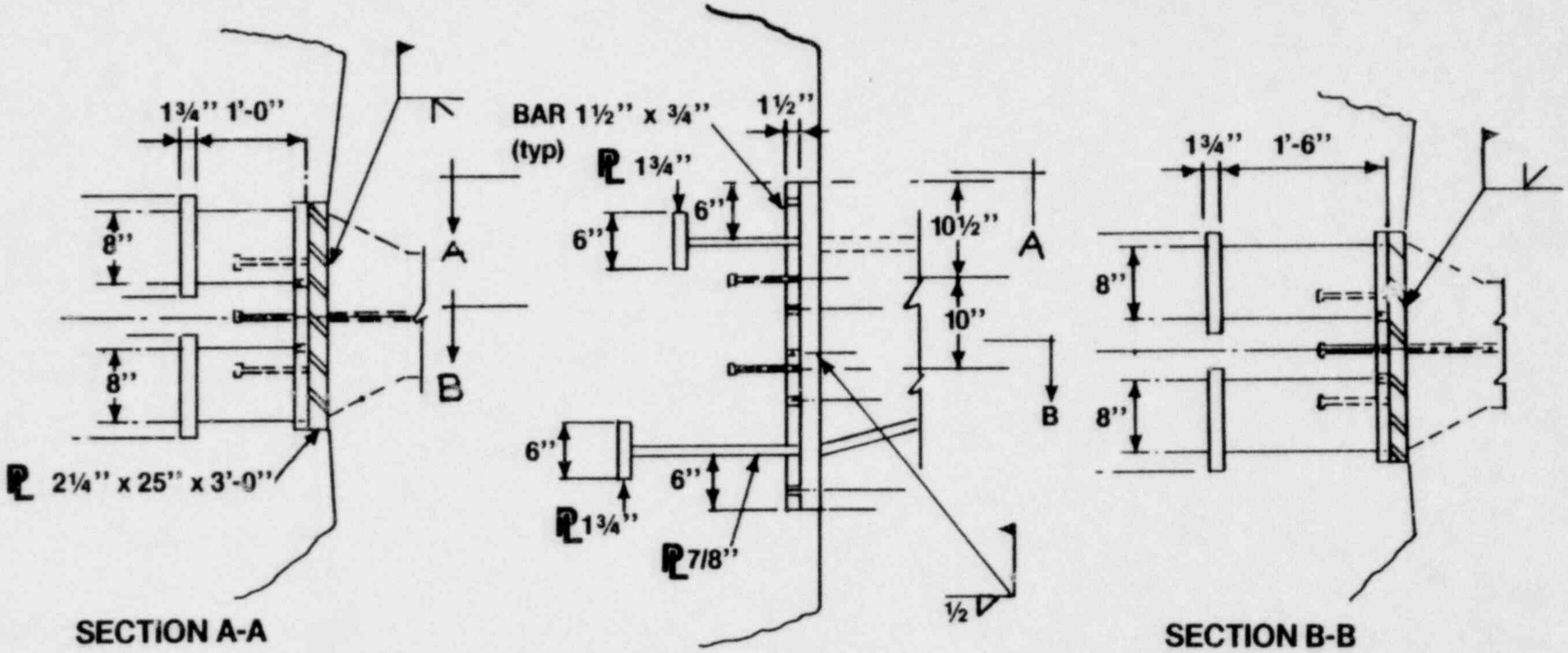
ELEVATION



PLAN AT EL 632'-3"

FIGURE (2.4)

REACTOR PRESSURE VESSEL
UPPER LATERAL SUPPORT BRACKET EMBEDMENT DETAIL



SECTION A-A

ELEVATION

SECTION B-B

FIGURE (2.5)

REACTOR PRESSURE VESSEL
PLAN

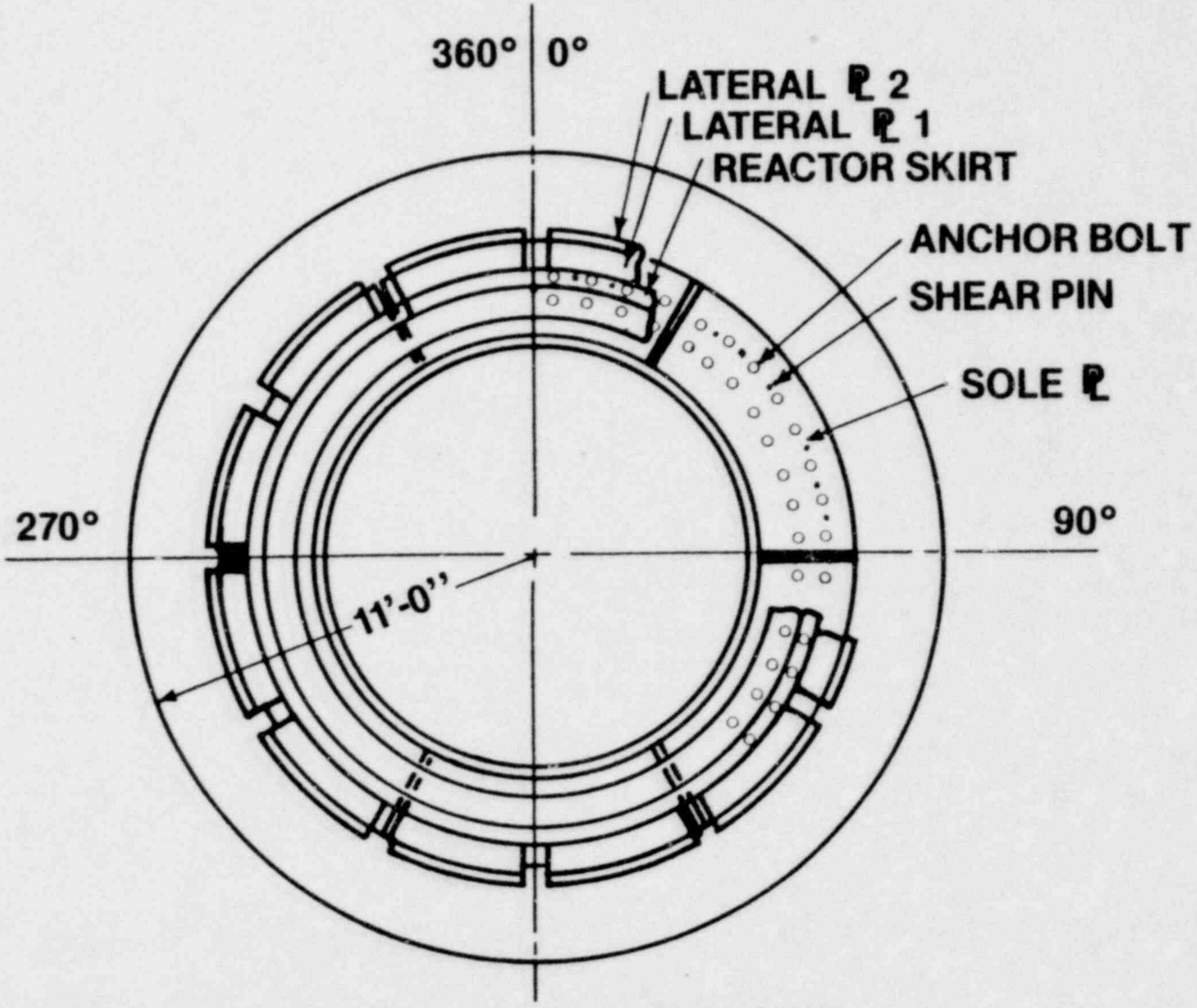


FIGURE (2.6)

REACTOR PRESSURE VESSEL
ANCHOR STUD DETAIL

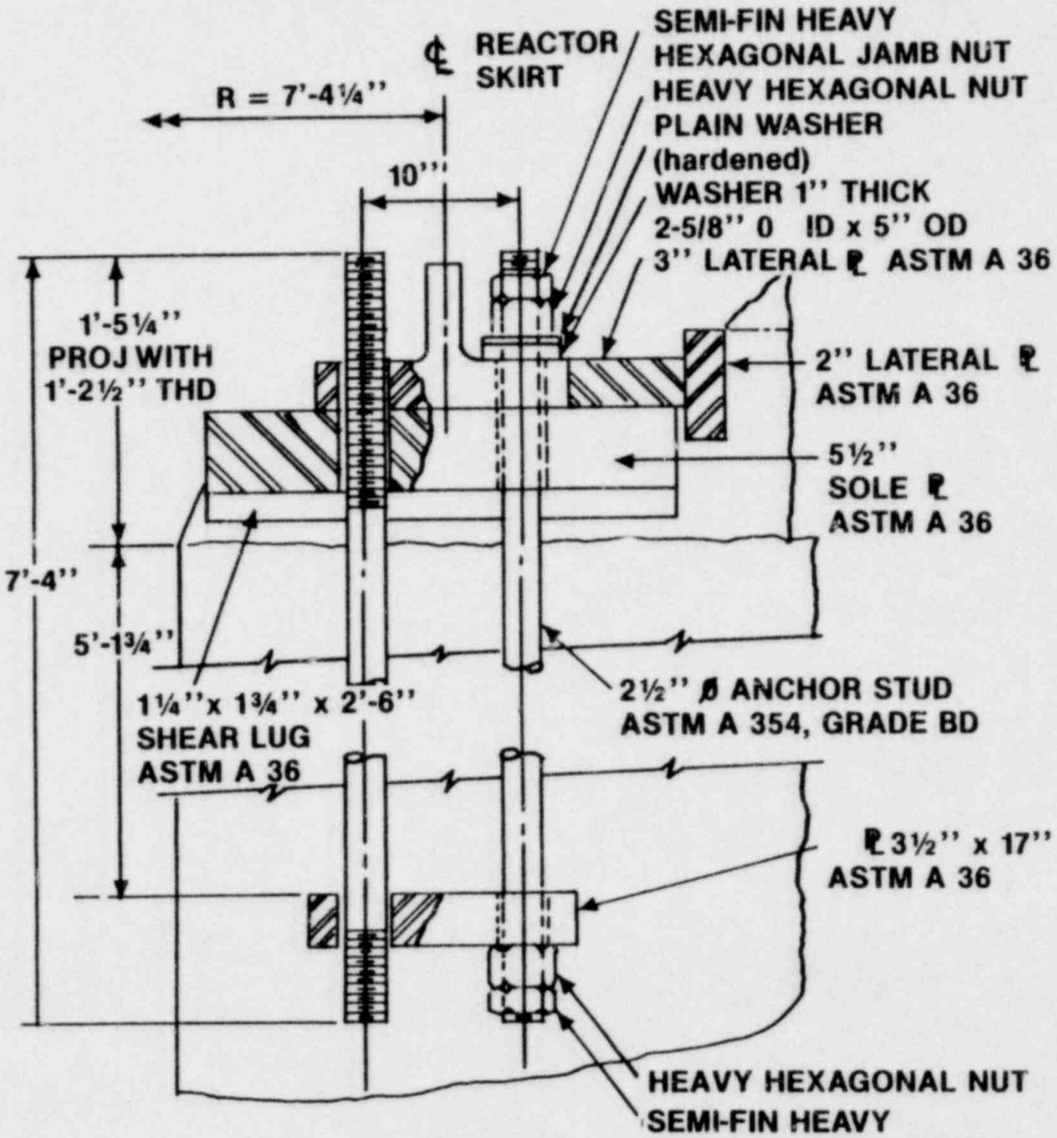


FIGURE (2.7)

REACTOR PRESSURE VESSEL
SHEAR-PIN DETAIL

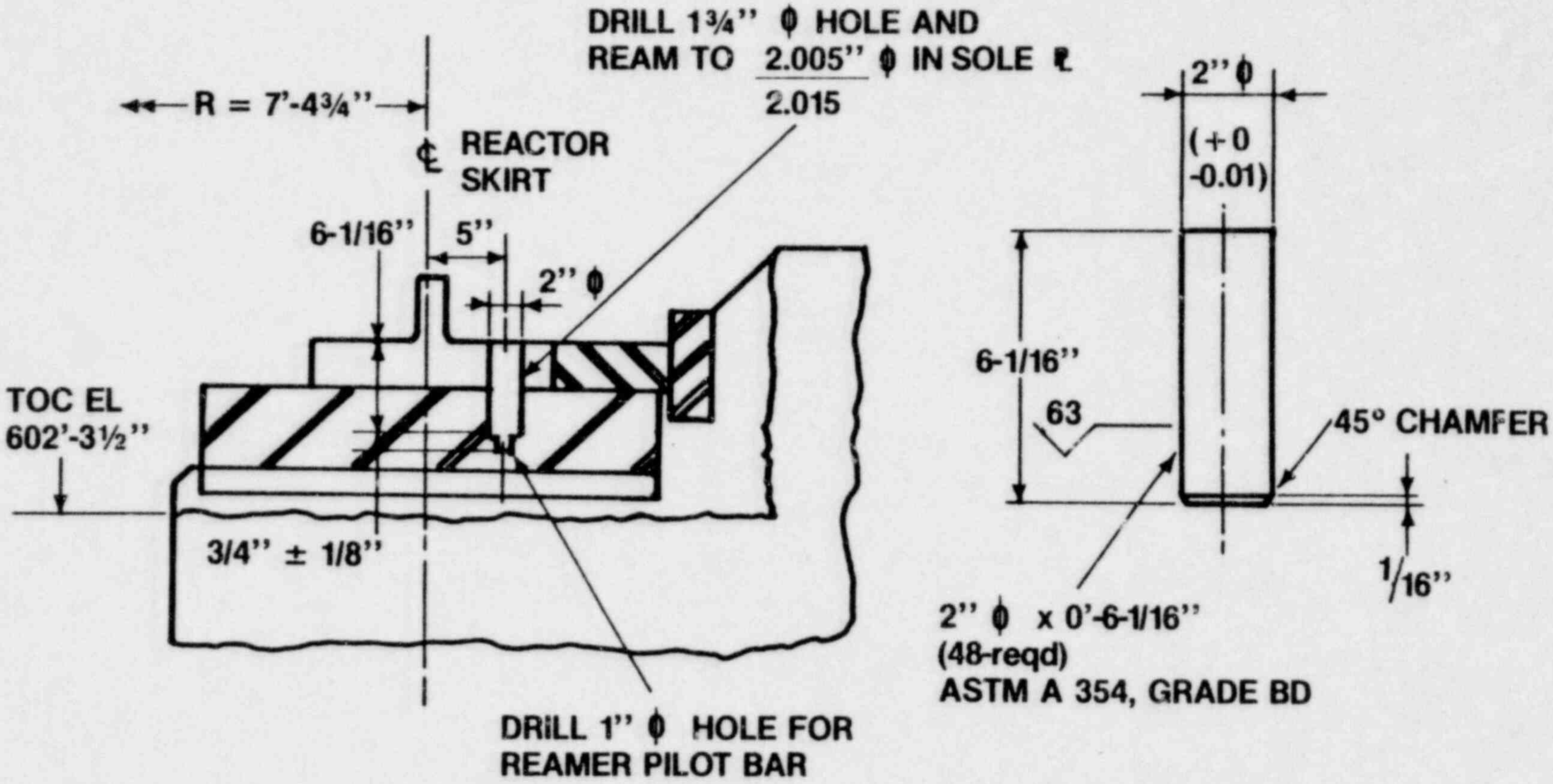


FIGURE (2.8)

3.0 FUNCTION AND DESIGN CRITERIA

3.1 SAFETY DESIGN FUNCTION

The safety design function of the RV support system is to provide support for the RV as specified in the following.

3.2 FUNCTION CRITERIA

3.2.1 The RV support system shall remain functional during a safe shutdown earthquake (SSE), or from a LOCA. The loads from SSE and LOCA are combined.

3.2.2 The postulated LOCA shall be assumed under 100% power operating condition.

3.2.3 The effects of jet impingement shall not render the RV support system inoperable during the postulated LOCA design basis event.

3.2.4 During the normal, upset, faulted, and test conditions with the exception of LOCA, as stated in 3.2.2 above, the following conditions must be met;

a. Reactor coolant system (RCS) temperature variations resulting in RV radial and vertical expansions will not result in forces being placed on the RV by the ULS.

b. RCS temperature variations resulting in RV radial and vertical expansions will not result in forces on the RV support system causing the system to be impaired or damaged to the degree it cannot perform its safety design function.

3.2.5 Based on operating condition information, temperature variations resulting in RV and ULS radial expansion will not create a gap between the RV and the ULS small enough to cause contact during an SSE seismic event.

3.2.6 The ULS shall be designed such that temperature variations induced in the RV because of the proximity of the ULS and the insulation cutouts for the ULS do not result in RV stresses in excess of the RV acceptance criteria stated in the FSAR.

3.2.7 The RV support system shall be designed so that the temperature of the concrete in the local vicinity of the supports shall not exceed 200°F during all operational modes.

3.2.8 The RV support system shall be designed so that a continuous 40 year total radiation dosage will not result in unacceptable degradation of the support material.

3.2.9 The RV support system shall be designed assuming forced cavity air flow. Forced air flow shall be ensured or appropriate operating restrictions shall be imposed in the event of a loss of forced flow.

3.2.10 The temperature differences that may exist at different locations on the RV during all normal operating conditions shall be considered in establishing the proper gap size at individual ULS brackets in order to satisfy the functional criteria set forth above.

3.3 DESIGN CRITERIA

3.3.1 Introduction

The criteria under this section shall apply in the design of the RV support system for Midland Plant Units 1 and 2.

3.3.2 Codes and Regulations

3.3.2.1 Rv Support system

The design of the RV support system shall conform with, but not be limited to the applicable codes and specifications listed below, except where specifically stated otherwise.

1.) American Concrete Institute Building Code Requirements for Reinforced Concrete (ACI 318-71).

2.) American Institute of Steel Construction Specification for the design, fabrication and erection of structural steel for buildings - 1969 Edition with Supplements 1, 2 and 3.

3.3.2.2 NSSS

The design of the NSSS shall conform with, but not be limited to the applicable codes and specifications listed in FSAR Table 5-2.1. In summary, the RV and RV skirt shall conform with, but not limited to, the following code:

1.) American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, 1968.

3.3.2.3 The following ASTM material specifications:

A516 Grade 70 plate material*

E7018 Filler metal for shielded metal arc welding

A240 Type XM-19 stainless steel

A354 Grade BD bolts and A325 high strength bolts**

*Note: See the discussion in Section 2.0 on the A516 material.

**Note: The anchor stud material for Unit 1 are subject to the conditions of the Teledyne reports (References 1 thru 5) since they do not satisfy the requirements for the A354 Grade BD material.

3.3.3 Midland Plant FSAR

3.3.4 System Classification

The supporting system is classified as a Seismic Category I structure.

3.3.5 Construction Material

3.3.5.1 The concrete compressive strength (f'_c) is 5,000 psi and the reinforcing steel is ASTM A615 Grade 60.

3.3.5.2 The structural steel materials are as follows:

Plates	A516, Grade 70*
Filler metal for Welding	E7018
Stainless steel for the shim block	A240, Type XM-19
Bolts in the ULS	A325
Anchor studs and shear pins	A354, Grade BD*

*Note: See the foot notes provided for section 3.3.2.3.

3.3.6 Design Loads

The RV support system will be designed to take loads from:

a. Permanent weights (DL)

b. Stud prestressing (P_t)

c. Operating thermal loads (T_o)

d. Operating basis earthquake loads (OBE)

e. Safe shutdown earthquake loads (SSE)

f. Loads from design basis (LOCA)

3.3.7 Load Combinations and Allowable Stresses

3.3.7.1 Upper Lateral Supports

a. DL + T_o***	AISC specification allowable
b. DL + T_o + OBE**	AISC specification allowable

c. $DL + T_o + SSE^{**}$ AISC specification allowable

d. $DL + T_o + SSE^{**} + LOCA$ AISC specification allowable x 1.5*

*Notes: Under LOCA loads, yield strain may be exceeded. The maximum strain, however, shall not exceed 10 times the strain at the initiation of yielding. See Appendix D for the justification of the ductility ratio for use.

** Since the RV will not be in contact with the ULS, the seismic loads will consist of permanent weight (DL) inertia loads.

*** Thermal effects on the ULS only serve to reduce both the allowable stress and the Young's modulus for the steel.

3.3.7.2 Anchor Studs

a. P_t $\leqq 6$ ksi(1)

b. $DL + T_o + P_t$ $\leqq 6$ ksi and $\geqq 1.5$ ksi(2)

c. $DL + To + (SSE \text{ or } P_t)$ $\leqq 0.5$ Proof test load(3)

d. $DL + T_o + \sqrt{SSE^2 + LOCA^2}$ $\leqq 0.7$ Proof test load(3)

Notes: (1) See Reference 2.

(2) Required to mitigate normal operating vibrations

(3) The faulted condition allowable stress level for the anchor studs has been increased from 0.5 P_t to 0.7 P_t as described in Reference 9 and Appendix F.

3.3.7.3 NSSS

The acceptance criteria for the NSSS and in particular the RV skirt is covered in the 1968 ASME Code Section III "Nuclear Vessel". The code does require that, "where compressive stresses occur . . . the critical buckling stress shall be taken into account". When the stress reports are revised for the final loadings from Section 11.0, this requirement will be satisfied.

3.3.8 Parameters to be Considered in the Design

The following parameters shall be considered in the design.

3.3.8.1 Irradiation effects:

a. Gamma radiation heating.

b. Embrittlement of the structural steel, filler material for welding, and anchor studs

3.3.8.2 Temperature variation and heat transfer:

a. The temperature gradient in the brackets and the temperature at the bracket-concrete interface.

b. Effect of temperature variation on the studs pretension load.

3.3.9 Tolerances

3.3.9.1 Construction tolerance in setting the gap of +1/64 inch is allowed.

3.3.9.2 Construction tolerance in prestressing the studs of ±0.5 ksi is allowed.

4.0 GENERATION OF PRELIMINARY SUPPORT LOADS

The seismic analyses of the NSSS needed to generate the support loads have been finalized at this time and they are described in Section 11.0.

Preliminary analyses of the RV with the modified support system for the design basis LOCA has been performed to allow for the design of the upper lateral supports to proceed. The following subsections describe the process by which the preliminary LOCA loads were developed.

4.1 PRELIMINARY LOCA LOADS

To expedite the design of the modified reactor support system, a simplified nonlinear computer model of the RV shell, RV internals, and the concrete internal walls structure has been used to predict the design basis LOCA loadings as a function of variable gap size between the ULS and the RV.

4.1.1 Design Basis Breaks

Design basis LOCA breaks are assumed to occur at 100 percent power operating conditions. Two design basis breaks are considered:

1) 0.39A* guillotine at the RV outlet nozzle

2) 0.24A* guillotine at the RV inlet nozzle

*Note: A is equivalent to the internal cross-sectional area of the pipe being considered.

4.1.2 Analytical Model

The analytical model used to determine the preliminary RV support system design LOCA loads is a simplified version of the model described in Section 11.0.

The model consists of two springs and a single degree of freedom. One spring represents the combined spring rate of the RV anchor support, the RV support skirt and the hot leg and cold leg piping. The second spring represents the combined effects of the ULS, localized wall spring rates, and radial flexibility of the RV shell. The single degree of freedom (SDOF) has a mass representative of the RV shell and RV internals. The mass/spring rates which represent the RV are developed such that the SDOF oscillator frequency closely matches that of the first mode of the RV shell and RV internals. Damping for the SDOF is 7 percent of the critical damping. Forcing functions, representing LOCA presures versus time, acting on the SDOF consist of combined time phased phenomena of both asymmetric cavity pressure across the RV shell, and to pressure differentials inside the RV. These forces are described in more detail in Section 11.0.

4.1.3 Design Basis LOCA Loads and Displacements

The model described in 4.1.2 is subjected to loadings through gaps ranging between 0.0 inches and 0.3 inches. The resulting force in the ULS and the moment on the RV base anchor are depicted in Figures 4.1 and 4.2 as a function of gap size.

Also determined was the deflection in the most critical ULS bracket. The critical ULS bracket is defined as the bracket subjected to the largest axial compressive deformations which therefore have the potential to exceed the ductility limits imposed by the criteria set forth in Section 3.3.6. Figure 4.3 illustrates the critical ULS bracket, and ensuing deflections for both hot and cold leg LOCA's. A vertical force at the RV base of ±4,697 kips is considered in the design.

4.2 DEAD LOADS AND THERMAL LOADS

The modification of the RV support system does not affect the dead loads and thermal loads on the RV base support. There are no loadings on the ULS due to deadweight or thermal expansion of the NSSS. The previously calculated dead loads and thermal loads on the RV skirt base are given below.

Deadweight = - 2595 kips
Thermal (8% power) = + 420 kips
Thermal (15% power) = + 356 kips
Thermal (100% power) = + 330 kips

*Note: A negative sign indicates a downward applied load, and positive sign indicates an uplift load.

4.3 PRELIMINARY VERSUS FINAL LOADS

The preliminary loadings given in the report have been determined to allow design of the modified RV support system to proceed in an orderly manner. Models and forcing functions are similar and/or identical to those used to produce final loadings.

Deadweight and thermal loads are being revised to reflect refinements in the internal walls structure model. These results are not expected to vary significantly from those previously calculated. Seismic results as presented in Section 11.0 are final. LOCA displacements and loads are considered adequate for design use. The parameters reflected in the simplified LOCA model are those which are most significant in determining RV support loads. Although more detailed LOCA analyses are currently being performed (See Section 11.0) which will verify the preliminary loadings, the major reason for the more detailed analyses is to determine the effects of LOCA on the reactor internals.

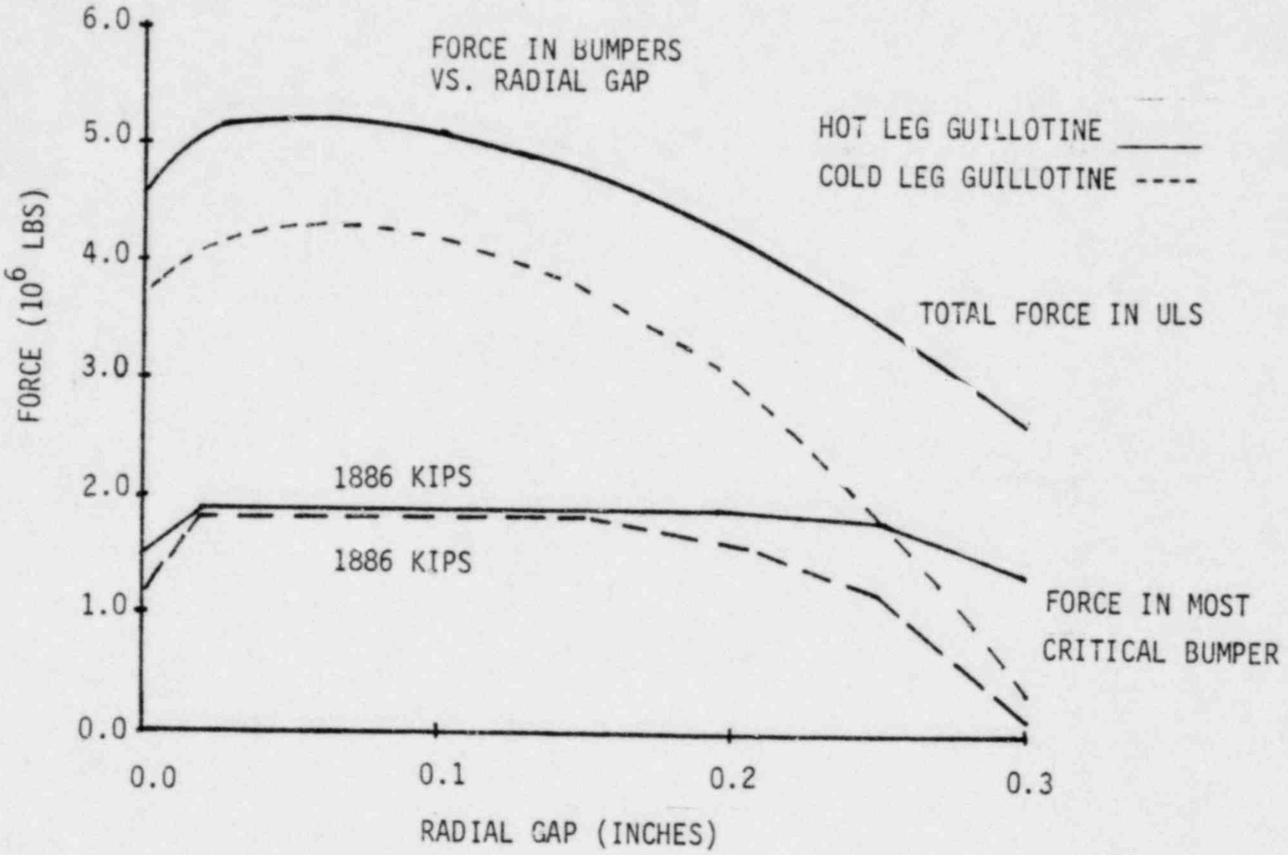


FIGURE 4.1

Force In Bumpers VS Radial Gap

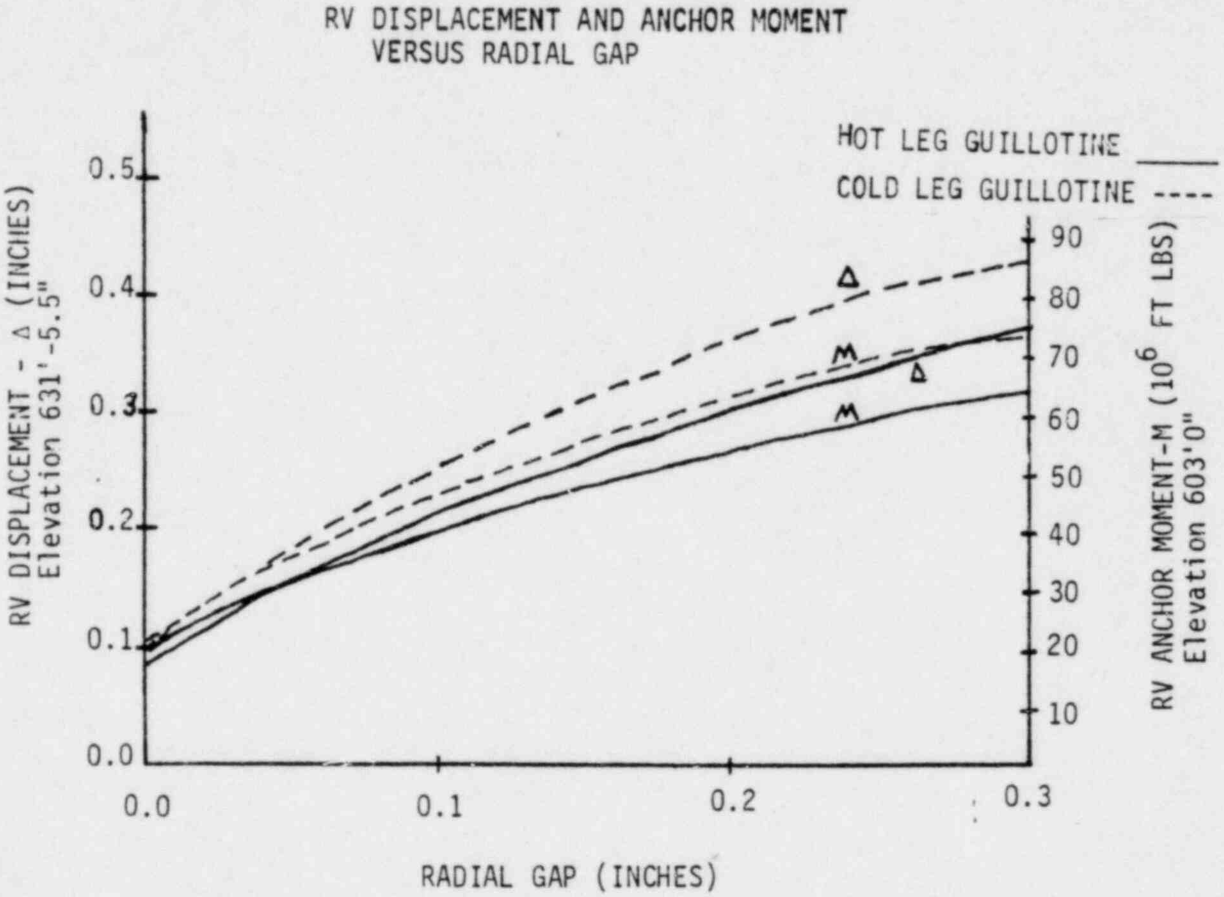
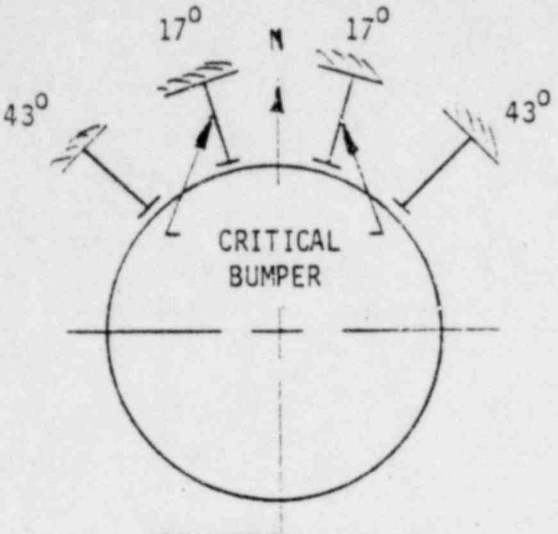
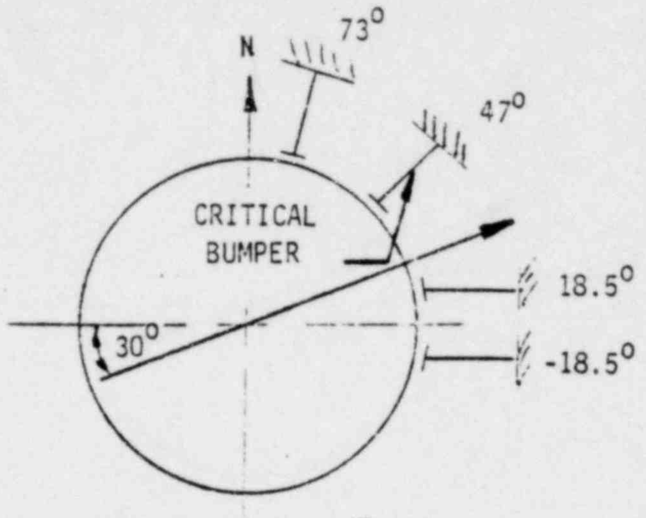


FIGURE 4.2

RV Displacement And Base Anchor Moment Versus Radial Gap



SUPPORT CONDITIONS FOR
HLG at RV



SUPPORT CONDITIONS FOR
CLG at RV

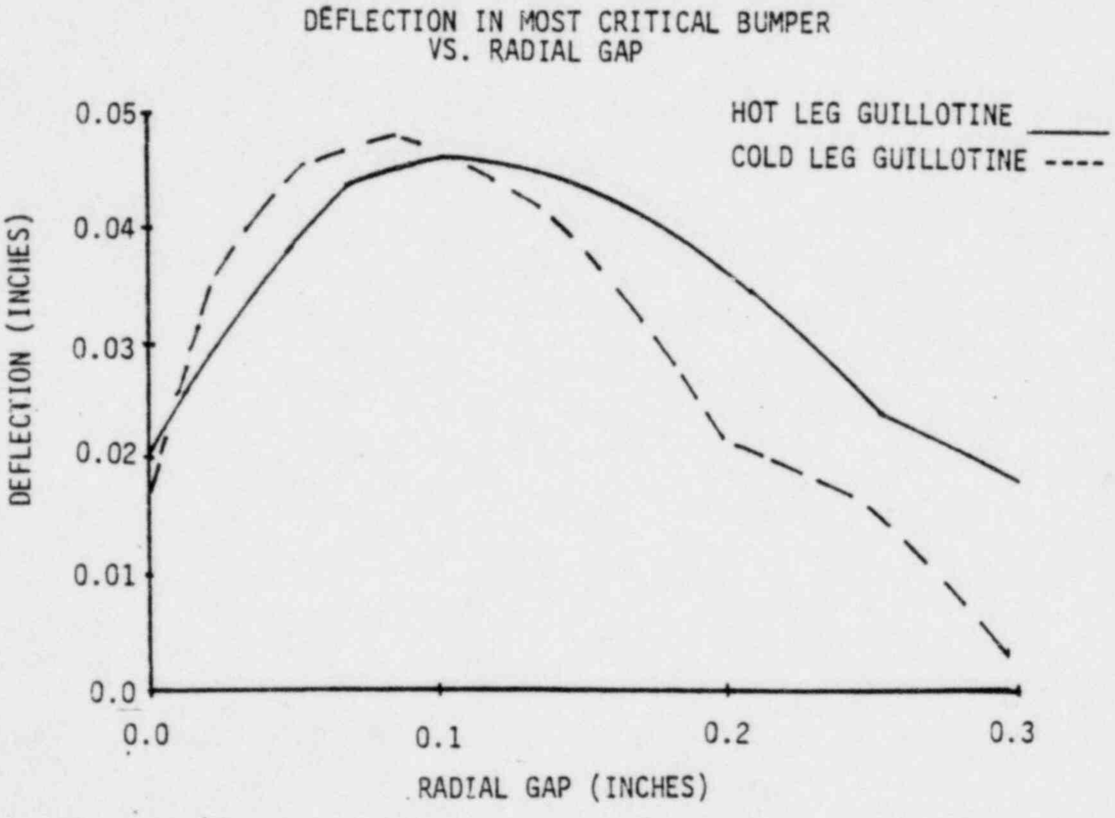


FIGURE 4.3

DEFLECTION IN MOST CRITICAL BUMPER VERSUS RADIAL GAP

Deflection in the most critical bumper is given for the two LOCA cases. Displacements are measured in the axial direction. Any deflection due to bending was ignored. For a CLG (Gap$>$0 inches), the critical bumper was considered active after contact with the 73° bumper was obtained.

5.0 ANALYSIS AND DESIGN OF THE SUPPORT SYSTEM

The reinforcement provided for the upper lateral support brackets were designed based on the preliminary loads described in Section 4.0. The stresses in the anchor studs were analyzed to show that they are within the allowable limits specified in Section 3.3.6.

5.1 UPPER LATERAL SUPPORT

5.1.1 Upper Lateral Support Brackets - Maximum Design Vs Allowable Stresses and Displacements

The stresses at the sections shown in Figure 5.1 were governed by the following load combination,

$$DL + SSE^{\dagger} + LOCA$$

The resulting stresses at Sections 1, 4 and 6 are given in the table below:

Section	Maximum Design Stress Or Interaction Value*	Allowable Stresses Or Interaction Value*
1**	9.32 ksi	33.48 ksi
4	0.963	1.000
6	1.000	1.000

*Notes: The interaction of axial compression and bending is according to the AISC specification, Section 1.6.1.

** Critical loading on Section 1 is from cavity pressure only.

† Inertia loads due to ULS self weight, and weights supported by the ULS.

It should be noted that the axial load in the bracket used is the maximum allowed which will result in yielding of the bracket based upon the minimum specified yield stress.

From Figures 11.11 through 11.13, it can be noted that the maximum allowed displacement of the bracket is 0.2548 inches (based on a ductility ratio of 10). The preliminary calculations indicate a maximum displacement of 0.045 inches which is considerably less than the maximum allowed displacement. Refer to Section 11.1.2.4 for the discussion on the proper use of Figures 11.11 through 11.13.

5.1.2 Embedments - Maximum Design Vs Allowable Stresses

For the most critical load combination (DL + SSE + LOCA), the stresses in the components of the embedments are given in the table below. In the same table the corresponding allowable stresses are shown.

	Maximum Design* Stress (ksi)	Allowable Stress (ksi)
a. Bearing stress behind embedment plate	5.94	5.95
b. Bending stress in embedment plate	32.4	32.4
c. Tensile stress in anchor bar	30.4	32.4
d. Bearing stress between anchor block & concrete	3.6	5.95
e. Bending stress in anchor block	23.2	32.4

f. Bearing stress between shear lugs and concrete	2.2	2.975
g. Bending stress in shear lugs	26.4	32.4
h. Shear stress in shear lugs	4.53	18.0

*Note: It should be noted that the axial load in the bracket used is the maximum which will result in yielding based on the maximum yield stress of the material.

5.2 ANCHOR STUDS

5.2.1 Analytical Model to Determine Stress Distribution

The reactor pressure vessel skirt and skirt flange have been modeled with flat rectangular shell elements (5 degrees of freedom per node) using the finite element computer program BSAP* (CE-800). The finite element model is shown in Figure 5.2. The anchor studs and the concrete pedestal are modeled using linear springs which can be axially loaded only. The stiffness of these springs in tension is equal to the stiffness of the studs, and their stiffness in compression is equal to the stiffness of the pedestal. The loads are applied at the center of the circular top edge of the skirt which is connected to the nodes on the top edge of the skirt by a spoked arrangement of rigid links, thus representing the boundary edge effect of the RV.

The solution for the stud stresses is obtained through iteration by first assuming the position of the neutral axis and then checking the assumption and adjusting it as required until the location of the neutral axis is determined. Due to the nonlinear nature of this analysis, this procedure was followed to calculate the stresses in the bolts due to loads from the design basis LOCA and East-West, North-South and vertical SSE earthquake, respectively.

*Note: The description of BSAP along with its validation is provided in Appendix 3C of the FSAR.

5.2.2 Maximum Design Vs Allowable Stresses

5.2.2.1 For Unit 1

The maximum design stresses due to dead loads, thermal loads, SSE loads, and design basis LOCA loads are given in the table below along with their corresponding allowable stresses. These stresses were calculated by combining the stresses from SSE and LOCA loads by the square-root-of-the-sum-of-the-squares method (SRSS). The governing LOCA load case was a break in the cold leg of the NSSS closest to the two broken studs in the outer radius of Unit 1. The Level D, or Faulted, allowable stresses for the reactor vessel anchor studs will be 0.7 times the minimum measured test load resulting from the 1980 detensioning effort (ie, 0.7 x 75 ksi = 52.5 ksi) but if higher allowables are desired, these allowables for individual studs will be based on 0.7 times a "new" test load where sufficient controls have been applied to assure the accuracy of the load measured. The criteria is discussed further in Appendix F and Reference 9.

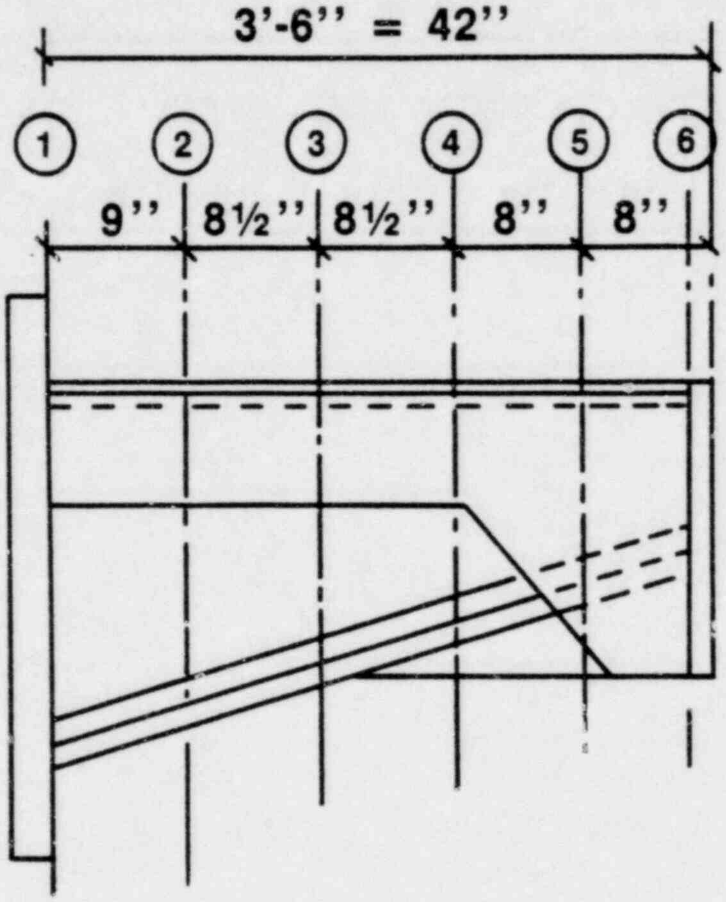
Stud Number	Maximum Design Stress (ksi)	Allowable Stress* (ksi)
Outside Diameter		
39	33.2	52.5
38	37.5	52.5
37	44.8	52.5
36	-------------BROKEN-------------	
35	-------------BROKEN-------------	
34	49.2	52.5
33	44.6	52.5
32	43.0	52.5
31	41.9	52.5
Inside Diameter		
39	28.8	52.5
38	30.0	52.5
37	29.7	52.5
36	29.1	52.5
35	30.3	52.5
34	33.5	52.5
33	36.4	52.5
32	37.5	52.5
31	37.4	52.5

For stud number location, see Figure 5.3.

*Note: The allowable stresses are obtained from Reference 9 and Appendices C and F.

5.2.2.2 For Unit 2

The allowable stresses will be determined in conjunction with Reference 9 and Appendices A and F at the time of detensioning.

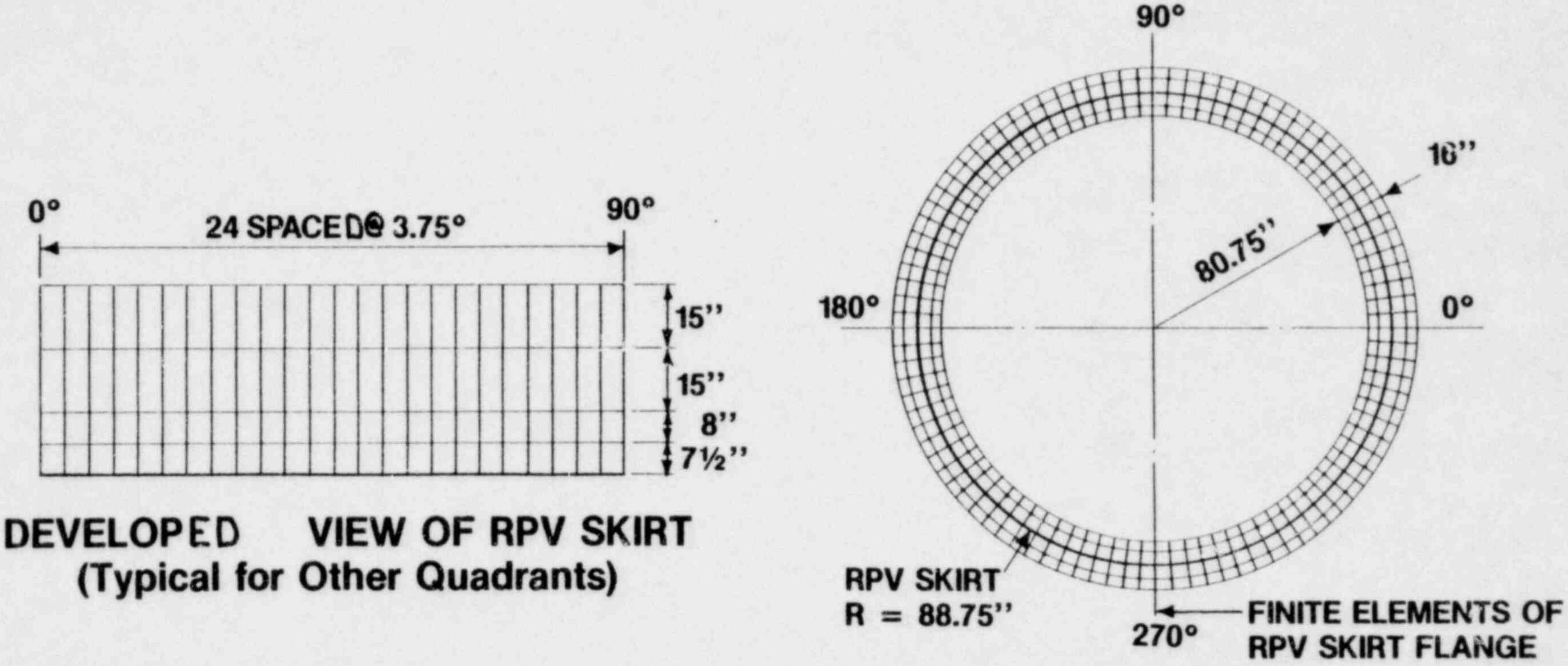


BRACKET ANALYSIS SECTIONS

FIGURE 5.1

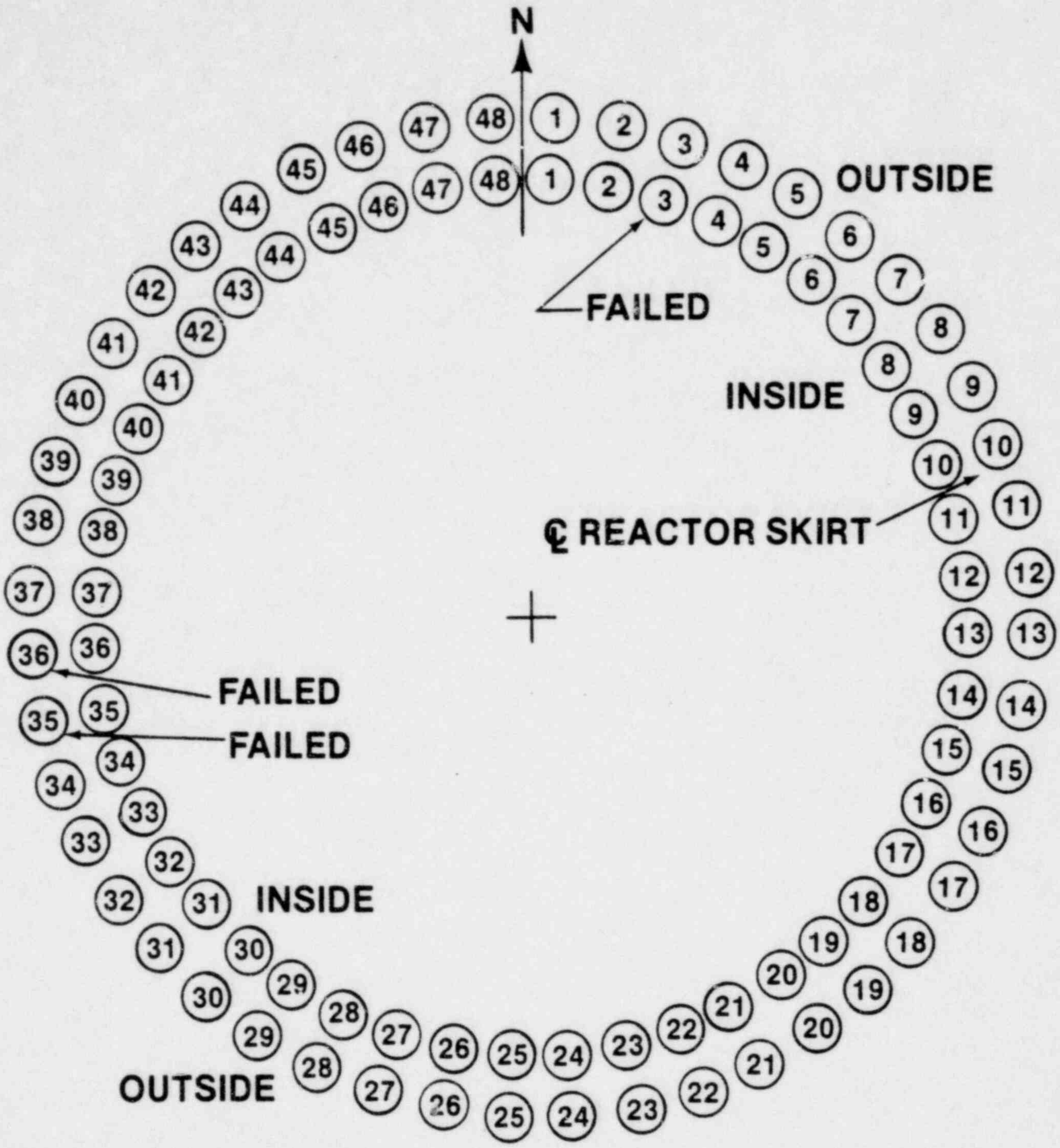
REACTOR PRESSURE VESSEL

FINITE ELEMENT MODEL OF SKIRT



DEVELOPED VIEW OF RPV SKIRT
(Typical for Other Quadrants)

FIGURE (5.2)



POSITION AND NUMBERING OF STUDS IN UNITS 1 AND 2

FIGURE (5.3)

6.0 HEAT TRANSFER AND THERMAL ANALYSIS

6.1 INTRODUCTION

An investigation into the relative motion of the RV and the ULS as a result of variation in the NSSS system temperatures and pressures during normal plant operating and upset conditions has been conducted. The investigation included heat transfer analysis to determine the temperature distribution in the ULS, of the concrete behind the ULS and the RV shell. In order to benchmark the investigation, the same techniques were used to predict the conditions of hot-functional testing (HFT). See Section 10.0 for further discussion of the HFT testing program. The calculated values will be correlated against measured values during HFT. The results obtained from the study, confirmed or modified during HFT, will be used to finalize the gap required between the upper lateral supports and the RV.

6.2 TEMPERATURE AND PRESSURE CONDITIONS OF REACTOR PRESSURE VESSEL NEAR UPPER LATERAL SUPPORTS

The part of the RV shell opposite the ULS is exposed to the inlet, or cold leg, fluid temperature. The predominant temperature values are 532°F (0% power hot standby), 550°F (8% power), 575°F (15% power), and 554°F (100% power). This range covers all anticipated normal operating conditions other than heatup and cooldown which will have temperatures less than 532°F and two upset transients: 1) reactor trip (loss of feedwater), and 2) accidental rod withdrawal. These transients are similar with respect to inlet fluid temperature in that there is a change in temperature from 554°F to 590°F in approximately 30 seconds and then a return to 550°F in 1 to 3 minutes. (Note: The 590°F temperature is held for a very short time; i.e., approximately 10 seconds.)

The reactor pressure is nominally at 2,250 psi. Again there are short time fluctuations where pressure varies over a range of 2,100 psi to 2,600 psi. Of course, during the heatup and cooldown operations the pressure falls below 2,100 psi.

The outlet nozzles, or hot legs, below the restraints carry the coolant fluid which is at a higher temperature. An analysis has indicated that the outside surface of the RV shell is 567°F at a distance of 41.5 inches from the nozzle centerline when the fluid temperatures for the hot and cold leg are 607°F and 554°F, respectively. The outside surface of the RV shell at 34.5 inches from the hot leg nozzle centerline is 575°F. The bottom of the machined contact surface opposite the ULS on the RV is 48.5 inches from the outlet centerline. Therefore, there will be very little if any effect of the hot leg fluid at the ULS location.

As stated previously, the basic temperature conditions of the reactor inlet are below 575°F except for certain trip conditions. To eliminate considerations of these short-time temperature excursions, calculations were made with the aid of formulae developed in Reference 10. If the RV shell external temperature is a uniform 550°F, and the inner surface temperature is increased to 590°F, the time required to raise outside surface temperature to 575°F is 1.53 hours. Since the entire transient is less than 5 minutes, it can be concluded that reactor inlet temperatures higher than 575°F need not be considered.

6.3 UPPER LATERAL SUPPORTS VESSEL INTERFACE

The parameters involved in modeling the RV interface with the ULS are very difficult to precisely predict. Considerations are width of gap (Δ_G), conditions of surfaces, and possible air flow conditions. Because of the nature of the insulation and proximity of the restraint to the vessel, convective effects should be small. Conduction through air and radiant effects are functions of the gap and surface conditions. The conditions affecting radiant effects will change over the plant life due to oxidation of the surfaces. To bound the potential effect of these parameters, three cases were analyzed. Two gapped cases 0.1 inch and 0.03125 inch, allowing conduction through the air as the only heat transfer mode, were analyzed. A third case assumed continuous metal between the vessel and restraints. The vessel fluid and cavity air conditions were not varied. In all cases, convective effects were included on the ULS.

The most severe temperature distribution in the vessel wall was identified and a finite element structural analysis was performed to determine stresses and thermal deflections associated with this condition. An isothermal case was also run as a base comparison case. The fluid temperature was 570°F and the air temperature was 132°F. The hand-calculated radial thermal deflection is 0.3588 inch*. The computer-calculated deflection is 0.3589 inch*. The calculated radial deflection opposite the restraints due to the most severe thermal gradient is 0.350 inches. Therefore, with respect to the RV, the restraint to the RV interface has the potential for a small error from thermal growth considerations.

*Note: Based on $\Delta T = 570-70 = 500°F$, $\alpha = 7.45x10^{-6}$, $R = 96.3125$ inches.

6.4 PRESSURE DEFLECTION OF VESSEL

The deflection of a cylinder at the outer surface subjected to internal pressure is:

$$\Delta_{RV}^{P} = \frac{2Pa^2b}{E(b^2-a^2)}$$

where:

Δ_{j}^{i} = The radial displacement due to i (= P for Pressure, or TH for Thermal) in component j (= RV or ULS)

a = Outer surface radius

b = Inner surface radius

α = The coefficient of linear thermal expansion

then:

b = 96.3125 in.,

a = 84 in.,

E = $27.8x10^6$ psi at 550°F.

which reduces to:

$$\Delta_{RV}^{P} = P(2.202x10^{-5}) \text{ in.}$$

thus:

Δ_{RV}^{P} = 0.05 in., for P = 2250 psid

Δ_{RV}^{P} = 0.055 in., for P = 2500 psid

Δ_{RV}^{P} = 0.0605 in., for P = 2750 psid

The closure of the RV hemispherical dome head does affect the RV deflection, however, the effect is small (maximum = 0.009 inches.)

6.5 POTENTIAL GAP CHANGES DURING OPERATION

For the case when the RV starts in an untensioned (head bolts) and cold condition (70°F), the maximum thermal growth of the RV will be achieved if there is a prolonged hold at 15% power (575°F).

$$\Delta_{RV}^{TH} = \Delta T \; \alpha \; R$$

$$\Delta_{RV}^{TH} = (7.38\text{x}10^{-6})(96.3125)(505) = 0.359 \text{ in.}$$

where:

$\Delta T = 575-70=505°F$

$\alpha = 7.38\text{x}10^{-6}$ at 575°F

$R = 96.3125$ in.

Assuming a design pressure condition, $\Delta_{RV}^{P} = 0.055$ inch, the closure effect Δ_{RV}^{c}, adds an additional 0.009 inch.

$$\Delta_{RV} = \Delta_{RV}^{TH} + \Delta_{RV}^{P} + \Delta_{RV}^{C}$$

$$\Delta_{RV} = 0.359 + 0.055 + 0.009 = 0.423 \text{ inch at 15\% power (maximum)}$$

For the case during either 0% power, or hot functional testing, the vessel is at 532°F and 2,200 to 2,250 psi. The 2,200 psi will be used because minimum deflections are of interest.

$$\Delta_{RV}^{TH} = (7.308\text{x}10^{-6})(96.3125)(462) = 0.325 \text{ in.}$$

$$\Delta_{RV}^{P} = 0.048 \text{ in.}$$

The deflection due to closure is approximately 0.008 inches. Hence, the RV displacement is,

$$\Delta_{RV} = 0.325 + 0.048 + 0.008 = 0.381 \text{ inch at 0\% power}$$

For the case when the NSSS is at 100% power the vessel is at 554°F and 2,200 psid is assumed, hence

$$\Delta_{RV}^{TH} = (7.346\text{x}10^{-6})(96.3125)(484) = 0.342 \text{ in.}$$

$$\Delta_{RV}^{P} = 0.048 \text{ in.}$$

$$\Delta_{RV}^{C} = 0.008 \text{ in.}$$

$$\Delta_{RV} = 0.342 + 0.048 + 0.008 = 0.398 \text{ in.} \quad \text{100\% power.}$$

The thermal growth of the ULS needs to be assessed for different gap conditions. The thermal distribution through the center of the ULS is as follows. (Node points are listed from the outer surface of the RV towards the concrete primary shield wall surface.)

Node	Distance From Free Edge of Bracket (inches)	Temperature (°F)		
		0.1 gap	0.03125 gap	Metal continuity
613	(0.00)	184.8	260.9	476.4
638	(0.00)	177.7	244.7	451.9
686	(6.00)	157.7	196.4	327.9
734		157.0	194.8	322.4
858		153.0	184.6	290.9
859		150.8	179.0	273.4
860		150.1	177.2	267.7
861	(21.50)	149.8	176.5	265.5
959		149.8	176.5	265.5

Radial distance from RV and material is as follows:

Node	Distance Between Nodes	Material
613 -> 638	0.08 in.	stainless (A240 X M-19)
638 -> 686	5.92 in.	stainless (A240 X M-19)
686 -> 861	15.5 in.	carbon steel (A516 GR70)

Node 861 represents radial location where bottom of the ULS enters concrete

Location	Metal Temperature (°F)		
	0.1 gap	0.03125 gap	0.0 gap
Average nodes 613 638	181.3	252.8	464.2
Average nodes 638 686	167.7	220.6	389.9
Average remainder of nodes excluding 959	152.1	182.4	284

Thermal growth of the ULS for a 0.1 inch gap is as follows:

$$\Delta_{ULS}^{TH} = (8.3\times10^{-6})(111.3)(0.08) + (8.3\times10^{-6})(97.7)(5.92) + (6.03\times10^{-6})(82.1)(15.5)$$

$$\Delta_{ULS}^{TH} = (7.4\times10^{-5}) + (4.80\times10^{-3}) + (7.67\times10^{-3}) = 0.0124 \text{ in.}$$

Similarly, the thermal growth of the ULS for a 0.03125 inch gap is 0.0182 inches and for a zero inch gap is 0.0385 inches.

6.6 CREEP, THERMAL RACHETING, AND ELASTIC SHAKE DOWN

The long-term positional stability of parts is a consideration in the design of a gapped structure. This section is concerned specifically with the stability of the reactor vessel. The vessel was subjected to an ASME code heat treat at the conclusion of all welding. The vessel is in a vertical position and will not be again subjected to temperatures near the heat treatment range (i.e., T_{max} operation is 575°F while the temperature at heat treat was 1,100 to 1,150°F). Therefore, additional stress relaxation would not be expected to occur, unless creep effect occurs.

ASME Section III stress criteria requires that the highest temperature versus stress allowable be within the bounds of creep criteria stated in ASME Section I. The highest reported temperature in the 1968 ASME Section III for SA-508 CL 2 is 700°F. The reported S_m value is 26,700 psi which is constant for the full temperature range. This is one-third the minimum ultimate strength of 80 ksi. The material SA-508 CL 2 is not in ASME Section I, but SA-302 GR B is listed and has strength and chemistry characteristics very similar to SA-508 CL 2. ASME Section I stress allowables do not diverge from $1/4\sigma_u$ until a temperature of 800°F. Therefore, it can be concluded that the vessel is not operating in the creep range.

Thermal racheting is another consideration in the design of a gapped structure. The relevant criteria is given in ASME Section III. Under this thermal condition, cyclic radial gradient thermal stresses occur in an essentially constant pressure stress field.

$$\chi = \frac{\text{maximum general membrane stress}}{\text{yield strength*}}$$

$$\text{Maximum general membrane stress} = 2500\frac{(84)}{12} = 17.5 \text{ ksi}$$

$$\chi = 17.5 \text{ ksi}/26 = 0.673$$

$$y' = \frac{\text{maximum allowable range of thermal stress}}{\text{yield strength*}}$$

$$y'_{min} \approx 4(1 - \chi) = 1.308 \qquad \sigma_{TH\ range} = 1.308(26) = 34 \text{ ksi}$$

*Note: For additional precautions against thermal rachet, the following endurance limit should be used: 2 x S_a at 10^6 cycles for SA-508 CL 2; 2(13) = 26 ksi.

Under conditions where the pressure in the system is relatively constant, and the fluid temperature is between 532 and 590°F. The maximum up-ramp is either 532 - 575°F = 43°F or 554 - 590°F = 36°F. Thus, maximum up-ramp is 43°F. As discussed earlier, the outside diameter of vessel will not reach 590°F, therefore, the maximum down-ramp is 575 - 532°F = 43°F. Assuming a step change in fluid temperature and an infinite film coefficient, the radial gradient thermal stress cannot exceed:

$$\sigma = \frac{E\ \alpha\ \Delta T}{0.7} = \frac{27 \times 10^3 (7.5 \times 10^{-6})(43)}{0.7} = 12.4 \text{ ksi}$$

or

$$\sigma_{TH\ range} = 2(12.4) = 24.8 \text{ ksi} < 34 \text{ ksi}$$

Therefore, thermal racheting is not possible.

A third criteria, stated in ASME Section III, which allows primary plus secondary stress range of $3S_m$ should be investigated. This limit ensures elastic shakedown in a few cycles, but it does not prohibit a small incremental growth. The primary and secondary stress range in this area is 48.9 ksi, which is composed of a plus stress intensity of 18.1 ksi and a minus stress intensity of -30.8 ksi. Because both of these stresses are below the yield strength of the material (42 ksi), there would be a negligible, if any, strain cycling.

The maximum additional stress induced in the vessel during the extreme condition of contact with the bumper was 9.36 ksi. The stress allowance for $3S_m$, and the material yield strength are not exceeded under this condition. Therefore long-term distortion of the vessel is considered unlikely.

7.0 REACTOR PRESSURE VESSEL SURFACE PREPARATION

Twelve local areas on the RV opposite to the ULS have been machined flat to improve the contact surface between the ULS and the RV. The machined area is 13.5 (±.125) inches wide and the top edge of the flat is located at el 631'6-1/2" (±1/16") with its bottom edge 8 (±1/16) inches below the top. The flat areas are within 1/500 of vertical and 1/500 of perpendicular to the RV radius and have a surface finish of 250. The aforementioned dimensions and location guarantee a flat smooth surface, and a full area of contact between the 5 x 12-inch stainless steel pad at the end of the ULS and the RV in the event of the design basis LOCA.

The amount of material to be machined off the RV was checked before it was removed and found to be within the acceptable wall thickness limits. B&W Construction Company designed and built the tools required for the machining, and the machining of both Midland Units 1 and 2 is now complete.

8.0 DETENSIONING AND TENSIONING OF THE ANCHOR STUDS

8.1 DETENSIONING PROCEDURE

In detensioning Unit 1, a scatter in the lift-off load values was observed (See Appendix C). A more rigorous and accurate detensioning procedure will be used for Unit 2 in measuring the lift-off load values. This will aid in explaining the scatter of lift-off values observed in Unit 1. The criteria and procedure to be used to detension the Unit 2 studs is described in detail in Appendix A.

8.2 CREEP RECOVERY

The reactor pressure vessel anchor studs in Unit 2 were tensioned to 92 ksi during the summer of 1979. When they are detensioned more than two years later, part of the compressive strain of the concrete will be recovered instantaneously. This will be followed by a time-dependent recovery known as creep-recovery or delayed elasticity. This creep recovery reaches a limiting value leaving an irrecoverable strain or permanent set.

This creep recovery, if not accounted for, will increase the tension in the studs if they retensioned shortly after being detensioned. For this reason, retensioning will not commence immediately after detensioning. Furthermore, depending on the time duration between detensioning and retensioning, the magnitude of the tension load will be adjusted to account for the increase due to creep recovery of the concrete. In addition, after tensioning and after sufficient time has elapsed, such that almost full creep recovery has taken place, the tension in the studs will be checked using an ultrasonic extensometer device as described in Appendix A and adjusted if required.

8.3 RETENSIONING PROCEDURE

The retensioning procedure for use on the Units 1 and 2 RV anchor studs is described in Appendix A.

9.0 REACTOR PRESSURE VESSEL INSULATION MODIFICATION

Cutouts will be made in the reflective insulation to accommodate the penetration of the upper lateral restraints. These penetrations will be fitted with seals to reduce heat losses.

10.0 GAP AND TEMPERATURE MEASUREMENTS AND GAP SETTING

In order to benchmark the assumptions made in the heat transfer and thermal analyses discussed in Section 6 of this report, displacement and temperature measurements will be taken while the NSSS undergoes hot functional testing.

10.1 MEASUREMENTS DURING HOT FUNCTIONAL TESTING

The following additional measurements will be taken during hot functional testing:

a. The change in gap between the reactor vessel upper lateral supports and the RV.

b. The change in the RV surface temperature, the temperature of the upper lateral support and the concrete wall.

10.2 MEASUREMENT PROCEDURE

The criteria and procedure is described in detail in Appendix B.

10.3 CORRELATION BETWEEN MEASURED AND CALCULATED VALUES

Comparison between the measured and calculated temperatures and displacements will be made. If differences occur, the calculation will be modified to account for this difference. In this case, the calculated temperatures and displacements for operating conditions will be as accurate as possible.

10.4 SETTING THE GAP

In order to prevent contact between the RV and the ULS during normal operational conditions and in the case of a seismic event, the gap was calculated as follows: The SSE displacements of the RV and ULS in both horizontal directions are individually summed by vector addition. The maximum seismic gap computed is 0.076 inch (0.043 inch wall displacement and 0.033 inch vessel displacement). The seismic gap was calculated using the conservative approach of adding (using the absolute sum) the displacements of the wall and the vessel thus assuming that they will move out of phase. The gap required to compensate for the thermal growth of the vessel and the wall as well as the effect of the pressure in the vessel and the closure effect is as shown for 0%, 15% and 100% power, in the table below.

Thermal Displacements* (inches)

Case	Power Level		
	0%	15%	100%
Thermal growth of vessel from 70°F	.325	.359	.342
Pressure in vessel	.048	.055	.048
Thermal growth of bracket from 70°F	.012	.012	.012
Thermal growth of concrete wall from 70°F	-.046	-.046	-.046
Effect of Closure	.008	.009	.008
Total	.347 in	.389 in	.364 in

*Note: A positive sign on the displacement indicates a gap closing motion, and a negative sign indicates a gap opening motion.

The following assumptions were made in the above table.

a. The overall wall temperature during normal operational conditions is 130°F.

b. The growth of the ULS is based on a 0.1 inch gap between the ULS and the RV during normal operation.

From the above information, the gap required between the ULS and the RV at 70°F (approximately the construction temperature) is determined and is necessary to prevent contact between the RV and the ULS at 15% power (most critical condition, maximum thermal growth) during an SSE is calculated as follows:

	Displacement (in)
Thermal growth, effect of pressure, and effect of closure	0.389
Seismic gap	0.076
Construction tolerance	0.016
TOTAL	0.481
	or (15/32" + 1/64" - 0")

11.0 ANALYSIS TO DETERMINE FINAL SUPPORT LOADS

11.1 GENERATION OF SUPPORT LOADS

11.1.1 Technical Basis

The methodology used to generate the design loads for the modified Nuclear Steam Supply System (NSSS) supports will utilize the same analytical techniques and computer codes as B&W Topical report, BAW-10131, Reactor Coolant System Structural Loading Analysis (Reference 11) and the B&W's Owners Group Report entitled, Effects of Asymmetric LOCA Loadings, BAW 1621 B&W 177-FA, (Reference 8) which has been submitted to the NRC for review in July 1980.

Modifications will be made to the existing mathematical models of the NSSS and its supports to incorporate the upper lateral support spring rates, reactor vessel anchor stud spring rates, internal walls structure, and boundary conditions at the reactor coolant pumps and steam generators specific to the Midland Plant. The seismic forcing functions are Midland specific, however the LOCA forcing functions used to determine the support loadings are based on break areas equal to or larger than those specifically applicable to Midland.

The analyses will incorporate state-of-the-art techniques (described herein) which insure that all components supporting, and attached to, the reactor vessel will receive a full review for structural integrity under the modified support design.

11.1.2 Mathematical Model

A single mathematical model will serve as the basis for both seismic and LOCA analyses. Minor modifications allow the model to be used for linear seismic or linear/nonlinear LOCA analyses.

For seismic analysis, the ULS will be gapped such that the RV and the ULS will not contact. The moment on the RV skirt is such that pretension of the anchor studs is not exceeded. Thus, linear elastic analysis for the support system will be applicable. Stresses are checked against allowables to insure the validity of this assumption. The STALUM computer code is used to generate results.

For LOCA analyses, the model will be modified to reflect the gap between the RV and the ULS, the inelastic properties of the ULS and the bilinear spring rate which reflects loads exceeding prestress on the anchor studs. The STALUM code, with linear elastic properties, will be used to establish "benchmark" LOCA results. The ANSYS code will be used to achieve results reflecting nonlinear and inelastic conditions of the support system. The results will be compared with linear STALUM analyses to insure reasonability.

11.1.2.1 NSSS Model

Because of the complexity of the RV loading conditions and the number of attachments to the vessel, a detailed isolated model of this component will be constructed. This model will be a complete representation of the reactor vessel and its appendages (eg, control rod drive mechanisms, service support structure, and reactor internals). It will also include both the hot legs extending to the steam generators and the four cold legs extending to the coolant pumps. Boundary conditions will be imposed at the ends of the pipes where they connect to the components to simulate the remainder of the NSSS. The isolated model is shown in Figures 11.1 through 11.7.

The isolated portion of the NSSS will be modeled utilizing finite beam-element and lumped mass representations of each component. Finite element methods are used where necessary to define the structural characteristics of components such as the fuel and plenum assemblies. Once determined by finite element techniques, the structural characteristics of components will be used to generate the equivalent finite-beam element and lumped mass representations. The criteria for developing the equivalent structural representation is that component stiffness and frequency must be retained.

The various components that make up the total RV and its internals are identified in Figure 11.8. By comparing Figure 11.8 with the lumped-mass model shown in Figure 11.1, the correlation between the components and the model elements representing them can be seen.

In addition to the structural representation of the components, the NSSS mathematical model incorporates the effects of fluid coupling between components into the overall structural response of the system. This is accomplished by developing a mass matrix using the height of concentric cylinders, the distance between the cylinders, and various parameters describing the fluid between the cylinders. The mass matrix which is generated is combined with the diagonal mass matrix terms defining component mass distribution to generate a full system mass matrix.

11.1.2.2 Internal Walls Structure

The internal walls structural model properties included are the axial area, shear area, moments of inertia, modulus of elasticity, and Poisson's ratio for different elevations in the wall. Lumped masses and mass moments of inertia at different elevations define the mass distribution and mass resistance of the wall structure. The internal wall structure is modeled in the seismic analysis to the center of the concrete basemat. The boundary conditions at that point are fixed such that no relative rotation or translation is allowed. This internal wall structure model is shown in Figure 11.4. For LOCA, the internal walls are modeled to include separately the primary and secondary shield walls along with springs at their base to represent the soil flexibility, this model is shown in Figure 11.7.

11.1.2.3 NSSS Supports

For the isolated RV model, the NSSS supports are described as the boundary conditions imposed on the cold leg piping at the pumps and the hot leg piping at the steam generators, the reactor vessel skirt support, and the upper lateral supports near the RV flange.

The boundary conditions imposed on the reactor coolant piping at the pumps and steam generators consist of stiffness matrices that represent the characteristics of the structures to which the pipes are attached. They are obtained from a full system model by disconnecting the pipes at the component nozzles and computing a stiffness matrix of the remaining component with its supporting structures and other attached piping.

The RV skirt support is modeled in the seismic analysis as a boundary condition at the base of the RV skirt support in the form of a set of springs. The boundary conditions reflect the flexibility of the anchor studs, localized concrete flexibility, and overall flexibility of the RV pedestal from the RV skirt support to the center of the basemat. In the seismic analysis, these stiffnesses are linear since the anchor stud prestress is not exceeded.

The LOCA analysis reflects the nonlinearity of the RV base support during "liftoff" in a series of equivalent nonlinear springs connecting the base of the RV skirt to the concrete pedestal.

The ULS are gapped such that they are not active during a seismic event. During a LOCA, the gap between the ULS and RV would close such that the ULS becomes an active support. ULS structural properties are incorporated into equivalent nonlinear springs which reflect the appropriate gap along with the inelastic properties of the support. Localized concrete and RV flexibility is included in series with the ULS springs. The ULS equivalent beams are shown in Figure 11.7 as they connect the RV with the primary shield wall.

11.1.2.4 Stiffness of Upper Lateral Supports

Lateral translation resistance versus displacement curves for the upper lateral restraints in three directions are developed. No movement of the wall is considered in the development of these curves, hence the stiffness of the brackets are added in series to the local wall stiffness.

The three directions considered are the hot leg direction (North-South), the core flood nozzle direction (East-West) and the cold leg direction that lie midway between the North-South and East-West axis. The resistance curves are developed for a gap in the range of 0.090 to 0.125 inches and represent the stiffness of four ULS, and are given in Figures 11.11 through 11.13. The origin in the curves represents the first contact between the RV and the ULS. For the curves representing the stiffness in the direction of the cold leg, the stiffness of the first bracket to come in contact with the RV is neglected (the deflection, however, was considered). The neglected stiffness is comparatively small since the brackets are relatively flexible in bending about their minor axis.

The local stiffness of the primary shield wall, which was determined by the finite element method of analysis is tabulated below:

Break/Direction	Spring Rate
cold leg	779×10^5 lb/in
hot leg (North-South)	215×10^6 lb/in
core flood nozzle (East-West)	723×10^5 lb/in

See Appendix E for further discussion on the methodology used to compute the spring rates.

11.1.2.5 Stiffness Of The Support At The Base Of The Reactor Pressure Vessel

The moment versus rotation curve for the reactor pressure vessel base, (rotational spring constants $K\vartheta_x$ and $K\vartheta_z$), is shown in Figure 11.14. The curve was developed by a finite element analysis that assumed the nominal prestressing load of 20 kips per stud (corresponding to a 5 ksi prestress). A dead weight of 27.9 kips per stud has also been factored into the analysis. The curve is bilinear and the flatter portion represents the stiffness after the studs have lifted off. For Unit 1, two slopes are given for the flat portion of the curve representing the upper and lower bound stiffness. The actual slope of the curve depends on the orientation of the moment with respect to the broken studs, and is between these two bounds. For Unit 2, where no studs are broken, the upper bound curve is used.

The stiffness in the other four directions are tabulated below:

Direction	Spring Rate
torsional ($K_{\phi y}$)	1197×10^{10} in-lb/rad
lateral (K_x or K_z)	578×10^{6} in-lb/rad
vertical (K_y, before lift off)	223×10^{6} lb/in
vertical (K_y, after lift off)	171×10^{6} lb/in

In deriving the above stiffnesses, a finite element analysis was also used. The studs have no contribution to the lateral stiffness K_x or K_z and the torsional stiffness $K_{\phi y}$. The lateral forces and torsional moments are transmitted via the shear pins between the RV skirt flange and the sole plate, and from the sole plate through the shear lugs welded on the bottom surface of the sole plate to the concrete pedestal support.

11.1.3 Load Cases Analyzed

The isolated model will be subjected to four load cases in the process of determining the design loads on the supports. Two sets of seismic analyses will be performed; one for the OBE and the other for SSE. Two LOCA cases will be considered in detail; a guillotine break at the hot leg outlet of the RV and a guillotine break at the cold leg inlet to the RV. Other LOCA load cases will be assessed if they are shown to produce contact between the RV and the ULS. The support system is designed such that the ULS will receive no deadweight or thermal loads from the RV.

Deadweight and thermal load on the RV base are analyzed using a larger loop model of the NSSS and supports. These results are currently being modified in a program unrelated to the RV support redesign. Preliminary results are given in Section 4.0.

11.1.4 Method Of Analysis

11.1.4.1 Seismic Forcing Functions

The seismic forcing functions that will be applied to the mathematical model consist of response spectra curves for SSE at damping values from 1% to 5%. Response spectra is supplied for earthquakes in five directions, North-South, East-West, vertical, rotation about North-South and rotation about East-West. The rotation is applied as occurring about the geometric center of the RV at the elevation of the basemat.

11.1.4.2 LOCA Forcing Functions

LOCA forcing functions are composed of three sets of time histories which are applied simultaneously to individual degrees of freedom. The forcing functions are the result of blowdown into the cavity between the RV and the primary shield wall, and pressure wave propagation inside the RV due to the break in the reactor coolant pressure boundary.

Core Bounce

The vertical response of the reactor internals and Fuel Assemblies (FA) result in a time varying force composed of the structural response to differential pressures. Core bounce is the terminology given to this response phenomena. The nonlinear structural response reflecting holddown springs and vertical gaps is calculated in a decoupled analysis. The FA core and reactor internals are simulated with a planar model consisting of beam elements, nonlinear axial springs, and lumped masses. The ANSYS code is used to calculate the vertical reactions of the core, which are then used as applied force time histories on the reactor vessel in the system dynamic analysis. The core bounce LOCA forcing functions are the result of the worst case double end guillotine pipe breaks at the RV nozzle.

Thermal Hydraulics and Dynamic Response

The pressure waves through the RV produce several reactions that are not considered in the core bounce forcing functions and which can be applied directly to a dynamic system.

For the reactor vessel, the horizontal pressure gradient results in horizontal forces on the RV, core support cylinder, thermal shield, and the plenum cylinder. The vertical gradient results in vertical forces on the RV.

The integration of the pressure-time history defines the time history forces which are applied to discrete mass joints of the mathematical model.

The thermal hydraulic loadings applied directly to the linear dynamic model are the result of a hot leg pipe rupture and a cold leg rupture.

Asymmetric Cavity Pressures

Pipe ruptures which occur in the cavity between the RV and the wall result in differential pressures across the RV in a time varying manner. The differential pressures, when integrated across the area of the RV, produce time varying forces which are applied to discrete mass joints on the RV. The cavity pressure loadings on the RV for these analyses result from mass and energy data for double ended pipe guillotine ruptures equivalent to or larger in area than the actual pipe break. The same differential pressures applied to the RV are also applied to the primary shield wall.

11.1.4.3 Computer Codes Used For NSSS Analysis

The three analytical computer programs and the four data reduction codes used in the seismic and/or LOCA analyses for the support design loads are described below.

Structural Analysis Codes

1. HYDROE - A computer code used in calculating the hydrodynamic mass coupling of concentric cylinders.

2. STALUM - A computer program for analyzing three-dimensional, finite segment systems consisting of uniform or nonuniform bar/piping segments, closed-loop arrangements, and supporting elements. STALUM performs both static and dynamic structural analyses undergoing small linear, elastic deformations. The static analysis is based on the matrix displacement method. The static loadings are static mechanical forces, thermal, and/or support displacement loadings. The dynamic analysis is based on lumped-mass and normal-mode extraction techniques. The dynamic input loadings can be response spectra or time history forcing functions.

   The essential input to the program consists of the physical properties of the system, the boundary conditions, and/or the loading information; the essential output consists of the resultant joint displacements, rotations, forces, moments at both ends of each segment, and stresses at various locations in each segment.

3. ANSYS - The ANSYS general purpose program solves a wide variety of engineering problems more efficiently than most special purpose programs. ANSYS includes capabilities for transient heat transfer analyses including conduction, convection, and radiation; structural analyses including static elastic, plastic, and creep, dynamic, and dynamic plastic analyses, and large deflection and stability analyses; and one-dimensional fluid flow analyses.

Data Reduction Codes

1. FTRAN - A computer code used for Fourier analysis of forcing functions to determine the frequency content of the forcing function.

2. S1235 - A post-processor program used to tabulate forces, moments, displacements, and rotations in a specification format.

3. INTFCE - A program used to convert pressure-loading data to force-loading data acceptable for use by the structural analysis codes.

4. LOPL - A post-processor program used to provide time history tabulations and plots of spring forces and resulting loads and displacements.

11.1.5 Seismic Analysis

Utilizing the geometric and structural properties of the mathematical model shown in Figures 11.1 thru 11.6; the STALUM code is used to determine the structural frequencies and mode shapes of the isolated NSSS, the internal walls structure and the NSSS supports as a coupled system. Each element or bar in the model is assigned a damping value based on the location and type of component the element represents. Strain energy damping is used to determine a composite damping for each mode. The modal accelerations are applied to the model dynamically to reflect the structural amplification. Equivalent static forces for each mode are determined and applied to each degree of freedom to give resulting modal displacements and member forces. The modal responses for each individual earthquake will be combined by the SRSS method as described in the response to Regulatory Guide 1.92 in Section 3A of the FSAR. The resulting member loads and displacements will be combined by taking the SRSS of all five earthquake excitations (three translational and two rotational). Figure 11.10 shows the flow diagram for the seismic analysis.

RV Lower Support Loads

The seismic loads on the RV lower support are taken directly from the seismic analyses and are the forces and moments from the combined five earthquake components at the base of the RV skirt. These centerline loads are resolved into support loads for the stress evaluation described in Section 12.3.1. The final seismic loads and displacements are given below.

REACTOR VESSEL SUPPORT LOADS

SKIRT LOAD AT ANCHOR JOINT 50 FIGURE 11.1

	FORCES (KIPS)			MOMENTS (FT-KIPS)		
LOAD CASE	FX	FY	FZ	MX	MY	MZ
SSE X Trans-Z ROT	276.4	4.4	62.7	1332.1	154.1	8105.7
SSE Y Tran	1.4	193.9	8.5	70.3	89.9	31.9
SSE Z Tran-x ROT	71.71	37.7	230.3	7157.3	145.3	1443.8
SSE (Combined)	285.6	197.6	238.8	7280.6	230.1	8233.3
OBE (Combined)	145.8	98.8	119.6	3806.2	120.6	4334.1

DISPLACEMENTS

RV PROFILE AT ULS JOINT 166 FIGURES 11.1, 11.4

	DISPLACEMENTS (INCHES)		
	X	Y	Z
SSE (Combined)	.02445	.00148	.02156
OBE (Combined)	.01284	.00074	.01124

WALL PROFILE AT ULS EL. 631'5-1/2" JOINT 170 FIGURE 11.4

	DISPLACEMENTS (INCHES)		
	X	Y	Z
SSE (Combined)	.03261	.00144	.02854
OBE (Combined)	.01891	.00072	.01711

ULS Loads

There is no interaction between the ULS and the RV during a seismic event.

11.1.6 LOCA Analysis

The geometric and structural properties along with the nonlinear properties of the ULS and the reactor skirt support are included in the model utilizing the ANSYS computer code. The three sets of LOCA forcing functions are applied simultaneously to individual DOF's to represent the structural loadings to the components during the LOCA event. Displacement and member force responses are determined for each node or joint and element. The resulting displacements and member forces and moments are stored such that time-for-time or peak results are available for any member or joint.

RV Lower Support Loads

The peak forces and moments, regardless of their time of occurrance, will be obtained from the time history LOCA analysis output, and used as the total centerline load imposed by the RV on the support.

ULS Loads

The total peak horizontal force on the equivalent springs representing the ULS will be given as the maximum load on the support and the primary shield wall. The peak displacement of the total ULS system will also be available as needed.

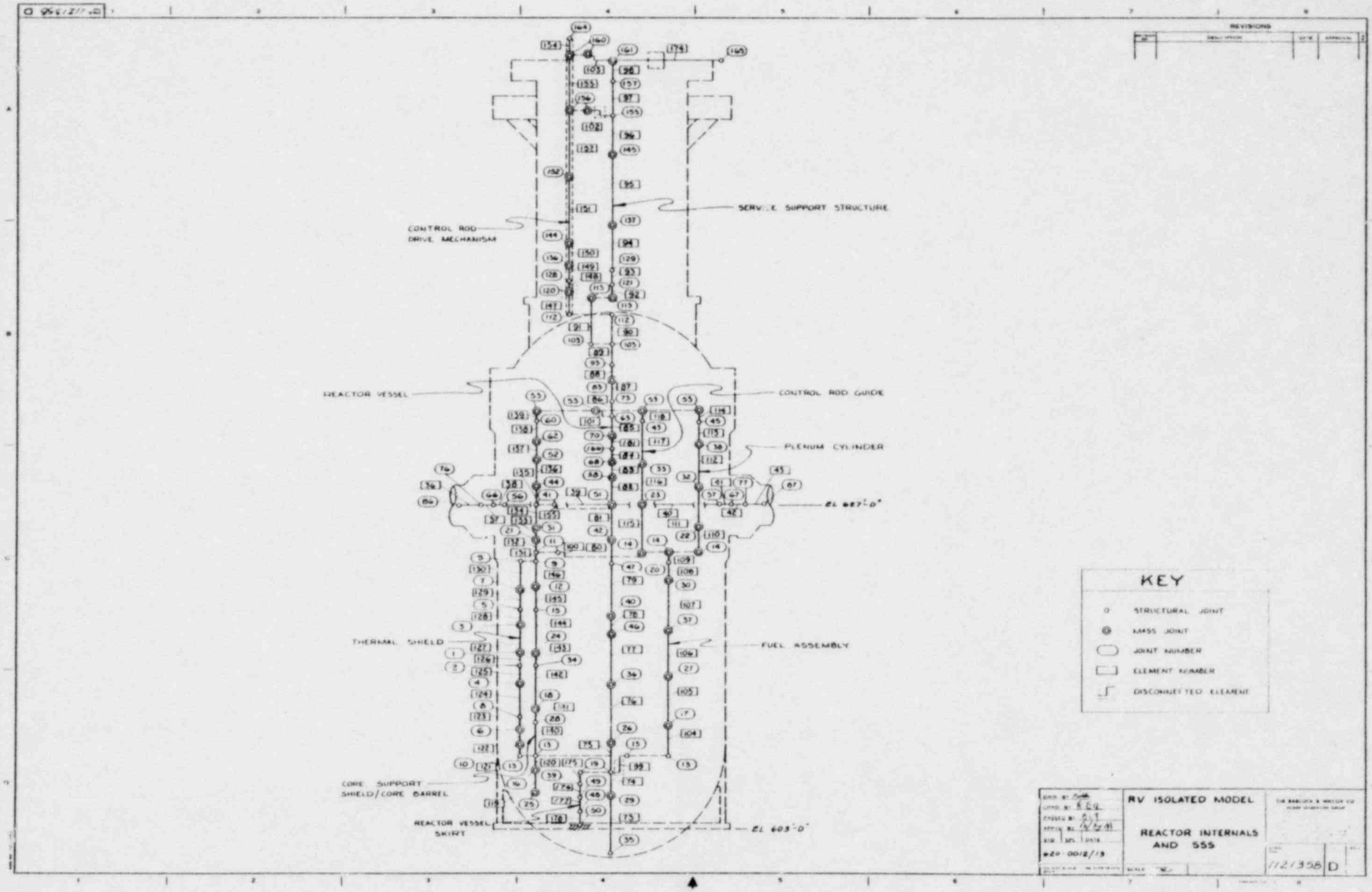

SERVICE SUPPORT STRUCTURE
CONTROL ROD
DRIVE MECHANISM
REACTOR VESSEL
CONTROL ROD GUIDE
PLENUM CYLINDER
EL 627'-0"
THERMAL SHIELD
FUEL ASSEMBLY
CORE SUPPORT
SHIELD/CORE BARREL
REACTOR VESSEL
SKIRT
EL 603'-0"
KEY
STRUCTURAL JOINT
MASS JOINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
REVISIONS
RV ISOLATED MODEL
REACTOR INTERNALS
AND SSS
THE BABCOCK & WILCOX CO.
112/358
D
#20-0012/13

FIGURE 11.1

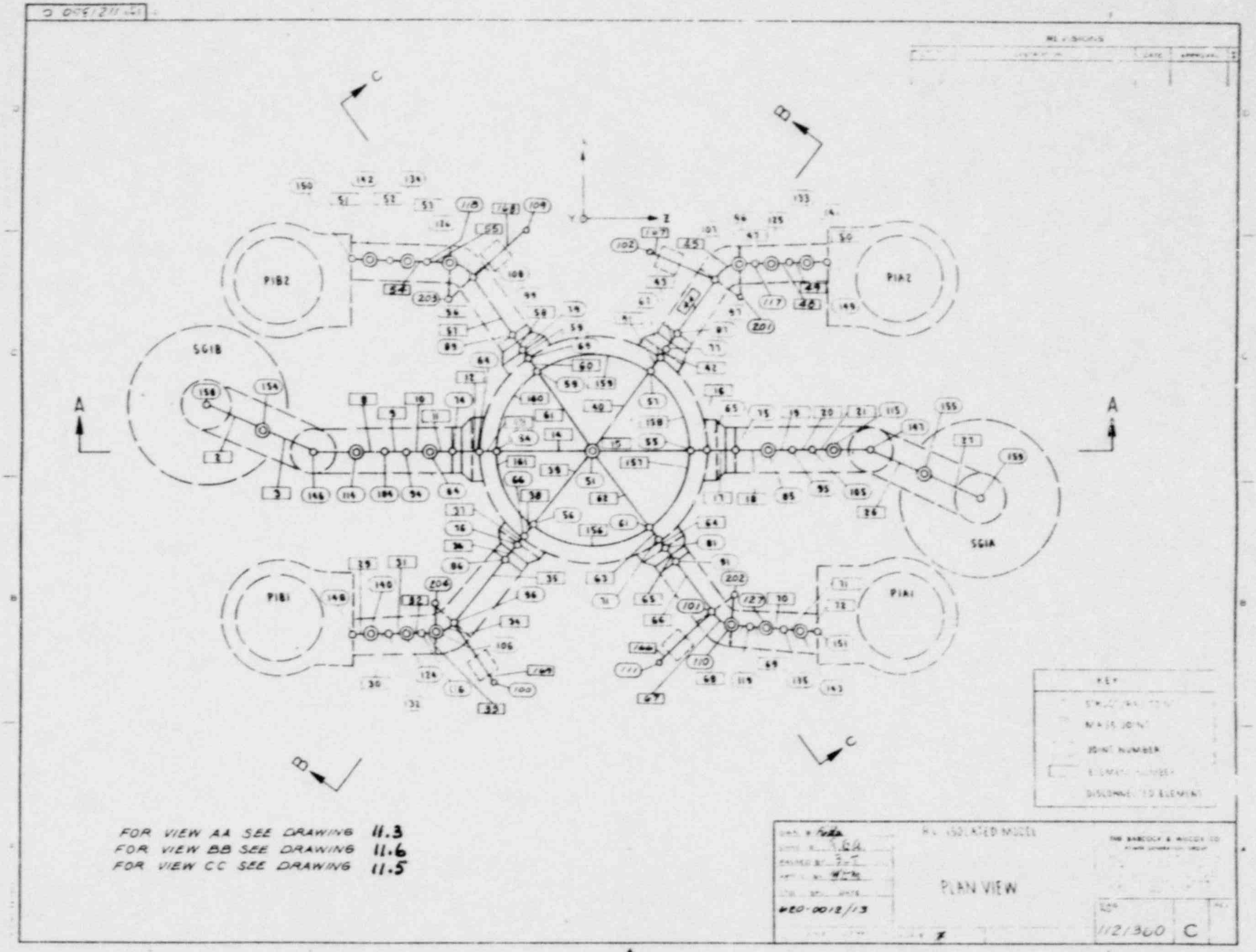

112/360 C
SG1A
SG1B
P1A1
P1A2
P1B1
P1B2
A
B
C
Y
Z
FOR VIEW AA SEE DRAWING 11.3
FOR VIEW BB SEE DRAWING 11.6
FOR VIEW CC SEE DRAWING 11.5
REVISIONS
DATE
APPROVAL
KEY
STRUCTURAL JOINT
MASS JOINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
RV ISOLATED MODEL
PLAN VIEW
THE BABCOCK & WILCOX CO.
POWER GENERATION GROUP
620-0012/13
112/360
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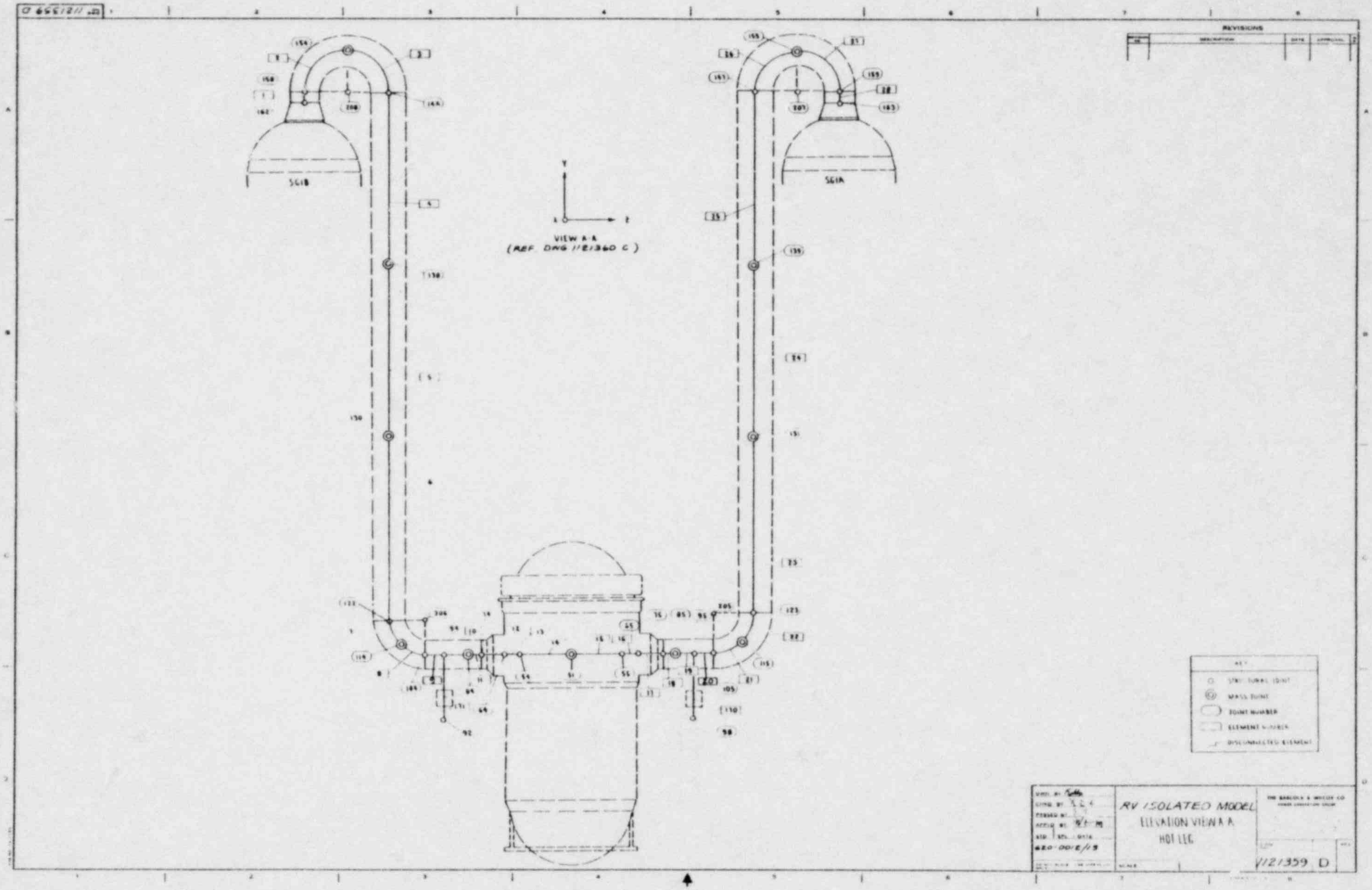
FIGURE 11.2


1121359 D
REVISIONS
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SGIB
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VIEW A-A
(REF DWG 1121360 C)
154
158
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157
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201
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205
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85
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65
54
51
55
92
98
105
110
KEY
STRUCTURAL JOINT
MASS POINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
RV ISOLATED MODEL
ELEVATION VIEW A-A
HOT LEG
THE BABCOCK & WILCOX CO.
620-0012/13
SCALE
1121359 D

FIGURE 11.3

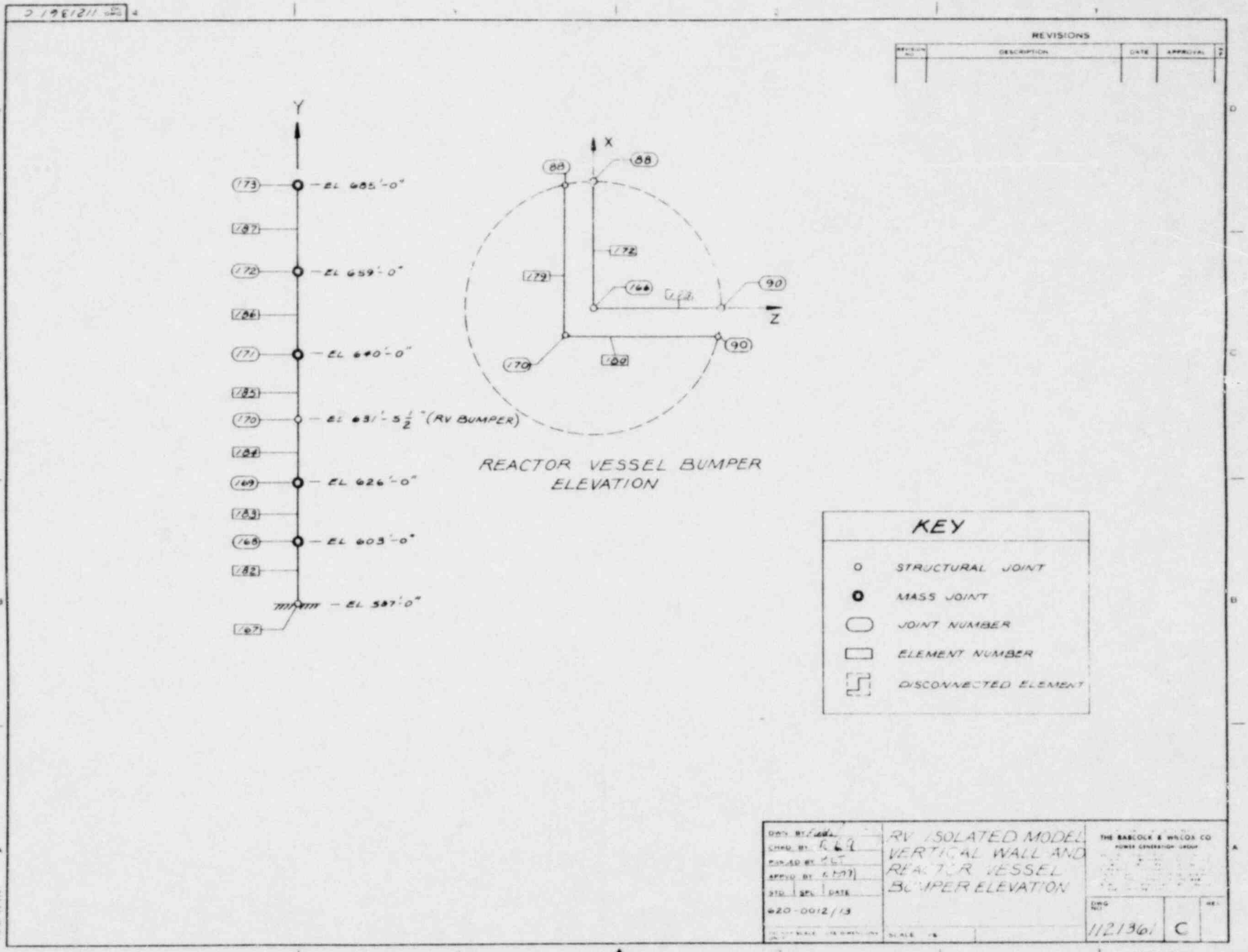
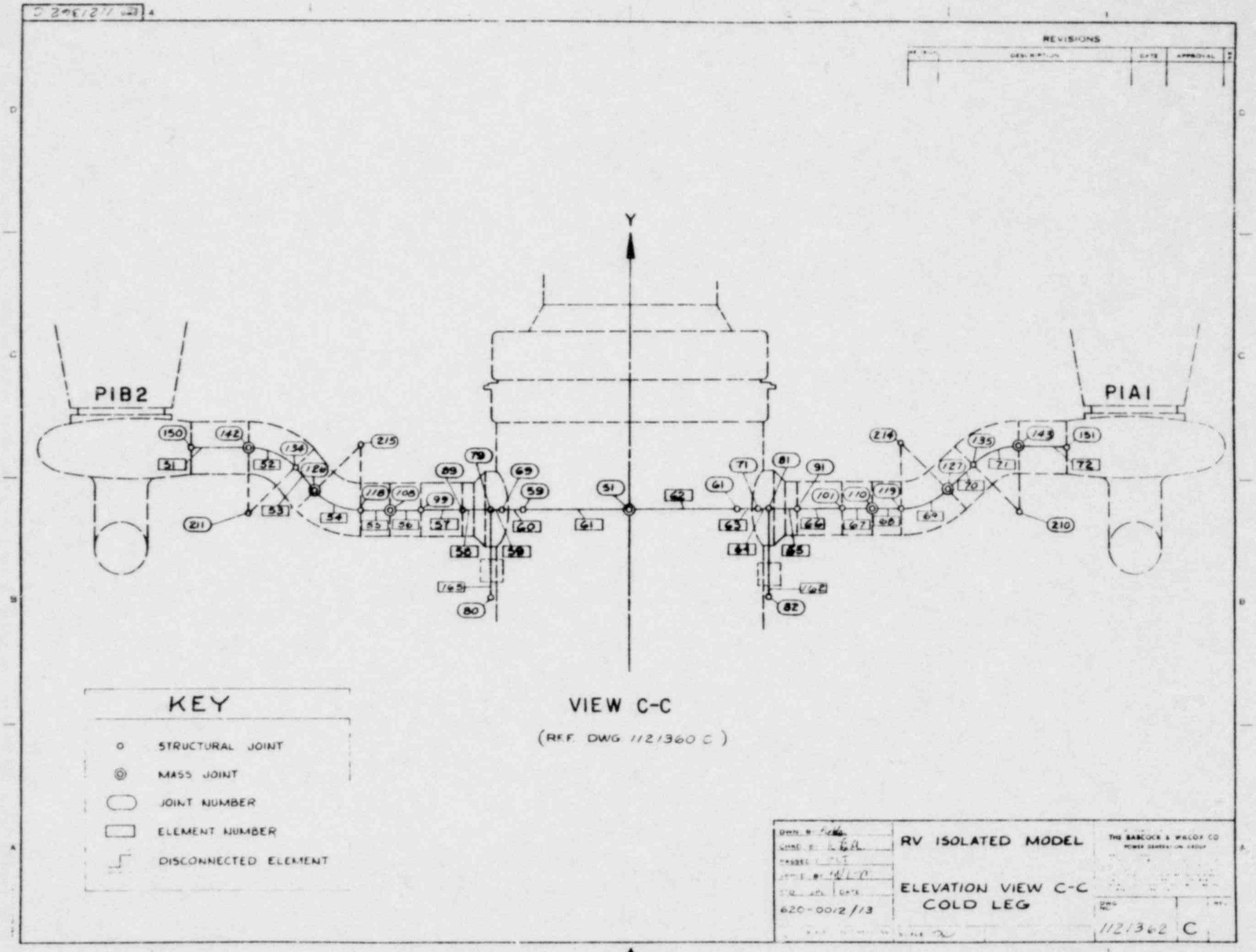

REVISIONS
DESCRIPTION
DATE
APPROVAL
Y
173
EL 685'-0"
187
172
EL 659'-0"
186
171
EL 640'-0"
185
170
EL 631'-5 1/2" (RV BUMPER)
184
169
EL 626'-0"
183
168
EL 603'-0"
182
EL 587'-0"
167
X
88
88
178
179
166
181
90
Z
90
170
180
REACTOR VESSEL BUMPER ELEVATION
KEY
STRUCTURAL JOINT
MASS JOINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
DWN BY
CHKD BY
ISSUED BY
APPVD BY
STD
SPL
DATE
620-0012/13
RV ISOLATED MODEL VERTICAL WALL AND REACTOR VESSEL BUMPER ELEVATION
THE BABCOCK & WILCOX CO
POWER GENERATION GROUP
SCALE
DWG NO
1121361
C
REV

FIGURE 11.4

112/362 C
REVISIONS
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68
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72
210
165
80
162
82
VIEW C-C
(REF. DWG 112/360 C)
KEY
STRUCTURAL JOINT
MASS JOINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
RV ISOLATED MODEL
ELEVATION VIEW C-C
COLD LEG
THE BABCOCK & WILCOX CO
POWER GENERATION GROUP
620-0012/13
112/362
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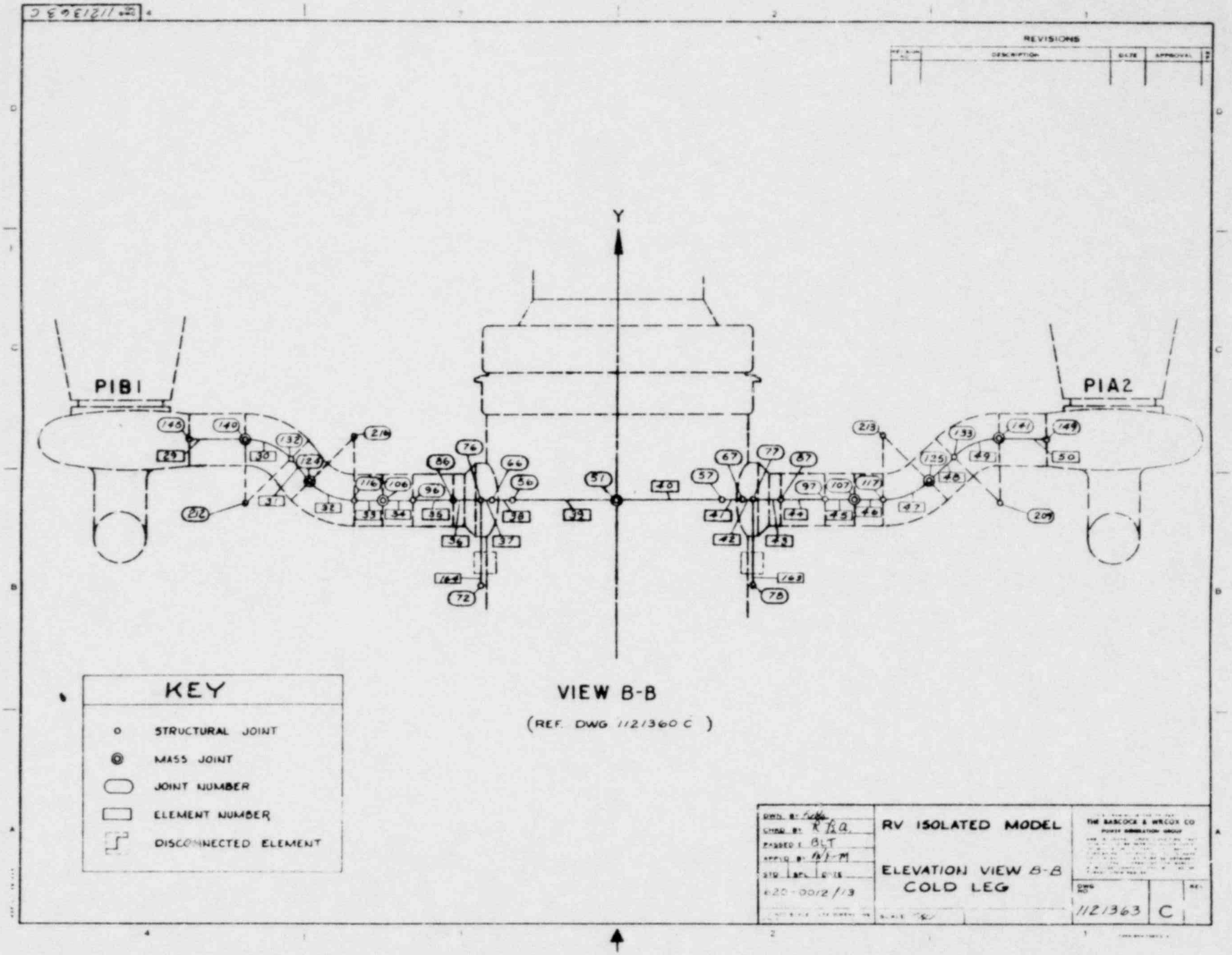
FIGURE 11.5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132
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51
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37
38
39
164
72
40
57
67
77
87
97
107
117
213
125
133
141
149
41
42
43
44
45
46
47
48
49
50
168
78
209
VIEW B-B
(REF. DWG 1121360 C)
KEY
STRUCTURAL JOINT
MASS JOINT
JOINT NUMBER
ELEMENT NUMBER
DISCONNECTED ELEMENT
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PASSED BLT
APP'D BY
620-0012/13
RV ISOLATED MODEL
ELEVATION VIEW B-B
COLD LEG
THE BABCOCK & WILCOX CO
POWER GENERATION GROUP
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FIGURE 11.6

DL162211

REVISIONS

REVISION NO	DESCRIPTION	DATE	APPROVAL

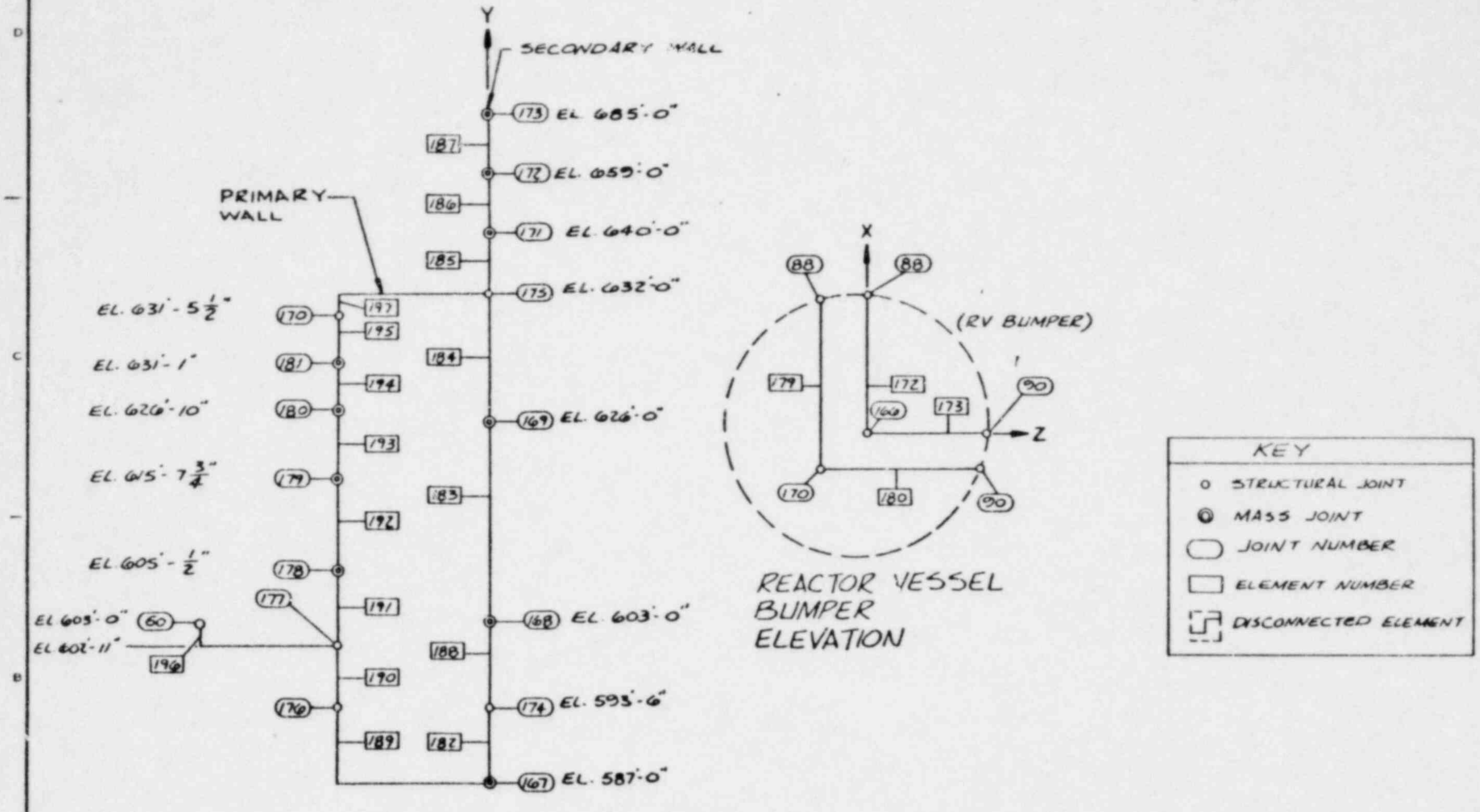

FIGURE 11.7

JEFF WOOD
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CHKD BY
PASSED BY
APPVD BY
STD | SPL | 2-13-81 DATE
620-0012/13
DO NOT SCALE - USE DIMENSIONS

RV ISOLATED
MODEL VERTICAL WALL
& REACTOR VESSEL
BUMPER ELEVATION
(LOCA)
SCALE NONE

THE BABCOCK & WILCOX CO
POWER GENERATION GROUP

DWG NO 1122917 C
REV 0

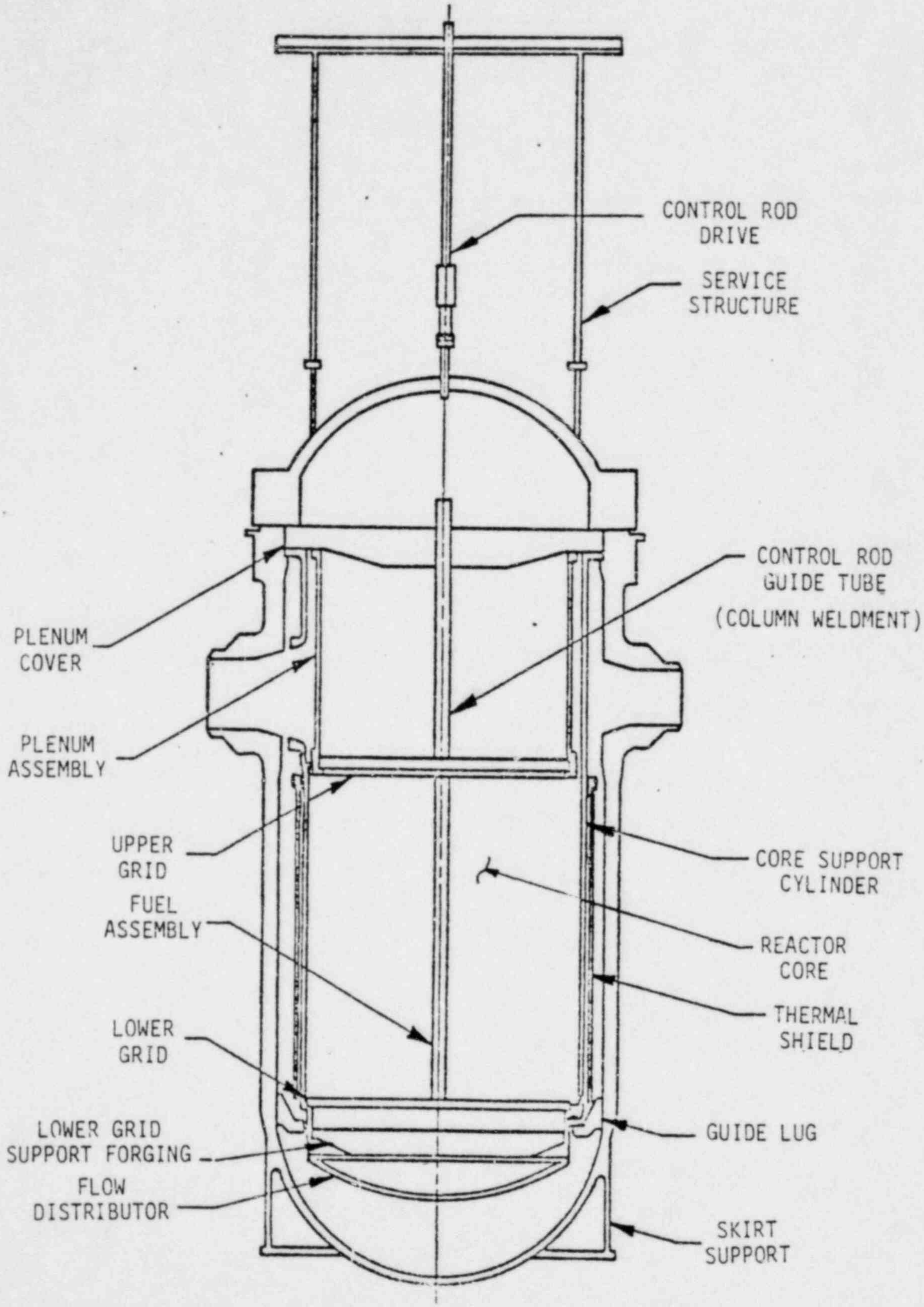
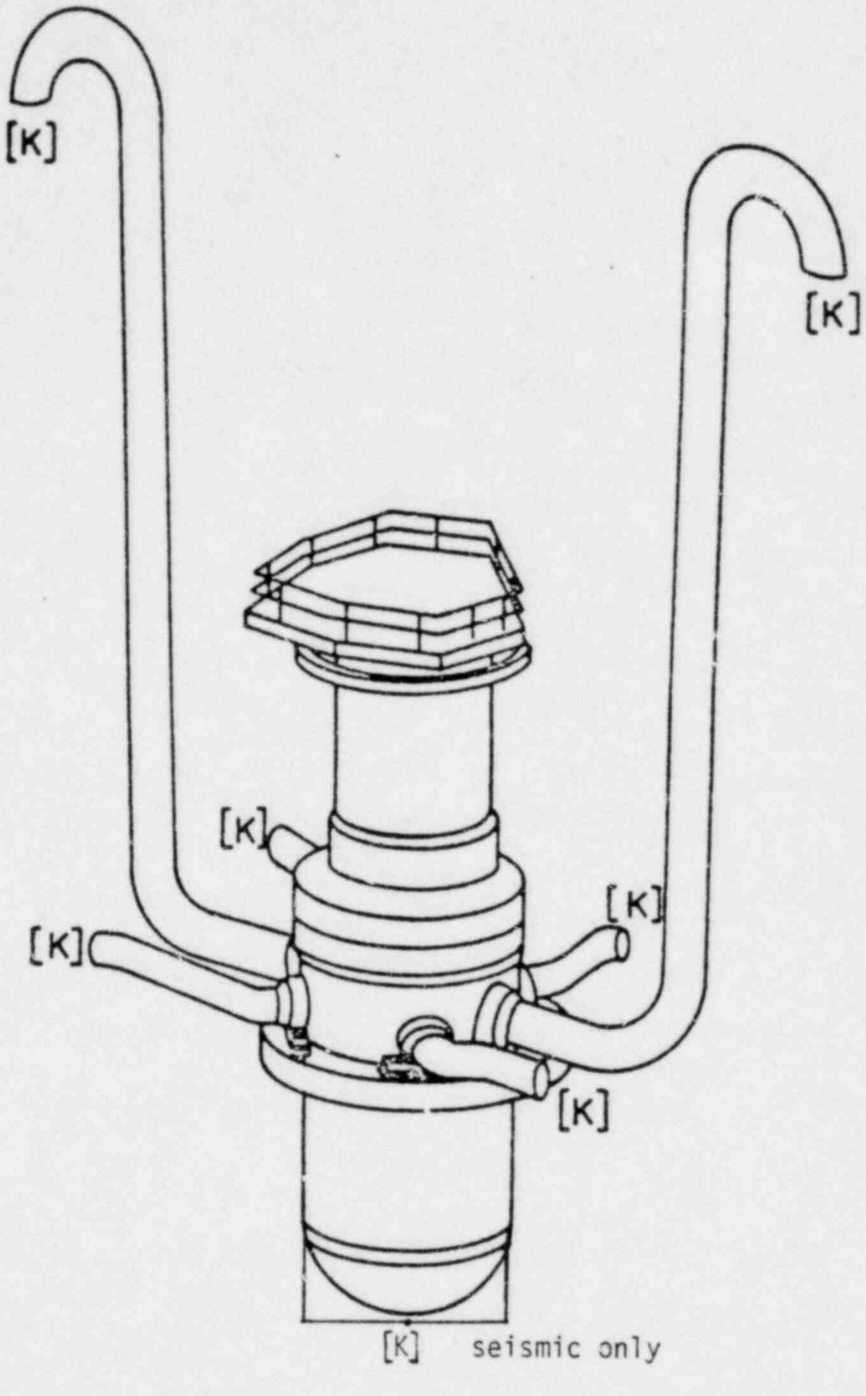


FIGURE 11.8

Reactor Internals and Service Support Structure



[K] = Stiffness matrix

FIGURE 11.9

Reactor Coolant System Boundaries

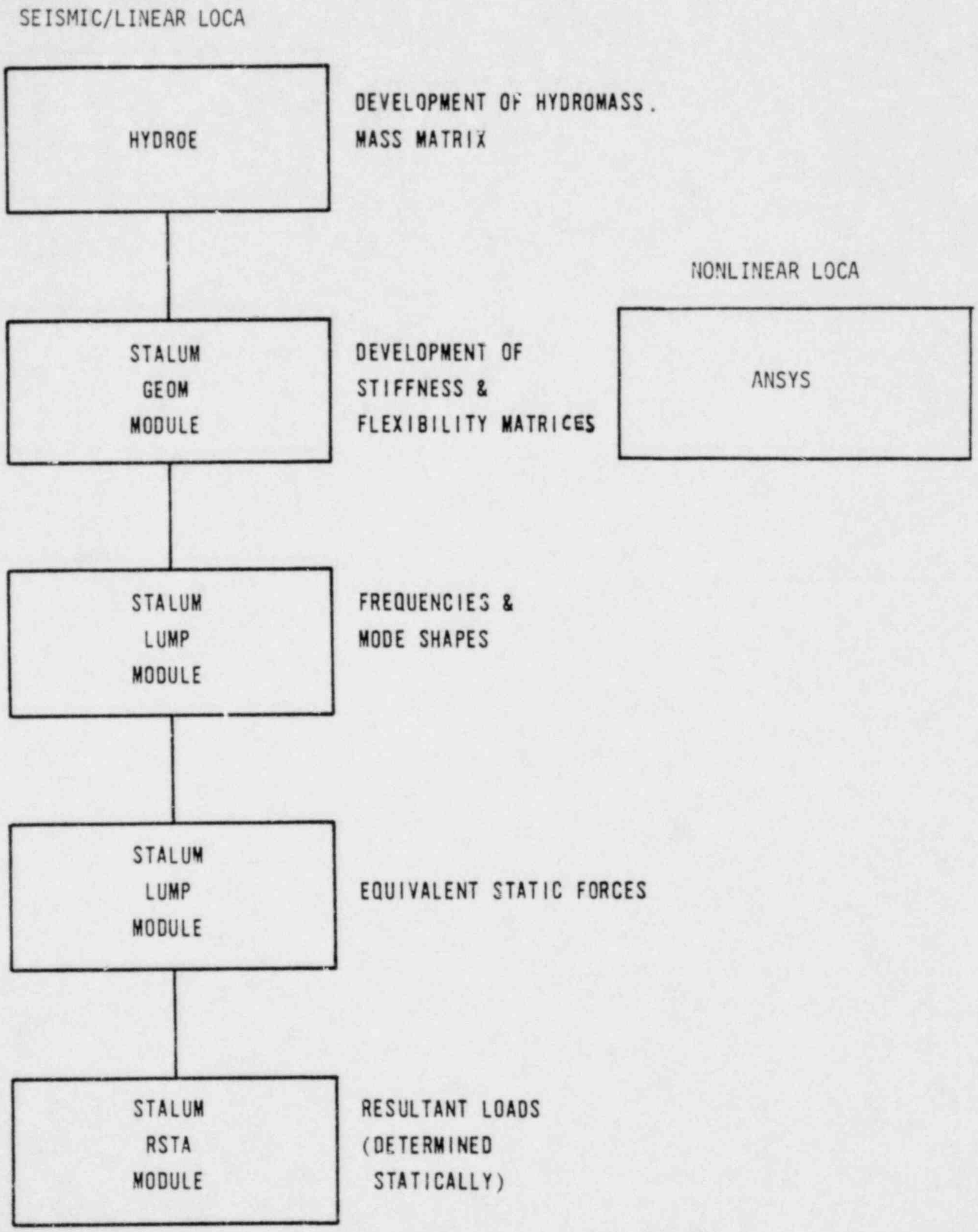
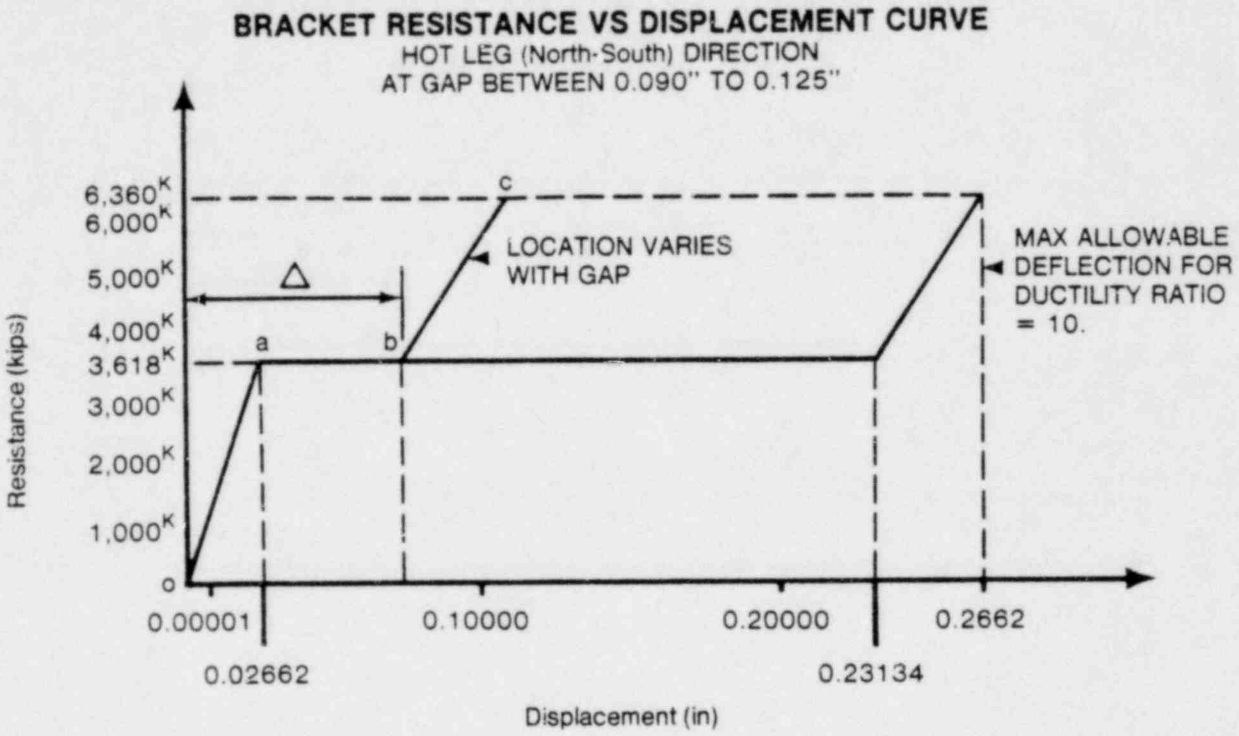


FIGURE 11.10

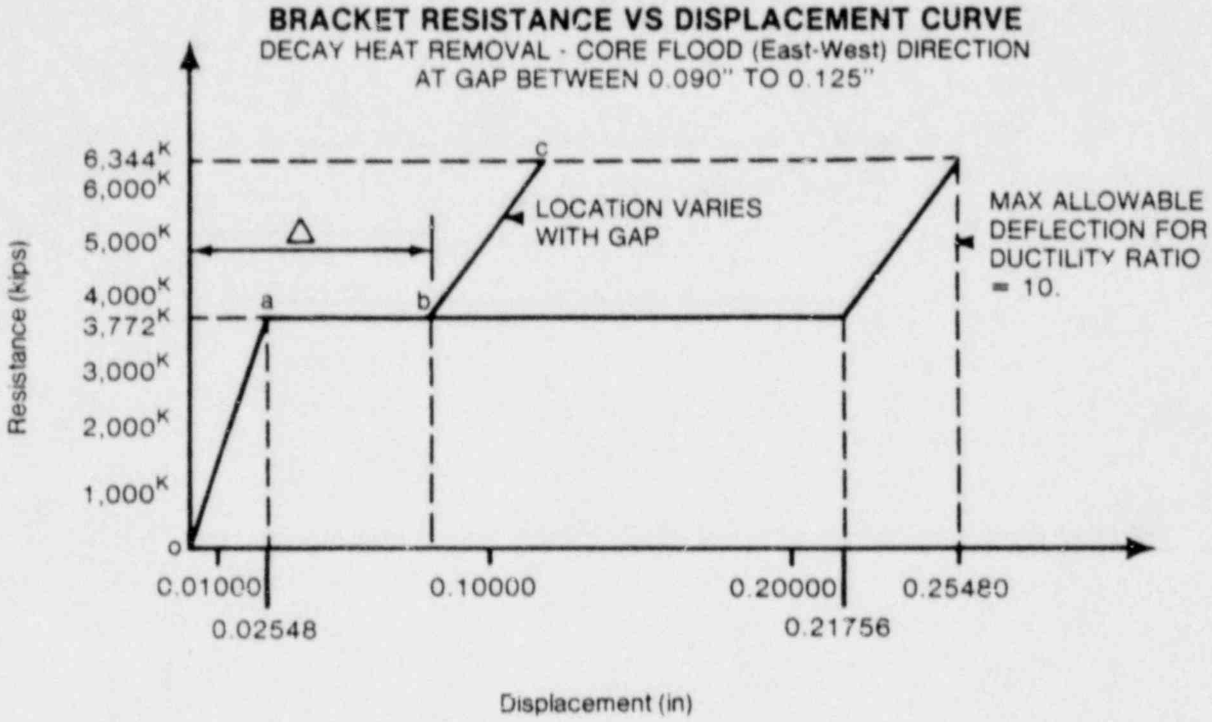
Utilization of Computer Programs



BRACKET RESISTANCE VS DISPLACEMENT CURVE
HOT LEG (North-South) DIRECTION
AT GAP BETWEEN 0.090" TO 0.125"

$$\Delta = \text{GAP}\left(\frac{1}{\text{COS } 43} - \frac{1}{\text{COS } 17}\right)$$

FIGURE 11.11

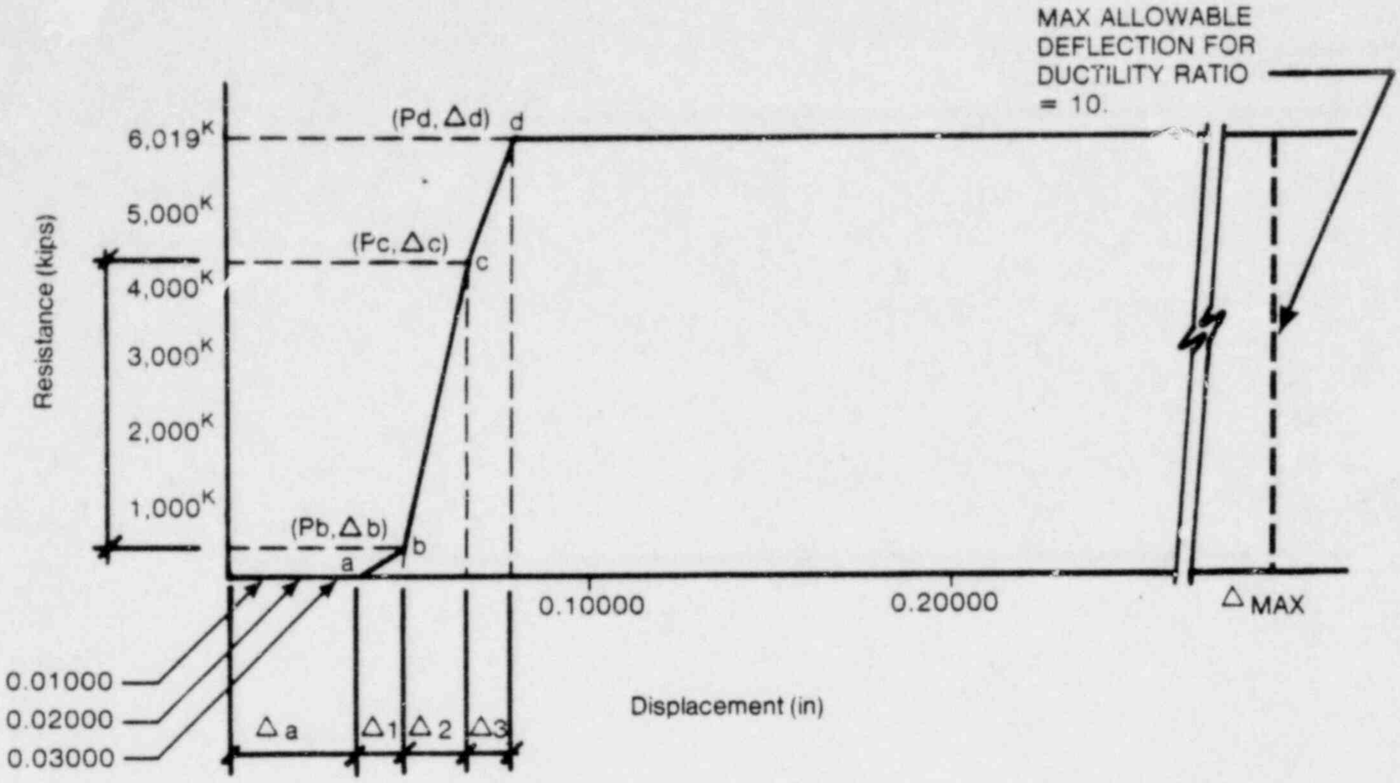


$$\Delta = \text{GAP}\left(\frac{1}{\cos 47} - \frac{1}{\cos 18.5}\right)$$

FIGURE 11.12

BRACKET RESISTANCE VS DISPLACEMENT CURVE

UPPER COLD LEG AT GAP BETWEEN 0.090" TO 0.125"



AT POINT A

$$\Delta_a = \text{GAP}\left(\frac{1}{\text{COS } 43} - \frac{1}{\text{COS } 11.5}\right)$$

AT POINT B

$$\Delta_1 = \text{GAP}\left(\frac{1}{\text{COS } 48.5} - \frac{1}{\text{COS } 43}\right) \quad \Delta P_1 = \frac{1212}{0.04734}\,\Delta_1$$

$$\Delta_b = \Delta_a + \Delta_1 \qquad P_b = \Delta P_1$$

AT POINT C

$$\Delta P_2 = \frac{4125}{1375.1}\left(1886 - \frac{6417.6}{4125}\,\Delta P_1\right)$$

$$P_c = \Delta P_2 + \Delta P_1$$

$$\Delta 2 = \frac{\Delta P_2}{4125} \times 0.01893$$

$$\Delta_c = \Delta_b + \Delta_2$$

AT POINT D

$$\Delta 3 = 0.02720\left(\frac{6019 - Pc}{4215.42}\right)$$

$$\Delta_d = \Delta_c + \Delta_3 \quad P_d = 6019^K$$

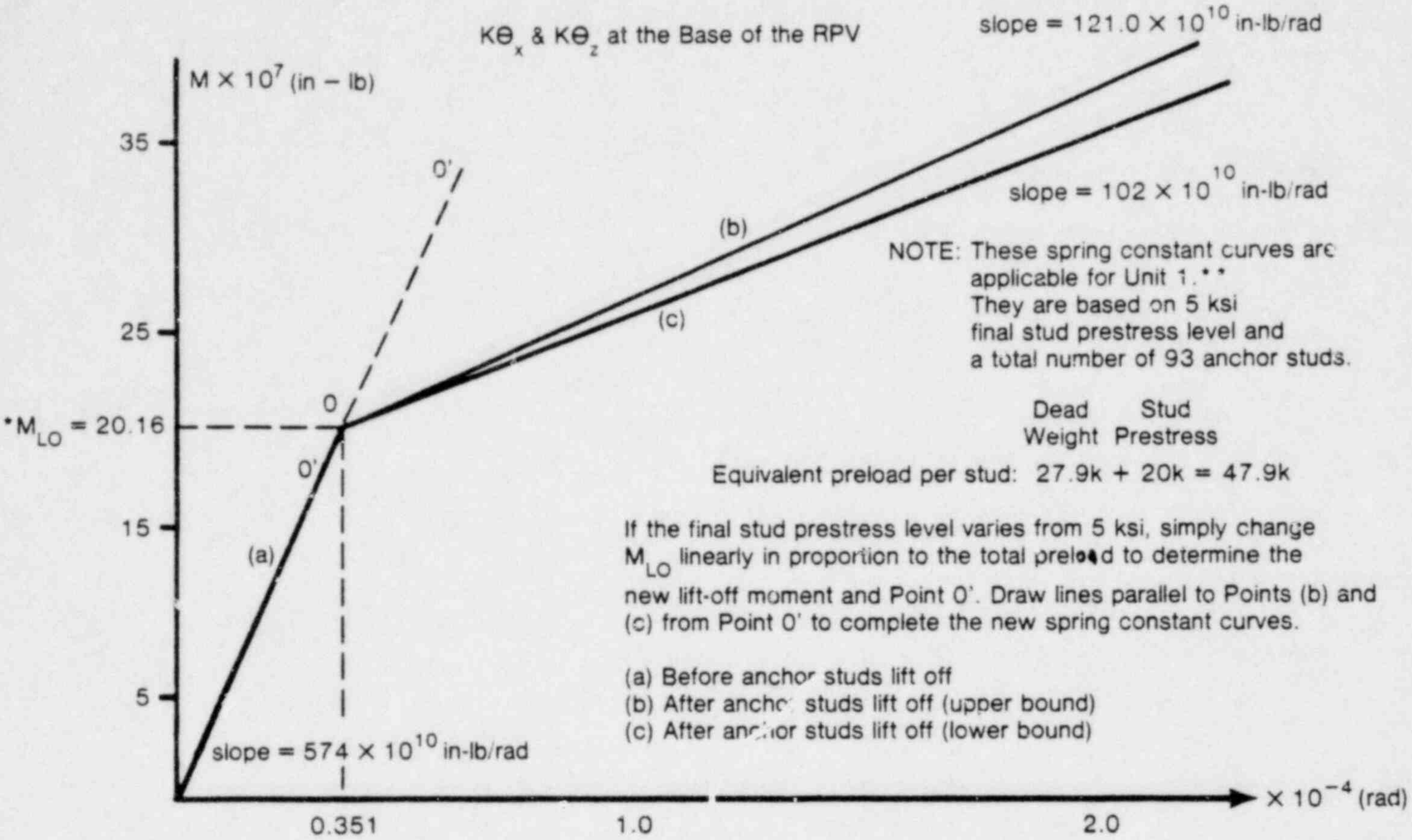
$$\Delta\,\text{MAX} = \Delta_a + (\Delta_1 + \Delta_2) \times 10$$

RANGE FROM 0.34862" TO 0.3833"

FIGURE 11.13

Rotational Spring Constants

$K\Theta_x$ & $K\Theta_z$ at the Base of the RPV



NOTE: These spring constant curves are applicable for Unit 1.** They are based on 5 ksi final stud prestress level and a total number of 93 anchor studs.

	Dead Weight		Stud Prestress	
Equivalent preload per stud:	27.9k	+	20k	= 47.9k

If the final stud prestress level varies from 5 ksi, simply change M_{LO} linearly in proportion to the total preload to determine the new lift-off moment and Point 0'. Draw lines parallel to Points (b) and (c) from Point 0' to complete the new spring constant curves.

(a) Before anchor studs lift off
(b) After anchor studs lift off (upper bound)
(c) After anchor studs lift off (lower bound)

*Moment when studs lift off
**The upper bound curve can be used for Unit 2.

FIGURE 11.14

12.0 CHECKING SYSTEMS AND SUPPORTS FOR THE RESULTS FROM FINAL ANALYSIS

All attached systems, components, and component supports will be evaluated for the results of the aforementioned analyses. The current forecast date for completion is anticipated in the spring of 1983.

13.0 Construction Status and Schedule

The stiffening of the shield plug brackets to form the ULS, and the machining of the flat surfaces on the reactor pressure vessel in both units are complete.

Unit 1 studs were detensioned to a nominal stress of 6 ksi and the lift-off forces measured during detensioning are given in Appendix C. Detensioning, measuring lift-off loads, and retensioning the studs in Unit 2, as described in Section 8 of this report, is scheduled for completion in May 1982. This will be followed by detensioning and retensioning the studs in Unit 1 to their final prestress level, and this is scheduled for completion on October 1982.

The insulation will be modified and installed as described in Section 9 of this report after the cold hydro and before the hot functional testing.

14.0 Conclusion

This report has described the analysis and design of the modified reactor vessel support system for the Midland Nuclear Power Station. Particular attention has been devoted to the physical modification required for the upper lateral support, computer modeling and analytical techniques being used. The methods presented herein represent the standard techniques utilized by the NSSS suppliers for primary system analyses and by A/E's in designing Category I structures.

The design modification is mandatory for Unit 1 because of the anchor stud failures experienced. Based on the investigations conducted, the Company has decided to modify the Unit 2 reactor support design to be identical with that of Unit 1. Thus the analyses of the NSSS for both units will be covered by a single analysis.

This report provides updated information regarding the design and analytical techniques stemming from engineering evolution in the course of this project. The design of the upper lateral supports has proceeded using preliminary design loads as described in this report. The supports are designed with respect to these preliminary loads using conservative assumptions. The confirmation of the adequacy of the design will be made upon receipt of the final support loads, and the project schedule indicates that this will occur around November of 1982. In the event that further evolutions occur in either the design or analyses described in this report, the Company will submit them as amendments of this report to the NRC. The final analytical results and design details will be incorporated, as necessary, by amendment into the FSAR.

15. References

1. Teledyne Engineering Services Report, TR-3887-1, Rev 1, Investigation of Preservice Failure of Midland RV Anchor Studs, May 15, 1980.

2. Teledyne Engineering Services Report, TR-3887-2, Rev 1, Acceptability for Service of Midland RV Anchor Studs, May 20, 1980.

3. Teledyne Engineering Services Report, TR-3887-1, Addendum 1, Investigation of Preservice Failure of Midland RV Anchor Studs, June 6, 1980.

4. Teledyne Engineering Service Report, TR-4599-1, Continued Investigation of the Failure of Midland Unit 1 RV Anchor Studs - Data Report, February 11, 1981.

5. Teledyne Engineering Services Report, TR-4599-2, Continued Investigation of the Failure of Midland Unit 1 RV Anchor Studs - Analysis Report, February 11, 1981.

6. Reactor Pressure Vessel Support Modification for Midland Nuclear Power Plant, Report No 1, July 1980.

7. Reactor Pressure Vessel Support Modification for Midland Nuclear Power Plant, Report No 2, December 1980.

8. BAW 1621 B&W 177-FA Owners Group, "Effects of Asymmetric LOCA Loadings", Phase II Analysis, July 1980.

9. "Letter Report - Teledyne Engineering Services (TES) Project 5355: Expanded Criteria for Acceptability for Service of Midland Unit 1 RV Anchor Stress" W.E. Cooper letter to H.W. Slager, dated October 6, 1981.

10. Thermal Stress Techniques, The Franklin Institute Research Laboratories, American Elsevier Publishing Company Inc., 1965.

11. Babcock & Wilcox Topical Report, BAW-10131, Reactor Coolant System Structural Loading Analysis, November 1976.

APPENDIX A:

Procedure for Detensioning and Retensioning the Reactor Building Reactor Pressure Vessel Anchor Studs

APPENDIX A

PROCEDURE FOR

DETENSIONING AND RETENSIONING REACTOR BUILDING REACTOR PRESSURE VESSEL ANCHOR STUDS

1.0 SCOPE

This appendix provides a procedure for detensioning and retensioning the reactor pressure vessel (RPV) anchor studs in Midland Plant Units 1 and 2.

A procedure for verifying the preload in the anchor studs is also included. Data collected during the detensioning of Unit 2 will be used for analyzing Unit 1 anchors which have already been detensioned.

1.1 The Procedure includes the following:

a. To detension and retension 96 anchor studs for the Unit 2 RPV and to detension and retension the 93 remaining anchor studs for the Unit 1 RPV.

b. Working with a bolting technology consultant who will supervise the use of an ultrasonic extensometer to monitor deformation in the anchor studs

2.0 QUALITY STANDARDS

The work shall be performed in accordance with requirements of a quality assurance program approved by Midland Project Quality Assurance Department (MPQAD).

3.0 Intentionally Left Blank

4.0 Intentionally Left Blank

5.0 REFERENCE DRAWINGS

The required detensioning frame is shown in Appendix 1, Pages 1-2 through 1-5. The description and details of the required retensioning frame are given in Appendix 1, Page 1-6.

6.0 MATERIALS AND EQUIPMENT

6.1 BOLTING MATERIALS

Replacement of nuts and washers, if required, shall conform to the purchase specifications.

6.2 LOADING FRAMES

Loading frame material shall be as noted in Appendix 1, Page 1-6.

6.3 HYDRAULIC RAMS

6.3.1 Rams for Detensioning

The two hydraulic rams to be used for the detensioning frame shall be a solid plunger type with 2-inch minimum stroke and a capacity of 100 tons each, such as Model RC-100-H-5.7 by Duff Norton. The base diameter shall be a maximum of 7 inches and a maximum closed height of 8 inches. The rams shall be a matched pair calibrated and certified, traceable to the National Bureau of Standards (see Section 8.1 for calibration procedure).

6.3.2 Rams for Retensioning

The hydraulic ram for the retensioning frame shall be a hollow-core type with 2-inch minimum stroke and a capacity of 20 tons such as Model RCH 202 by Enerpac (see Section 8.2 for calibration procedure). The minimum internal diameter of the core shall be 1-1/16 inch. The maximum base diameter shall be 6 inches and the maximum closed height shall be 8 inches.

6.4 HYDRAULIC SYSTEM ACCESSORIES

6.4.1 Pressure gages shall be test system gages, 8 to 10 inches in diameter, measuring 0 to 10,000 psi and shall be graduated in 50 psi maximum increments with 25 psi increments preferred . The gage shall be accurate to ±0.5% of actual pressure in the 2,000 to 10,000 psi range. The calibration shall be traceable to the National Bureau of Standards.

6.4.2 Hoses, fittings, valves, and pumps shall be compatible with the rams and gages specified. They shall be in good condition as determined by construction engineering and shall have no leaks or rapid losses of pressure when the equipment is assembled. The main lockoff valve shall be a manual, 3-way type for positive load holding, which, when closed, will prevent cylinder movement. The valves used for throttling shall be manual shutoff valves of fine needle, two-way directional type capable of being used for throttling.

6.5 ULTRASONIC EXTENSOMETER

The extensometer shall be a Raymond Engineering Inc., Power-Dyne Division, ultrasonic extensometer, with an acceptable transducer as determined by Raymond Engineering Inc., from test results for 2-1/2-inch diameter ASTM A 354 bolts 7 feet, 4 inches long.

6.6 DISPLACEMENT GAGES

Displacement gages (length and level) shall have graduations of 0.0001 inch and shall have a minimum extension of 0.5 inch. (1 inch is recommended.) The gages shall be calibrated to a standard traceable to the National Bureau of Standards.

7.0 SEQUENCE OF WORK

Work shall be performed in the following sequence:

a. Calibrate equipment

b. Take initial, as stressed, extensometer readings on Unit 2 anchor studs

c. Measure lift-off on Unit 2 anchor studs and proof test if necessary.

d. Detension Unit 2 anchor studs

e. Take unstressed extensometer readings on Unit 2 anchor studs

f. Check calibration of detensioning equipment

g. Retension Unit 2 anchor studs and take extensometer readings

h. Check calibration of retensioning equipment

I. Detension Unit 1 anchor studs

j. **Recheck calibration of retensioning equipment**

k. Intentionally left blank

l. **Check calibration of detensioning equipment**

m. Retension Unit 1 anchor studs and take extensometer readings

n. Recheck calibration of retensioning equipment

8.0 CALIBRATION

8.1 RAMS AND PRESSURE GAGES

Rams and pressure gages are to be calibrated as described below. Calibration or recalibration shall be done as shown in the sequence of work or at maximum 30-day intervals.

a. **Calibrate the pressure gages in the pressure range of 500 to 10,000 psi. Ensure that the pressure indicated by the gage is within ±0.5% of the true pressure in the 2,000 to 10,000 psi pressure range**

b. **Mark each ram and pressure gage set so they are easily identifiable as a set. These sets must be calibrated and used in the field as a set. Pressure gages shall not be switched between sets. If a gage requires repair or replacement, the set must be recalibrated unless a gage with a calibration curve matching the first is available. (Notify project engineering before proceeding with recalibration.)**

c. **Before calibration, exercise rams three strokes 0 to 0.9 of full extension at 30%, 50%, and 80% of ram capacity.**

d. **As a minimum, ram pressure calibration data points shall be taken at the following increments:**

Pressure Range (psi)	Pressure Increment (psi)
0 to 3,000	500
3,000 to 10,000 or maximum capacity of the ram	1,000

Three sets of load versus pressure readings shall be taken for each ram pressure gage combination. If the measured loads at a particular pressure level in the three sets of data deviate by more than ±1%, additional sets of data shall be taken until consistency is attained.

e. Rams are to be calibrated at an extension of 1 inch and must be calibrated in the active mode with the ram actuated by the pump and forcing load on the test machine

f. All calibration measurements are to be traceable to the National Bureau of Standards. If a testing machine is used for calibrations, its calibration shall have been certified within the last year. A copy of the testing machine's certification of calibration and any other reference standards used in the calibration shall be submitted to project engineering and MPQAD with the ram and pressure gage calibration data.

g. Recalibration shall be performed in a similar manner as described in Sections 8.1, Items c, d, e, and f. If the ram pressure gage combination recalibration readings are found to deviate more than ±1% from the measured load, the project engineer shall be notified immediately.

8.2 RETENSIONING EQUIPMENT

The retensioning ram and hydraulic pressure gage assembly shall be calibrated with a universal testing machine or other calibrated standard. The system shall be calibrated before tensioning

Unit 2 anchor bolts and again before tensioning Unit 1 anchor bolts. The system calibration shall also be checked after completing Unit 1 tensioning. The calibration can be rechecked using the frame shown in Appendix I, Page 1-9.

8.3 CALIBRATION OF EXTENSOMETER

The procedure for calibration and use of the extensometer shall be provided by Raymond Bolting Services and submitted for review to project engineering and MPQAD.

8.4 RECORDS

All calibration procedures and records shall be prepared and submitted to project engineering and MPQAD for review. Records shall be maintained indicating all pressure readings against standard pressure gages, load readings against standard loads, and extensometer readings against loads applied by a calibrated standard.

9.0 UNIT 2 DETENSIONING

9.1 PREPARATION

Prior to taking any readings or setting up detensioning equipment, all threads and stud ends shall be cleaned to facilitate removal of the nuts. The studs ends shall be inspected by Raymond Bolting Services for conditions which could affect extensometer readings. Methods of cleaning, acceptability of cleaning, and methods of repair shall be determined by field engineering. If there are burrs on the RPV skirt between anchor bolts in the bearing area of the detensioning frame, they shall be removed by procedures acceptable to the RPV manufacturer.

9.2 INITIAL EXTENSOMETER READINGS

When preparations have been completed, two complete sets of extensometer readings shall be taken on the studs in their present, tensioned state. These readings shall be taken according to the extensometer manufacturer's instructions. One complete set of readings shall be taken and recorded; then a second set shall be taken and recorded. If the two lengths are not identical (acceptable tolerance to be determined by Raymond Bolting Services), then the readings shall be repeated until agreement is reached. These readings shall be recorded against the Teledyne stud numbering system. (See Appendix 2 for the numbering system.)

9.3 LIFT-OFF READINGS

When the initial extensometer readings are complete, the existing preload forces in the Unit 2 anchor studs can be measured as follows:

The detensioning frame shall be set up as shown in Appendix 1, Pages 1-1 through 1-4, starting with stud 37 (Teledyne numbering system). The cross beam and ram support blocks shall be installed first (see schematic in Appendix 1, Page 1-7). When this is done, the stud coupler with the transducer and cable inserted can be installed. The transducer shall be attached to the stud end according to the instrument manufacturer's instructions. The stud coupler shall then be placed over the transducer and connected to the stud. During this operation, care shall be taken so the transducer is not dislodged or the cable from the transducer is not damaged.

When the cross beam and stud coupler are installed, the hydraulic ram support blocks can be placed on the RPV flange. The blocks shall be level and, if necessary, shall be modified to avoid overlapping washers or the fillet welds on the RPV skirt base. When the support blocks are level, the rams can be installed. The rams shall be vertical and placed directly under the cross beam centerline. The rams shall be installed so the hydraulic hoses are free of sharp kinks and do not rub against sharp corners. The pressure gages shall be positioned to allow easy reading. The rams shall then be jacked to level the cross beam and checked by using a mason's level. A minimum 1-inch extension of the rams is required during the leveling process. When this procedure is complete, the upper nut on the stud coupler shall be brought to a fingertight condition against the crossarm.

The displacement gages shall then be installed as shown in Appendix 1, (Page 1-7). The gage support shall be firmly attached to the RPV by a magnetic attachment so the gages are easily readable but cannot be dislodged during the testing procedure.

The lift-off procedure shall begin by recording the initial readings of all displacement gages, pressure gages, and the extensometer. Lift-off shall be determined when 0.002-inch feeler gages can be removed from between the stud washer and the nut. These feeler gages will be placed in position after passing lift-off on the first stud loading. To accomplish this, the rams shall be pressurized in 100 psi increments until two feeler gages can be easily installed approximately 1/2 to 1 inch under the nut on opposite sides of the stud. The feeler gages shall be within 1/4 inch of the stud and extend under the nut a minimum of 2 inches past the centerline of the stud. During stud loading, care must be taken to keep the crossarm level by keeping the changes in the level gage readings equal. Adjust the ram pressure to level the crossarm if necessary. If the ratio of ram pressures is greater than 1.05 or less than 0.95, depressurize the rams, check the alignment, and reset the rams, if necessary. The rams can then be repressurized. When the feeler gages have been installed, the pressures shall be reduced by a minimum of 500 psi below lift-off to the nearest 500 psi or 1,000 psi reading below apparent lift-off. Length gage, pressure gages and the extensometer shall then be read and recorded. During the next portion of the test, a plot of the length gage readings versus pressure shall be made as the test progresses. The pressures shall then be increased in 100 psi increments with the readings recorded and plotted at 200 psi intervals. During this time, the feeler gages shall be gently tugged. When the feeler gages pull out from under the nut, the readings of all instruments shall be recorded as corresponding to lift-off. The test shall carry on far enough (another 300 psi minimum) to show a break in the curve pressure gage reading versus length gage reading, to indicate lift-off. The rams shall then be returned to zero pressure. The nut shall not be turned at this time.

If any stud is loaded to 360 kips before lift-off occurs, the load shall be reduced to less than 200 kips and project engineering shall be informed. Alternatively, the load on the ram can be reduced to zero and the setup moved to the next stud while awaiting the project engineer's instructions.

It is anticipated that lift-off will occur at approximately 320 kips, although Unit 1 lift-off occurred at levels as low as 216 kips. Any stud for which lift-off occurs below 300 kips must be proof-loaded to 300 kips or two-times the maximum anticipated stress, but no higher than 344 kips. The proof test value will be given by project engineering before the start of detensioning. This can be done after lift-off is measured. Length displacement gage and extensometer readings shall be recorded at the proof-loading.

When studs with centerpoints for machining are encountered, this shall be recorded on the data sheets.

This procedure shall be performed on all studs in the sequence shown in Appendix 2, Pages 2-1 through 2-3, before detensioning. The lift-off readings on the first six studs shall be forwarded to project engineering within one working day of recording. Confirmation will then be made that the applied loads as measured by the pressure gages and, as determined from the extensometer readings are within acceptable tolerances.

9.4 DETENSIONING

When lift-off readings and proof-tests have been completed as described in Section 9.3, detensioning may begin. The detensioning frame is to be used as described in Section 9.3, including the nut socket ring. The studs shall be detensioned in the sequence shown in Appendix 2. The detensioning frame shall be installed as previously described, except the displacement gages are not required. When using the detensioning frame, care shall be taken to keep the crossarm level within tolerance and alignment. The studs can be loaded gradually to the previously recorded lift-off pressure. Pressures shall not be allowed to increase more than 100 psi over the previously recorded lift-off pressure. The socket ring is provided to turn the nut when lift-off pressure is reached. The nut shall then be retracted approximately 1/4 inch and load releasing can begin. The load shall be released in increments determined by the elongation measurement capacity of the extensometer. The nut shall be returned to a snugtight condition at each step of the detensioning and the extensometer dial gage and pressure gage readings shall be taken after the load has been released. A complete set of extensometer readings is to be recorded and retained for each detensioning step. This procedure shall be repeated until all Unit 2 studs are detensioned.

9.5 EXTENSOMETER READINGS

When the Unit 2 studs are detensioned, a complete set of extensometer readings shall be taken as follows:

a. Verify that all nuts are loose by inserting a feeler gage between each nut and washer

b. Following the manufacturer's instructions, attach the transducer and obtain an extensometer reading for each stud

c. Record this value

After this procedure has been completed for all studs, it shall be repeated a second time to verify the readings.

9.6 CHECK CALIBRATION OF DETENSIONING EQUIPMENT

Upon completion of detensioning the Unit 2 anchor studs, the calibration of the rams and pressure gages shall be checked as described in Section 8.1. Records shall be maintained as described in Section 8.4.

10.0 RETENSIONING UNIT 2 ANCHOR STUDS

10.1 PREPARATION

The anticipated deflection in the studs based upon the stress value of 5 ksi in the stud tensile stress area of 4 in^2 and which is equivalent to a load of 20 kips is given by:

$$= \frac{P}{E}\left(\frac{L_1}{A_1} + \frac{L_2}{A_2}\right)$$

where

L_1 = 68 inches (the stressed length of the unthreaded body of the bolt)

L_2 = 13.25 inches (the stressed length of the threaded bolt)

P = 5.0 ksi x 4.00 square inches = 20 kips

A_1 = 4.9 square inches

A_2 = 4.0 square inches

E = 29×10^3 ksi

This deflection equals 0.0119 inch for the standard stud.

The anticipated readings to be observed during the retensioning are as follows:

Load (kips)	Stress (ksi)	Displacement from Length Gage Reading at Coupler Top* (in.)	UT Length Reading on RV Stud End After Corrections (in.)
0	0.00	0.0000	88.0000
4	1.00	0.0053	88.0025
17	4.25	0.0224	88.0104
18	4.50	0.0230	88.0111
20	5.00	0.0264	88.0123

*The calculated stretch in the coupling stud and coupler are included.

The required gage pressure for the retensioner to develop the specified load of 20 kips shall also be determined from the ram and pressure gage calibration data.

10.2 RETENSIONING

The studs shall be retensioned in the same order of that shown in Appendix 2, Pages 2-1 through 2-4. The retensioning frame shall be installed as shown in Appendix 1, Page 1-8. First, the extensometer transducer shall be installed according to the manufacturer's instructions. The frame, pull rod and coupling shall then be placed over the stud.

The coupling and pull rod shall then be connected, taking care not to dislodge the transducer or to damage the cable from the transducer to the readout unit. After connecting the pull rod, caution must be exercised to ensure that the hollow-core hydraulic cylinder is centered on the pull rod and the frame and that all bearing surfaces are perpendicular to the pull rod. Care must also be taken to ensure that the frame does not rest on adjacent washers or on the RPV skirt fillets. When alignment is acceptable, the top nut of the pull rod shall be brought to a snugtight condition. When this is done, the ram extension shall be approximately 1 inch. Upon completion of the setup, hoses shall be checked to ensure that pressure gages are visible and no kinks exist The displacement gage shall be installed securely to the RPV and as shown in Appendix 1, Page 1-8. Retensioning may then begin as follows:

a. **Record the readings on the displacement gage and the extensometer**

b. **Gradually pressurize the system until it reaches the pressure equivalent to the specified loading of 20 kips per** stud on Unit 1. For Unit 2, the retensioning shall commence a minimum of 15 days after the detensioning of the last anchor stud. If the Unit 2 studs are to be retensioned 15 to 25 days after detensioning, the specified loading shall be 17 kips. If the Unit 2 studs are to be retensioned 26 to 40 days after detensioning, the specified loading shall be 18 kips. If more than 45 days, the specified loading shall be 20 kips.

c. Record the displacement gage and extensometer readings at that time

d. Bring the nut to a snugtight condition and release the load

e. Record the displacement gage and extensometer reading again

f. To compensate for relaxation, subtract the extensometer reading taken in Item e (above) from that taken in Item c (above). Add this difference to the readings taken in Item c and reload this stud until the displacement gage and extensometer reaches the total value. Bring the nut to a snugtight condition and release the load.

g. Recheck the displacement gage and extensometers to ensure that they are within ±5% of the readings taken in Item c above which correspond to the specified loading. Record the displacement gage and extensometer reading. If the values are not acceptable, repeat the retensioning of the particular stud.

h. Repeat this procedure on all studs

When retensioning of all bolts has been completed once, the load level shall be checked and adjusted in the following manner. For retensioning, the procedure shall follow in the same order of that given in Appendix 2, pages 2-1 through 2-4.

First, a complete set of extensometer readings shall be taken. The reference length of the respective stud obtained in 9.5c shall be dialed in to the instrument, and the existing stretch read and recorded. The existing load shall then be obtained as follows:

$$P_A = 20 \text{ kips} \quad X \quad \left(\frac{\Delta E_A}{\Delta E_C}\right)$$

where

P_A = the calculated actual load existing in the stud

ΔE_A = the measured stud extension (difference between remeasured length and initial length at zero load)

ΔE_C = the measured stud extension obtained with the 20 kip load in 10.2c

If P_A equals 20 kips ±10%, the load in the stud is acceptable. If P_A is less than 18 kips or greater than 22 kips, P_A shall be adjusted as follows: The values of P_A shall be submitted to Project Engineering. Project Engineering will calculate the UT extensometer deflection required for P_A to reach the specified load. The corresponding adjusted displacement gage reading including the stretch in the coupling stud will also be given. These data will then be used in the following procedure.

The retensioning frame shall be set up as described in Section 10.2. Initial readings in the extensometer and displacement gages shall be recorded. By dialing in the stud reference length, the initial extensometer extension reading should equal ΔE_A. Next, a plot of pressure versus length displacement shall be made. The ram shall be gradually pressurized. Extensometer readings shall be recorded, and length gage readings shall be recorded and plotted at 500 psi increments until the ram pressure is within 500 psi of the pressure required at P_A (the existing load in the bolt). Subsequently, readings shall be taken and plotted at 100 psi intervals.

The tensioning shall continue until the extensometer stretch is that required for P = 20 kips. The plotted curve should then show a change in slope at P_A, and the change in length gage reading from P_A to P = 20 kips should equal that calculated by project engineering. If this is not the case, notify project engineering. If the readings are correct, complete the tension adjustment by following the procedure outlined in Section 10.2, Items d, e, f, and g. This procedure shall be repeated until all measured elongations (loads) are within ±10% of that obtained at the specified load. This is considered to be equivalent to a stress of 5 ksi ±0.5 ksi.

When the actual loads have been found acceptable, the jam nuts shall be placed on the studs and tightened shortly before installation of the insulation on the Unit 2 RPV and a minimum of 30 days after all of the studs have been found acceptable and the jam nuts installed on additional set of two extensometer readings on each Unit 2 anchor stud shall be taken. These readings shall be reported to Project Engineering for review.

10.3 CHECK CALIBRATION OF RETENSIONING EQUIPMENT

Upon completion of the retensioning of the Unit 2 anchor studs, the calibration of the rams and pressure gages shall be checked as described in Section 8.1 and 8.2. Records shall be maintained as described in Section 8.4.

11.0 DETENSIONING UNIT 1 ANCHOR STUDS

11.1 PREPARATION

Anchor studs shall be prepared as described in Section 9.1.

11.2 INITIAL EXTENSOMETER READINGS

One set of extensometer readings shall be taken on the studs as described in Section 9.2. These values shall be recorded and are for project engineering information purposes only.

11.3 DETENSIONING

When the initial extensometer readings are taken, the jam nut can be removed from the stud and the stud can be detensioned. This shall be done in the order shown in Appendix 2. Detensioning is to be done using the retensioning frame without the displacement gages or extensometer installed.

12.0 RETENSIONING UNIT 1 ANCHOR STUDS

12.1 PREPARATION

Preparation for retensioning Unit 1 is as described in Section 10.1.

12.2 EXTENSOMETER READINGS

A complete set of extensometer readings shall be taken on the detensioned studs as described in Section 9.5.

12.3 RECALIBRATION

Before commencing Unit 1 anchor stud ram retensioning, the retensioning ram, pressure gage, and pump assembly shall be recalibrated as described in Section 8.2 or by checking the assembly in the strain gage frame shown in Appendix 1, Page 1-9. This frame shall have been previously calibrated by measuring the strain shown in the strain gages versus the applied load applied by a certified testing machine. Records shall be maintained as described in Section 8.4.

12.4 PROOF-TESTING

Designated studs in Unit 1 will require proof-testing to two times the maximum anticipated stress, but no higher than 344 kips. The proof test value and stud numbers will be given by project engineering before the start of retensioning. These proof test requirements will be determined upon review of the lift-off data from Unit 2.

The procedure is as follows. After the studs have been detensioned, two sets of extensometer readings shall be taken as described in Section 9.5. The Unit 2 detensioning frame shall be installed as described in Section 9.3 with the extensometer and dial gages in place. The load shall be brought to the given value in stages as determined by the extensometer capacity. When the load is at the proof-test value, it shall be held for 1 minute and then removed in stages as described in Section 9.4. A complete set of extensometer, pressure, and dial gage readings shall be recorded for this operation. Upon completion of the proof-testing of the Unit 1 anchor studs, the calibration of the rams and pressure gages shall be checked as described in Section 8.1. Records shall be maintained as described in Section 8.4.

12.5 RETENSIONING

Retensioning shall be done as described in Section 10.2. In addition to the anticipated readings shown in Section 10.1, the following are expected for studs which have a turned down shank with a gross area of 4.0 square inches. These studs have a centerpoint for machining.

Load (kips)	Stress (ksi)	Displacement Gage Reading (in.)	UT Length (in.)
0	0	0.0000	88.0000
4	1	0.0057	88.0029
20	5	0.0285	88.0144

12.6 RECALIBRATION

After completing Unit 1 retensioning, the ram and pressure gage calibration shall be rechecked as described in Section 8.2 or 12.3. If there is more than 2% variation between the load indicated by the previous calibration and the applied load, the load in the Unit 1 anchor studs shall be rechecked as described in Section 10.2 using the recalibration load versus pressure data.

13.0 DOCUMENTATION

On completion of the retensioning, a report shall be submitted to the project engineer listing the pressure, displacement gage, and extensometer readings occuring at:

a. Unit 2 lift-off

b. Unit 2 detensioning (each step) and proof-testing

c. Unit 2 retensioning

d. Unit 1 detensioning and proof-testing

e. Unit 1 retensioning

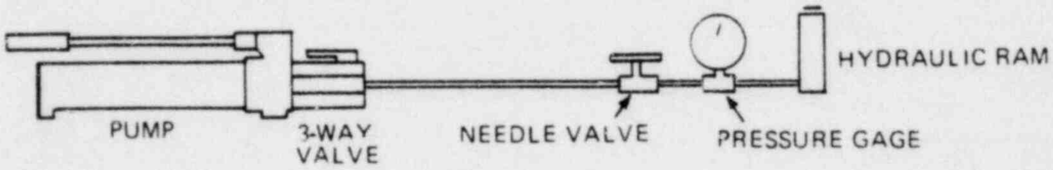
The report shall include a description of the operation, difficulties encountered, and pertinent remarks.

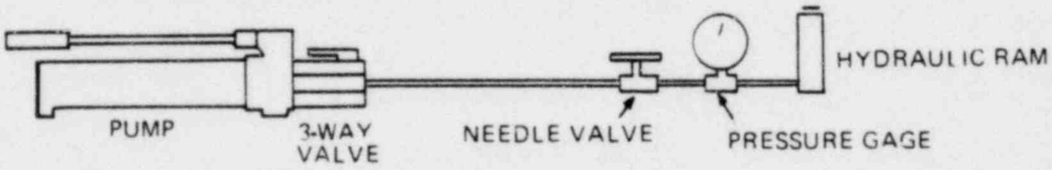
This information will be used by the project engineer and the consultant to explain scatter in the previous detensioning operation in Unit 1 and to certify that this tensioning operation ascertains that the anchor studs are at the specified load level.

APPENDIXES

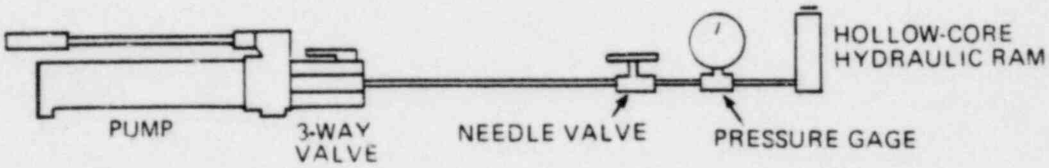
APPENDIX 1

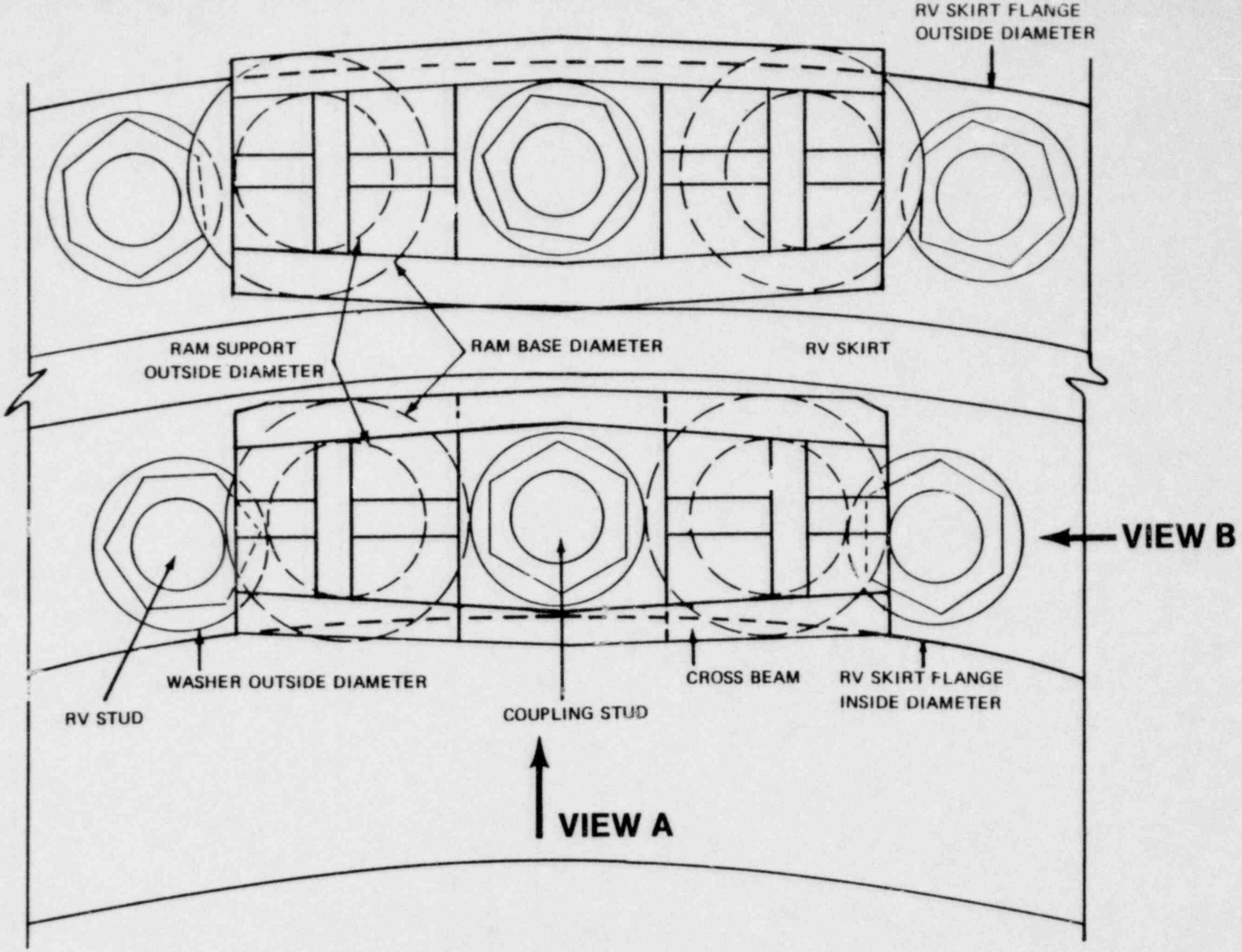
DETENSIONING SYSTEM



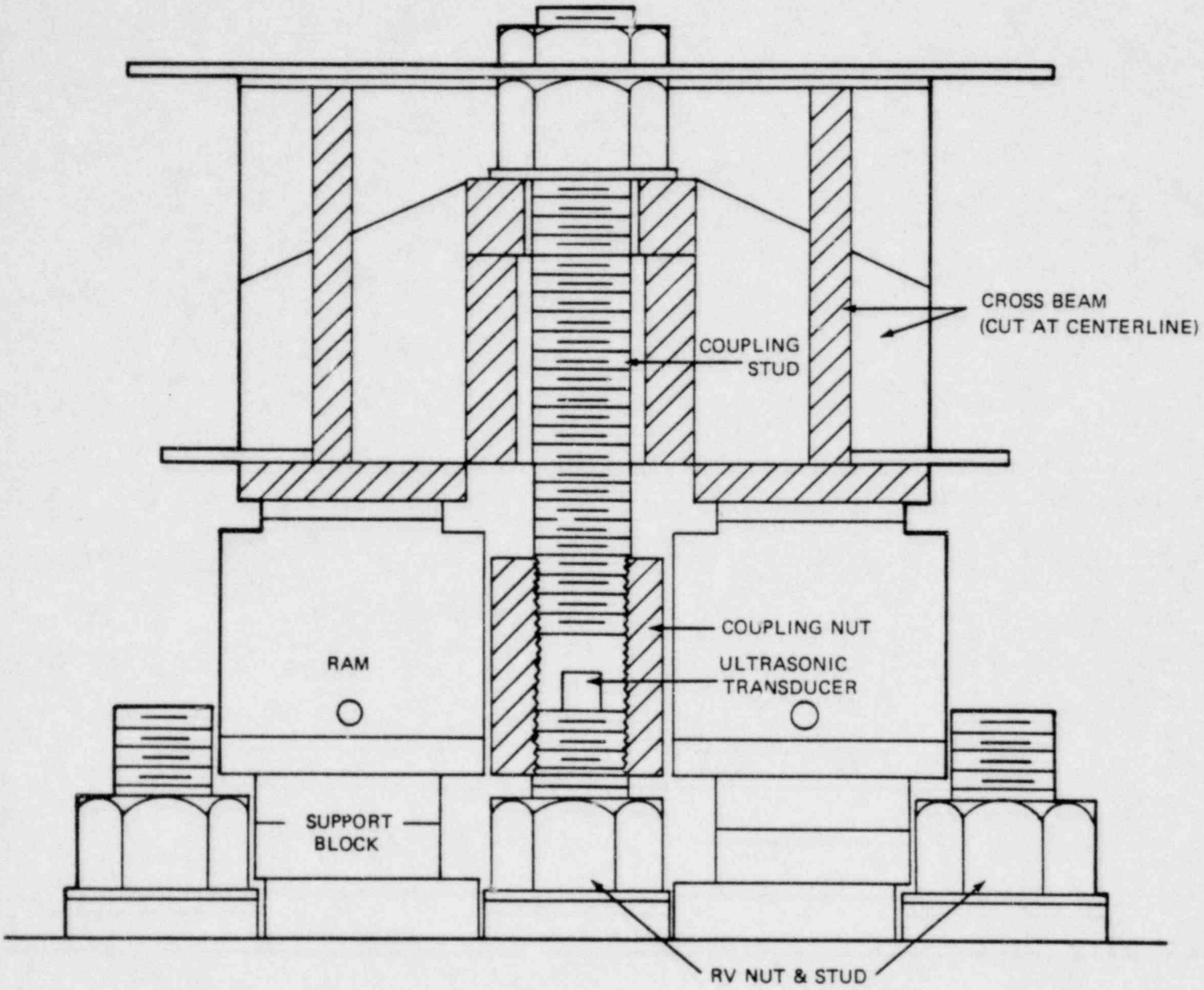


RETENSIONING SYSTEM



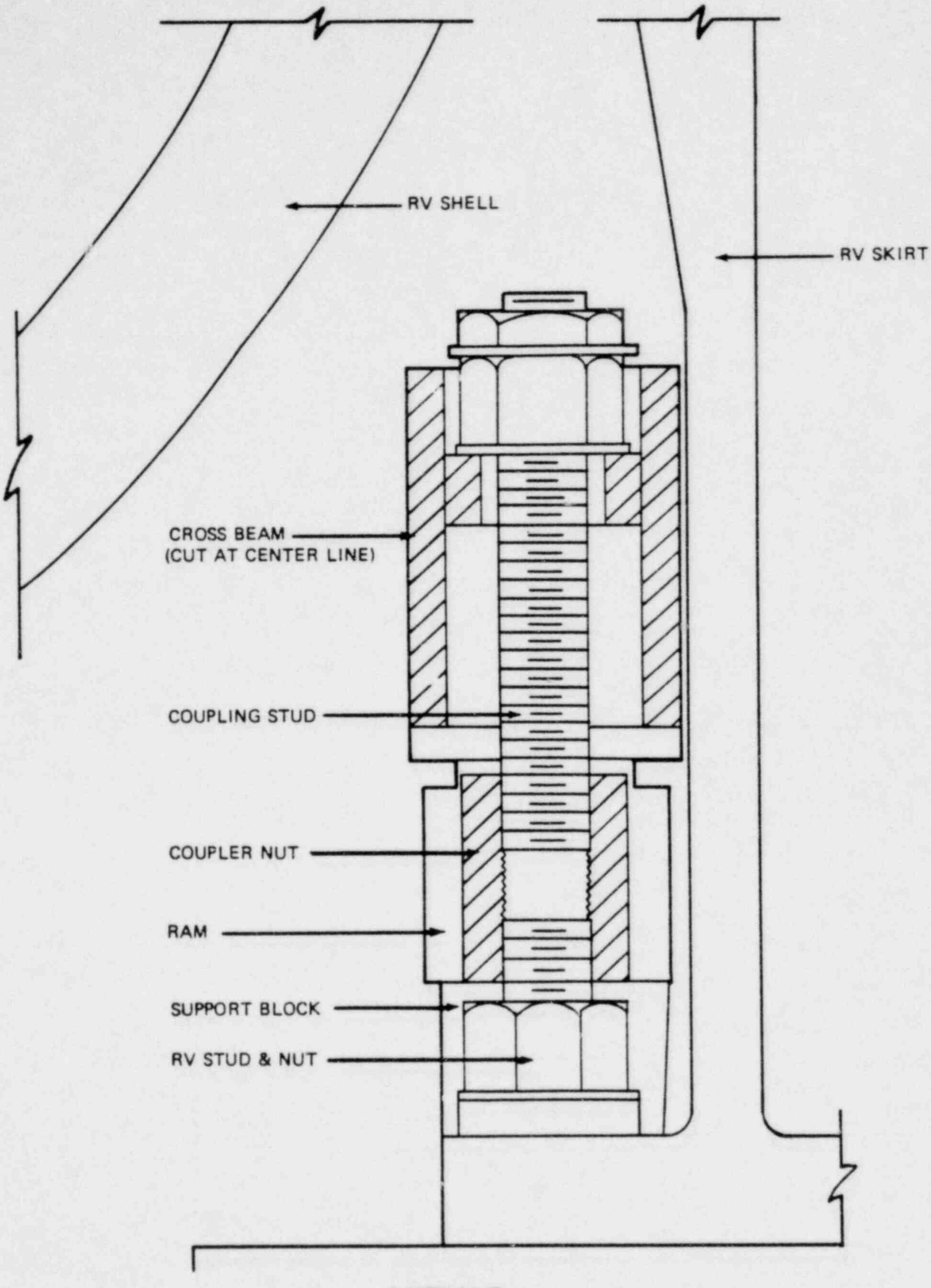


**DETENSIONING DEVICE
PLAN VIEW**



VIEW A

DETENSIONING DEVICE



VIEW B

DETENSIONING DEVICE

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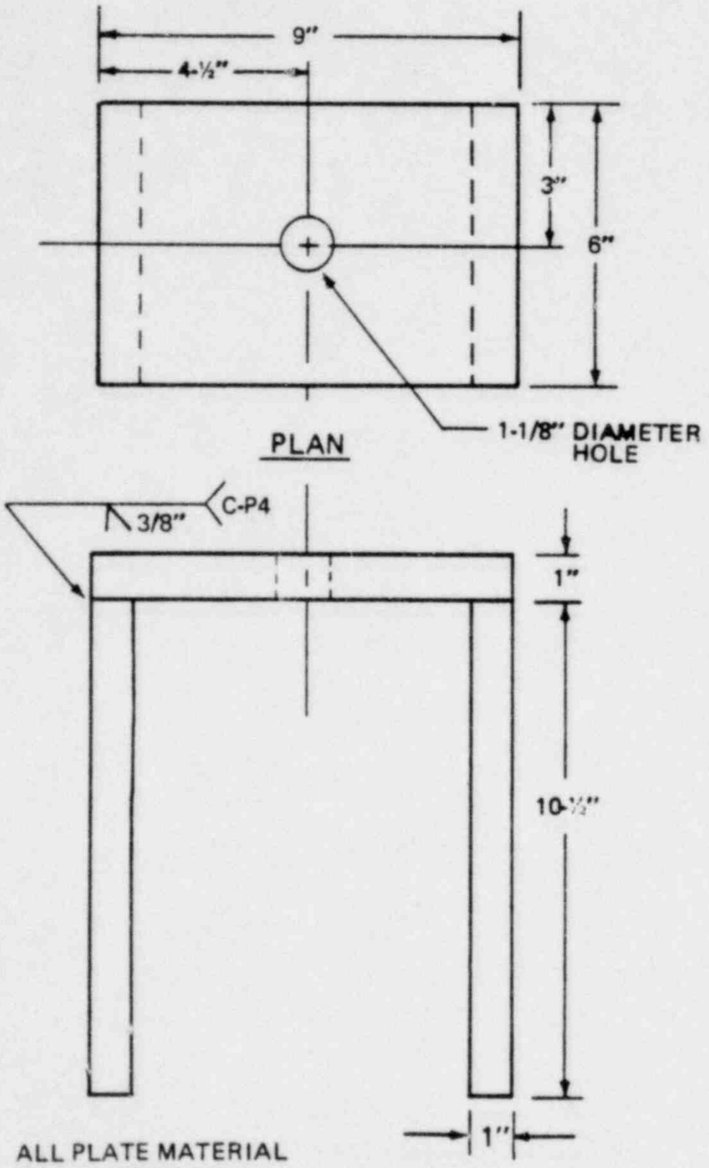
RETENSIONING FRAME

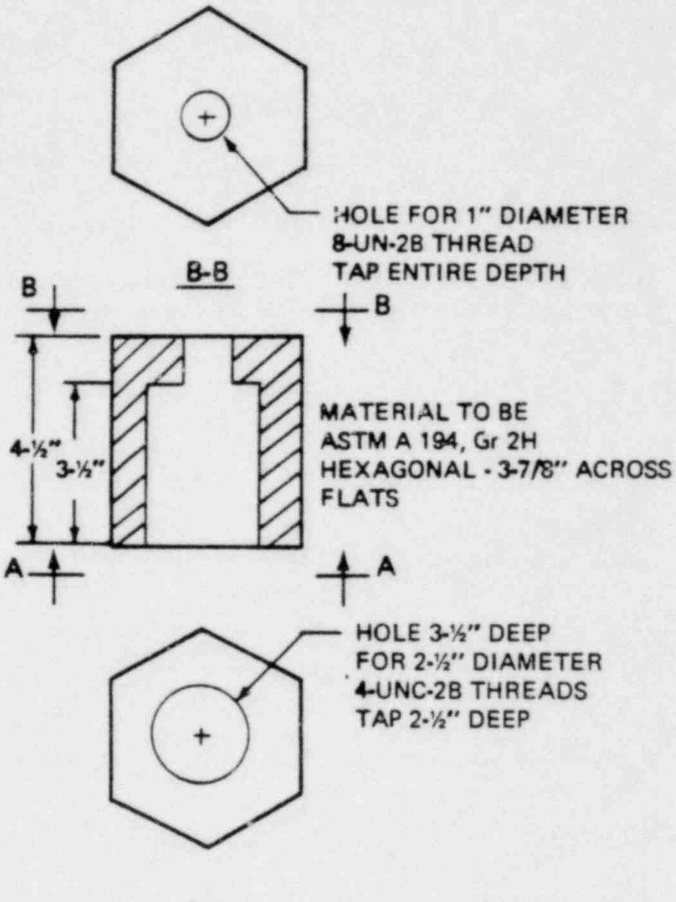


PLAN

ALL PLATE MATERIAL
TO BE ASTM A 36

ELEVATION

RAM SUPPORT FRAME



HOLE FOR 1" DIAMETER
8-UN-2B THREAD
TAP ENTIRE DEPTH

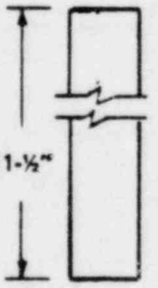
B-B

MATERIAL TO BE
ASTM A 194, Gr 2H
HEXAGONAL - 3-7/8" ACROSS
FLATS

HOLE 3-½" DEEP
FOR 2-½" DIAMETER
4-UNC-2B THREADS
TAP 2-½" DEEP

A-A

COUPLING NUT



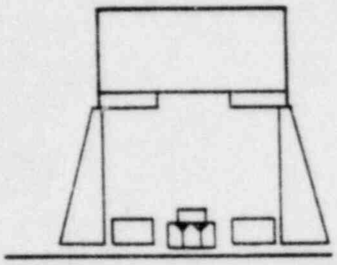
MATERIAL TO BE
1" DIAMETER 8-UN-2A
THREADS
ASTM A 490
A 354
or A 540
ANY GRADE

COUPLING STUD

DETENSIONING DEVICE

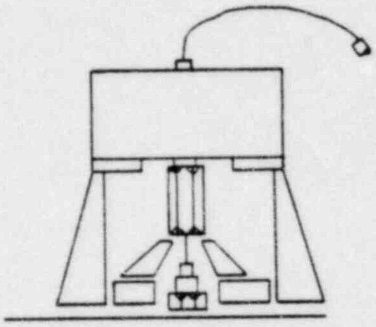
ASSEMBLY SEQUENCE

1)



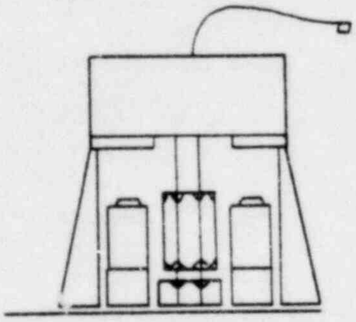
- BLOCK BEAM ABOVE STUD
- INSERT RAM SUPPORT BLOCKS
- INSERT NUT SOCKET RING

2)



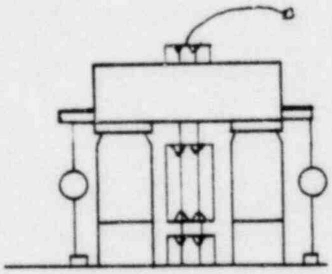
- INSERT & BLOCK STUD COUPLER
- ATTACH UT TRANSDUCER

3)



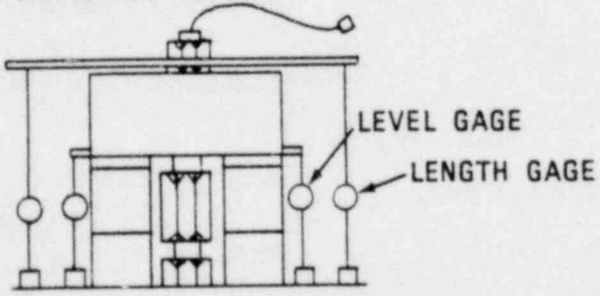
- ATTACH COUPLER
- INSERT RAMS

4)



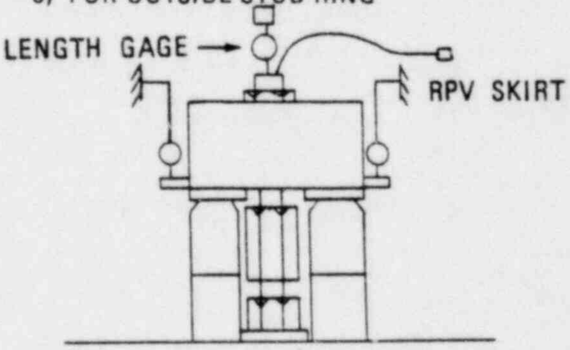
- UNBLOCK BEAM, REST ON RAMS
- MOUNT DISPLACEMENT INDICATORS & LEVEL BEAM, ATTACH TOP UNIT

5) FOR INSIDE STUD RING

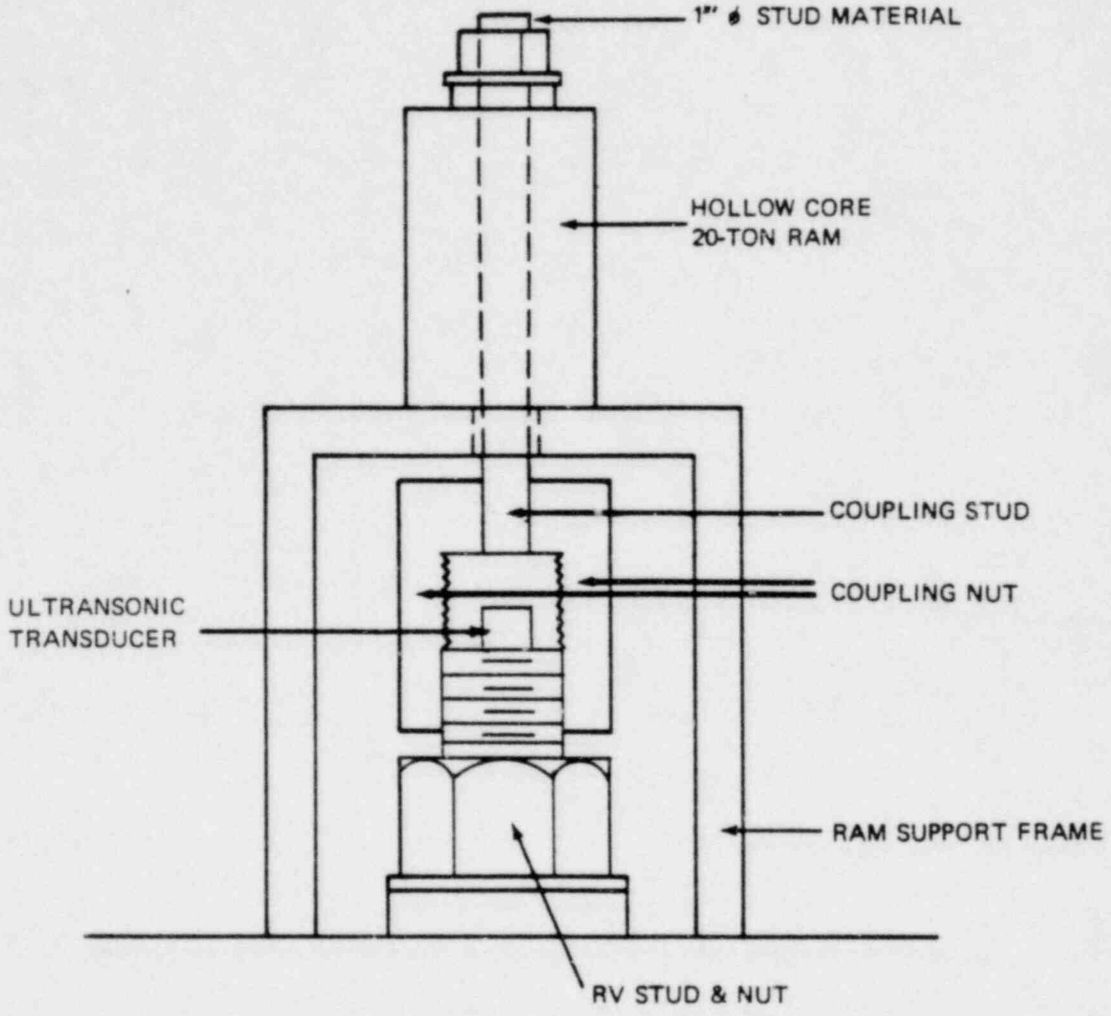


- PLACE ℄ ON TOP UNIT & FASTEN WITH JAM UNIT
- MOUNT DISPLACEMENT INDICATOR OFF ℄

6) FOR OUTSIDE STUD RING

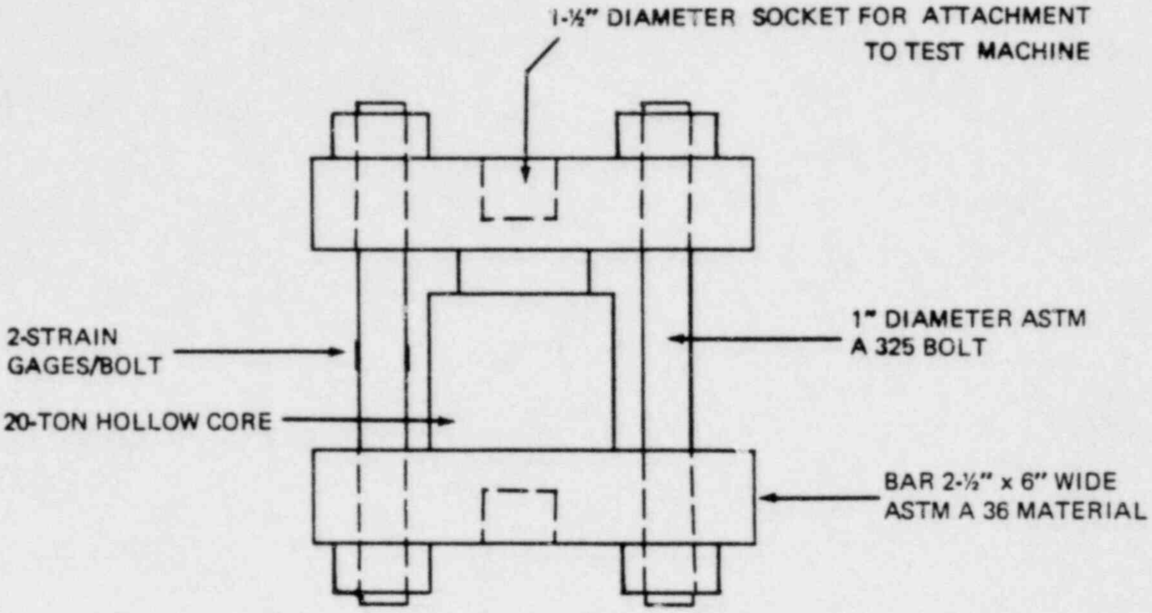


- MOUNT DISPLACEMENT INDICATOR ON TOP OFF COUPLER



RETENSIONING DEVICE

RECALIBRATION FRAME



NOTE:
CALIBRATE FRAME AND STRAIN GAGES IN TESTING MACHINE BEFORE USING TO CALIBRATE 20-TON RAM.

SCALE 3"=1'-0"

Appendix 2

TABLE 1

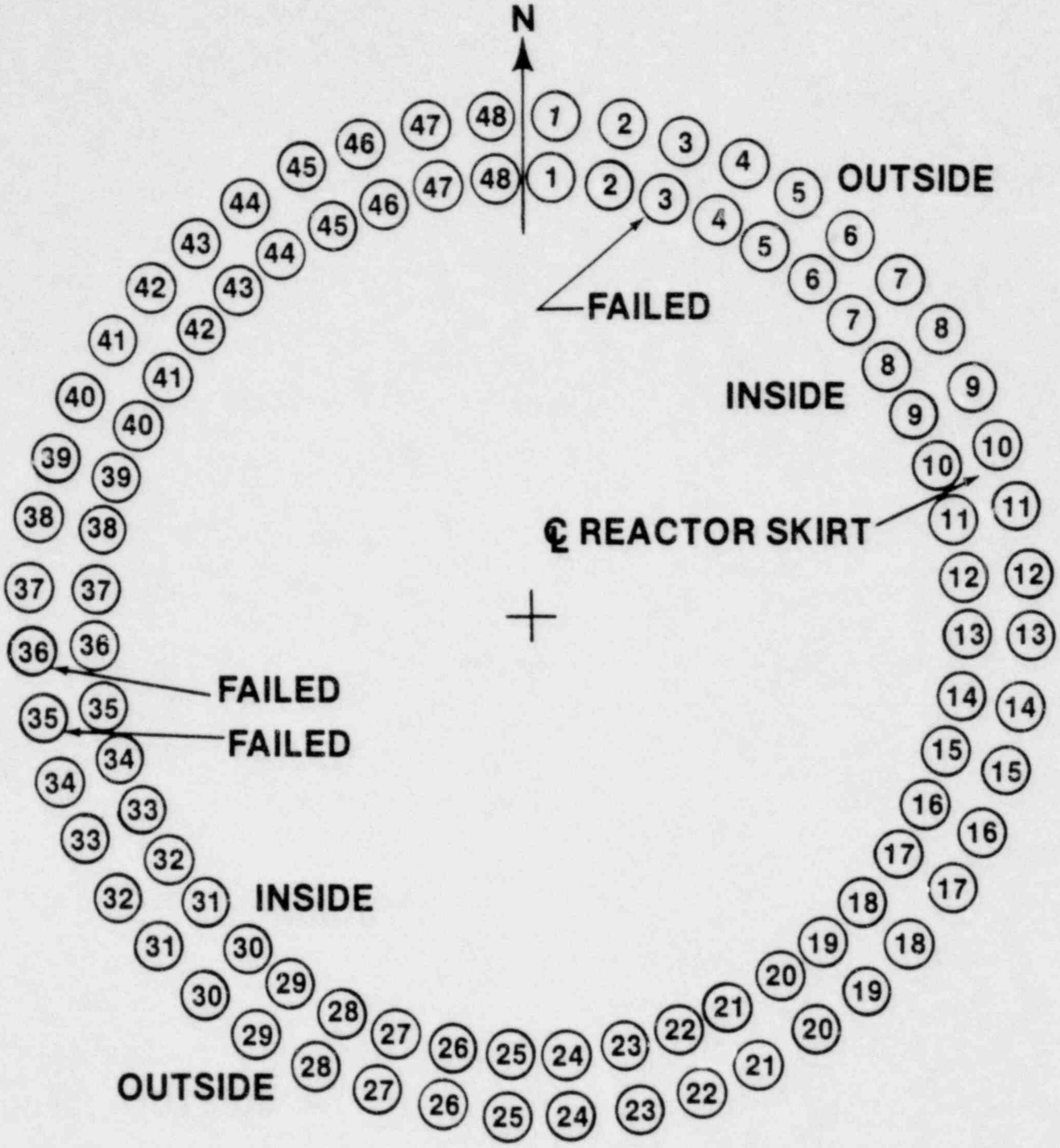
DETENSIONING AND RETENSIONING SEQUENCE

REACTOR VESSEL ANCHOR STUDS

	Bolt Number	
Sequence	B&W	Teledyne
1	01 in	37 in
2	02 in	13 in
3	03 in	01 in
4	04 in	25 in
5	01 out	37 out
6	02 out	13 out
7	03 out	01 out
8	04 out	25 out
9	05 out	43 out
10	06 out	19 out
11	07 out	07 out
12	08 out	31 out
13	05 in	43 in
14	06 in	19 in
15	07 in	07 in
16	08 in	31 in
17	09 in	40 in
18	10 in	16 in
19	11 in	04 in
20	12 in	28 in
21	09 out	40 out
22	10 out	16 out
23	11 out	04 out
24	12 out	28 out
25	13 out	46 out
26	14 out	22 out
27	15 out	10 out
28	16 out	34 out
29	13 in	46 in
30	14 in	22 in
31	15 in	10 in
32	16 in	34 in
33	17 in	38 in
34	18 in	14 in
35	19 in	02 in
36	20 in	26 in
37	17 out	38 out
38	18 out	14 out
39	19 out	02 out
40	20 out	26 out
41	21 out	44 out
42	22 out	20 out

	Bolt Number	
Sequence	B&W	Teledyne
43	23 out	08 out
44	24 out	32 out
45	21 in	44 in
46	22 in	20 in
47	23 in	08 in
48	24 in	32 in
49	25 in	41 in
50	26 in	17 in
51	27 in	05 in
52	28 in	29 in
53	25 out	41 out
54	26 out	17 out
55	27 out	05 out
56	28 out	29 out
57	29 out	47 out
58	30 out	23 out
59	31 out	11 out
60	32 out	35 out
61	29 in	47 in
62	30 in	23 in
63	31 in	11 in
64	32 in	35 in
65	33 in	39 in
66	34 in	15 in
67	35 in	03 in
68	36 in	27 in
69	33 out	39 out
70	34 out	15 out
71	35 out	03 out
72	36 out	27 out
73	37 out	45 out
74	38 out	21 out
75	39 out	09 out
76	40 out	33 out
77	37 in	45 in
78	38 in	21 in
79	39 in	09 in
80	40 in	33 in
81	41 in	42 in
82	42 in	18 in
83	43 in	06 in
84	44 in	30 in
85	41 out	42 out
86	42 out	18 out
87	43 out	06 out
88	44 out	30 out
89	45 out	48 out
90	46 out	24 out
91	47 out	12 out
92	48 out	36 out

Sequence	Bolt Number B&W	 Teledyne
93	45 in	48 in
94	46 in	24 in
95	47 in	12 in
96	48 in	36 in



POSITION AND NUMBERING OF STUDS IN UNITS 1 AND 2

APPENDIX B:

Procedure for Gap and Temperature Measurement at the Reactor Pressure Vessel Upper Lateral Support

APPENDIX B

PROCEDURE FOR

GAP AND TEMPERATURE MEASUREMENT

AT THE

REACTOR PRESSURE VESSEL

UPPER LATERAL SUPPORT

1.0 SCOPE

This appendix provides for the installation of equipment and the implementation of procedures necessary to measure the following while the nuclear steam supply system (NSSS) undergoes hot functional testing (HFT) (see Appendix 1, Page 1-2 for nomenclature):

a. The change in gap between the reactor vessel upper lateral support (ULS) and the reactor pressure vessel (RPV)

b. The corresponding change in ULS RPV surface and concrete surface temperature near the embedment.

This appendix does not specify the exact design of the electrical system (transducer, thermocouples, wiring, readout system, and other accessories) required to obtain and record the data. The intent of the appendix is to provide a system complete with all accessories sufficient to obtain the required data.

1.1 ITEMS INCLUDED

1.1.1 Supply, calibration, installation, and operation of thermocouples, distance-reading devices, and readout units. Supply of all associated wiring and other miscellaneous items required for obtaining measurements

1.1.2 Supply, installation, and removal of temporary shim pack replacement material

1.1.3 Collection of data from all instruments covered by this appendix.

1.1.4 Removal of all instruments and associated equipment and wiring upon completion of HFT

1.2 Intentionally left blank

2.0 Intentionally Left Blank

3.0 QUALITY STANDARDS

All procedures, calibrations, and measurements shall be in accordance with the requirements of a quality assurance program approved by the Midland Project Quality Assurance Department (MPQAD).

4.0 REFERENCED CODES AND STANDARDS

American National Standards Institute (ANSI) MC96.1

American Society for Testing and Materials (ASTM) B29-79 Standard Specification for Pig Lead

5.0 SUBMITTALS

The instrument supplier shall provide a complete description of all instruments, including method of operation, calibration, effect of temperature changes, wiring, accessories, and power required in its proposal for approval by project engineering. The supplier shall submit calibration procedures to project engineering for approval. Once calibration is completed, calibration data and certification of standards used shall be submitted for approval.

6.0 WORKING CONDITIONS

6.1 GENERAL

Work covered by this appendix is to be done during HFT for the Consumers Power Company Midland Plant Units 1 and 2 in Midland, Michigan. Hot functional tests are scheduled as follows:

Unit 1	May 1 to June 26, 1983
Unit 2	January 26 to March 22, 1983

Instruments for the gap and temperature measurement shall be installed before the HFT.

6.2 CONDITIONS OF SERVICE

The anticipated maximum temperature at the RPV surface is 530F. Although the reactor cavity air temperature will be lower, the distance measuring instruments, thermocouples and associated wiring shall be rated for use in the temperature range of 50° to 600° F and humidity range of 0 to 100%.

The recorders or readout units will be remote from the RPV in an area outside the reactor cavity and will be subject to changes in temperature and humidity during the testing period. The expected minimum and maximum temperatures are 50 and 120F, respectively.

7.0 GENERAL REQUIREMENTS

7.1 DEFINITIONS

a) Small distance transducers are a means of converting the physical movement of an object into an electrical signal. For purpose of this specification, the distances to be measured are less than 1 inch. The instruments are to be capable of resolving a movement of 0.001 inch. Two types of transducers are mentioned in this appendix: the eddy-current noncontacting type and the contacting type. The eddy-current noncontacting type works by producing magnetic fields which induce eddy currents in the adjacent target material. Changes in distance from the transducer to the target result in impedance changes in the active coil of the transducer, which can be measured and converted to a distance measurement. The contacting type transducer has a moveable spindle within a fixed coil assembly. When the spindle is displaced, a voltage change is produced, which can be measured and converted to a distance measurement.

b) The noncontacting transducer can be used remotely from the moving vessel by attaching a target of the same material as the vessel, at a fixed distance from the vessel.

c) Electronic ice point is a means of eliminating errors in thermocouple readings caused by changes in ambient temperature and internal thermal voltages generated in the readout instrument by referencing the thermocouple leads to a temperature of 0C or 32F.

7.2 GENERAL

As stated in Article 1.0, this document sets criteria for obtaining equipment and its calibration, installing the equipment, and establishing operation procedures to obtain the gap measurement between the ULS and the RPV and to obtain the RPV and ULS temperature at selected points during HFT. To measure the gap, temporary instrumentation consisting of small distance transducers installed on each ULS, their wiring, and readout units will be required. To obtain the RPV and ULS temperatures during HFT, a series of thermocouples installed on each ULS, their wiring, and readout devices will be required. Provisions will be made so that, if a portion of the system or one readout device fails, the amount of data lost will not invalidate the test.

7.3 Intentionally left blank.

7.4 BRACKET PREPARATION

The ULS, shall be complete with all coverplates, stiffeners, and machined faceplates in place and complete. The shim material shall be replaced by chemical lead 3/4-inch thick with additional stainless steel shims sufficient to bring the machined faceplate to 15/32 inch from the RPV at ambient temperature (see Section 8.2 and Appendix 1, Pgs. 1-1, 1-3, 1-4 and 1-5 for details). The lead shall be installed and the bolts connecting the faceplate to the end of the bracket shall be tightened to a snugtight condition. The gap between the RPV and the faceplate shall then be within +1/64 inch and -0.0 inch of the specified gap. The temperature of the RPV and ULS shall be recorded when the shims are installed and adjusted.

7.5 SHIELDING PREPARATION

The permanent concrete shield plug cover and the removable steel shield plug boxes, complete with filler material, will be completed and installed before the HFT.

7.6 THERMOCOUPLES

Five thermocouples are required at each ULS for a total of 60 per unit. One thermocouple shall be located on the RPV surface adjacent to the machined contact patch. The second shall be placed on the ULS web near the endplate. The third shall be placed midway along the ULS on the web. The fourth shall be placed on the embedment surface near the ULS web. The fifth shall be placed on the concrete surface adjacent to the embedment (see Appendix 1, Pgs. 1-1 and 1-3, for location). Thermocouples shall measure temperatures from 50 to 600F.

7.7 DISTANCE-MEASURING DEVICES

Each ULS requires two distance-measuring transducers (for a total of 24 per unit) of the contact or noncontacting type. The transducers shall be attached in the location shown in Appendix 1, Pages 1-1 and 1-4 or 1-5.

7.8 READOUT UNITS

Readout units may be strip type recorders and/or digital readout units. For the temperature readings, a single readout unit may read as many as 12 thermocouples (12 channels). For the distance measurements, a maximum of three ULS (six measurements) may be taken by one readout unit. If multiple measurements are taken by one readout unit, the unit shall be connected to the instruments so that failure of the readout unit or its wiring will not cause loss of all data from any group of three adjacent ULS. Instrument suppliers may propose data processors which will automatically record all output from the readout units simultaneously on paper. Relaxation in requirements for the number of readout units will be considered if the supplier can demonstrate acceptable reliability in its proposed unit.

7.9 WIRING

All wiring for the test instruments described in this specification is temporary. Wiring details and routing shall be determined in conjunction with the Consumers Power Company startup and testing group. Wiring in the reactor cavity shall be subject to the specified temperature and humidity (see Section 6.2). Types of wiring must be compatible with the instruments being used and the test conditions, and shall be reviewed by the instrument supplier. Sources and locations of temporary power shall be designated by the Consumers Power Company startup and testing group.

7.10 REACTOR PRESSURE VESSEL INSULATION

Before starting the HFT and after installing all instruments, all RPV insulation supplied by the Mirror Insulation Unit of Diamond Power shall be in place. This shall include any insulation required to seal the opening through which the ULS projects. Portions of this insulation may have to be removed later to remove the instrumentation and wiring. Supplying, installing, and removing the insulation is the responsibility of the NSSS supplier.

7.11 RELATED MEASUREMENTS

To relate the temperatures and distance measurements taken under this specification to operating conditions, temperature measurements of the reactor coolant system shall be recorded at reactor inlets and outlets. These data shall be recorded simultaneously with the thermocouple and distance readings. Additional reactor coolant system temperature measurements may be recorded between the thermocouple/distance readings.

7.12 CALIBRATION

All instruments to be used in accordance with this appendix shall be calibrated for use in the temperature range which will exist during the test. Each instrument supplier must furnish a calibration procedure for approval when instruments are purchased and shall produce a correction curve or demonstrate the means for the data to be corrected for temperature effects. Calibration procedures shall account for the temperature conditions and length and type of wire from the instrument to the readout unit. If an eddy-current, distance-measuring device is used, consideration for the target material is required in the calibration procedure. All calibrations must be traceable to the National Bureau of Standards (see Section 9.2).

8.0 MATERIALS

8.1 PERMANENT MATERIALS

Permanent materials are to be installed by others as specified in the design drawings or by the NSSS and insulation vendors. The exception is the shim pack between the endplate and the RPV faceplate (see Appendix 1, Pages 1-3, 1-4 and 1-5).

8.2 SHIM PACK

A 3/4 inch thick portion of the permanent shim stack material (ASTM A-240, stainless steel). shall be replaced for the duration of the HFT with chemical lead meeting the requirements of

ASTM B 29-79. The initial size and shape of the lead shall be as shown in Appendix 1, Page 1-6.

In the test shim pack, the lead shim shall be located between two 1/8 inch thick stainless steel shims. Additional stainless steel shims of various thicknesses will be added to bring the gap to the predetermined value (see Section 7.4). All stainless steel shims used in the test shim pack shall have the same configuration as those used for final construction.

8.3 THERMOCOUPLES

Thermocouples (60 plus 6 spares per unit) shall be Cement-on Thermocouples, Style III, ANSI Designation K Chromel-Alumel or E Chromel-Constantan or equivalent. Extension wire shall be chosen to match thermocouple type and layout to ensure sufficient signal output to sensing, sending (if required), and recording devices. Thermocouple and extension wire insulation shall be fused teflon, tape-teflon-impregnated glass, or equivalent suitable for continuous use to 600F. Cement to attach thermocouples to ULS, embedment and concrete shall be two-part thermocoat copper oxide cement. Cement to attach thermocouples to the RPV surface shall be Omega CC sodium silicate cement or equivalent. The brand name products discussed in this paragraph are supplied by Omega Engineering, Inc. The instrument supplier may propose alternative systems for review and approval by project engineering.

8.4 DISTANCE-MEASURING SYSTEMS

Systems shall include transducers, cables, power supplies, sending units (if required), readout units, and all necessary accessories.

8.4.1 Distance-measuring devices (24 and 2 spares per unit) shall be eddy-current, noncontacting type or contacting type transducers. The devices shall have a range from 0 to 1 inch. The transducer will be rated for service in a temperature range of 50 to 600F.

8.4.2 Power supplies shall be compatible with the transducer and the available temporary power. The electrical power for no more than six transducers shall be supplied from the same power circuit.

8.4.3 Cables shall be supplied with sufficient length to reach from the ends of the ULS to the readout and data acquisition area.

8.4.4 The distance-measuring system shall be calibrated throughout the given temperature range. The eddy-current system, if used, shall be calibrated using a target of the same material as the RPV (see Section 9.2.2 for the calibration procedure).

The instrument supplier may propose alternative or modified devices or materials if it deems them more suitable.

8.5 READOUT UNITS

Readout units shall be one of, or a combination of, the following: strip type chart recorders, digital readout indicator, multipoint recorders, data loggers, or alternative proposals by the instrument suppliers. Their range shall be from 0 to 650F for temperature, and 0 to 1 inch for linear displacement. They shall be capable of being read to the nearest 1.0F for temperature, and to 0.001 inch when measuring distance. When multichannel units are used to reduce the number of readout instruments required, input data from no more than three ULS shall be read or recorded on one instrument. At least four separate systems shall be used to record the data (see Section 7.8).

The readout system shall be compatible with the thermocouples, transducers, power supplies, wiring, and operating conditions present during the HFT. The instrument supplier shall provide complete details on its proposed system, including all instruments and accessories required and all equipment and power to be supplied by others.

Possible data collection systems include:

a) Strip type chart recorders with one to three channels using such accessories as the Dataplex 10 Automatic Signal Scanner, expander/marker and pen lift, electronic ice point, amplifiers, and two-wire transmitters as supplied by Omega Engineering, Inc

b) Digital readout indicators in combination with multipoint selectors, amplifiers, and transmitters may be used; electronic ice point and other accessories are to be supplied, if necessary, by Omega Engineering, Inc.

A tranducer indicator similar to Model 1002-0010 with eight-channel output can be used for displaying contacting type transducer data. These are as supplied by Trans-Tek, Inc.

The eddy-current noncontacting transducer is part of a measurement system which includes a digital readout. The instrument supplier could provide multiple readout units for a combination of as many as eight transducers. Such a system is supplied by Kaman Science Corporation.

c) A recording device, such as Digistrip by Kaye Instruments, may be considered for use provided that the supplier can demonstrate the recorder's reliability to the satisfaction of project engineering.

d) Alternative proposals shall be submitted for project engineering approval. The instrument supplier must provide complete data on devices to be used, as well as all required accessories and wiring. The supplier shall provide technical data necessary to assess sensitivity, range, and accuracy of all instruments as well as their suitability for use in this application. The supplier shall also describe all requirements for the proper operation of its equipment (see Section 5.0).

9.0 INSTALLATION AND TESTING

9.1 SEQUENCE OF WORK

Work shall be performed in the following sequence:

a) Calibrate (in the laboratory) distance-measuring devices and thermocouples as specified in Section 9.2

b) Install distance-measuring devices and thermocouples

c) Test installed devices for proper operation

d) Install power supplies, readout unit wiring, and associated accessories

e) Test and calibrate the measuring system in place

f) Complete RPV insulation

g) Hot functional test Unit 2 (January 1983)

h) Hot functional test Unit 1 (May 1983)

i) Remove testing equipment

9.2 CALIBRATION

9.2.1 Thermocouples shall be calibrated such that the output voltages at standard temperatures in the range of 50 to 600F are within ANSI MC96.1 error limits for the thermocouple type supplied. A minimum of three thermocouples shall be checked by heating the thermocouples through the range of 50 to 600F, allowing them to cool to 50F, and plotting the output voltage against the actual temperatures (indicated by a calibrated standard) at 25F intervals throughout the range. This heating and cooling sequence shall be repeated a second time to show repeatability. The three thermocouples used in the calibration shall be of the same type and from the same production run as those to be supplied.

Calibration procedures and certification of standards shall be submitted to project engineering for approval, as described in Section 5.0. All standards must be traceable to the National Bureau of Standards. Alternative calibration methods based on recognized standards or codes may be prepared and used with prior project engineering approval. Calibration data shall be submitted, as described in Section 5.0, to project engineering for review and approval before installing any thermocouples.

9.2.2 Transducers shall be calibrated as follows.

The transducer shall be attached to a section of 1-1/2-inch thick plate in the same manner in which it will be attached to the ULS during the HFT. A target or rod of the same type to be used in the actual test shall also be mounted on the plate. The transducer, its mounting plate, target, or rod shall be installed in a furnace or oven capable of bringing the unit to a uniform temperature and holding it at 50F and at intervals of 50 to 500F. The temperature shall be held at each data point for 2 minutes. The transducer shall be connected to a readout unit of the same type to be used in the actual test. The rod from the target or the transducer shall extend out of the furnace in such a manner that it can be deflected by a calibrated micrometer or dial gage through the design range of the transducer (see Appendix A, page 8 for suggested arrangement of test apparatus). Plots shall be made of actual deflection versus indicated deflection for increments a minimum 0.025 inch and a maximum 0.05 inch. Three sets of readings shall be taken at each temperature. The readings at each point are not acceptable if they vary by more than 0.005 inch. Nonconforming transducers shall be adjusted or repaired and recalibrated or replaced with a calibrated transducer. At temperatures beyond the normal operating range of the transducer, the actual deflection may vary considerably from the measured deflection. This variation must be consistent and predictable at each point of measurement.

Calibration procedures shall be submitted to project engineering for review and approval before commencing calibration. All measurements will be traceable to the National Bureau of Standards. Calibration results are to be submitted to project engineering for review and approval, as specified in Section 5.0, before installing any instruments.

9.3 INSTALLATION

9.3.1 Transducers shall be installed with 10 gage sheet metal brackets screwed to the ULS sideplate. The bracket shall hold the transducer by a clamp or other means suited to the transducer design. In either case, the attachment shall be positive, have essentially zero deformation, and shall not relax with time or heat. The transducer contact rods or (if used) targets shall be inserted through the 1/2 inch diameter holes in the ULS bearing plates.

Refer to Appendix 1, Pages 1-4 and 1-5, for transducer location details. Care shall be taken to ensure that the transducer is installed so that it may detect RPV movement through the range of 0 to 0.5 inch.

9.3.2 Thermocouples shall be installed with cement suitable for approximately 600F. Suggested cements are Thermocoat and Omega CC high-temperature cement by Omega Engineering Inc. Refer to Appendix 1, Page 1-3 for thermocouple locations.

9.3.3 Wiring shall be installed as recommended by the instrument supplier. Wiring in the reactor cavity which is subject to heat shall be protected or coated as recommended by instrument suppliers. Although the wiring is temporary, it shall be neatly tied to supports, protected from abrasion, and installed so it will not fail during the test period. All connections shall be protected consistent with good electrical practice to ensure continuous system operation during the test.

9.3.4 Readout instruments shall be located in the area designated by the Consumers Power Company startup and testing group. Equipment shall be neatly installed.

9.3.5 The location of all instruments shall be documented according to the instrument serial number. Wiring diagrams shall be made which indicate the instrument number, power supply circuit, accessories, and readout unit and which trace the physical path of the wiring. The ULS shall be designated as shown in Appendix 1, page 1.

9.4 TESTING

As instruments are installed, they shall be checked for proper operation. Transducers and thermocouples installed according to Sections 9.3.1 and 9.3.2 shall be checked using a temporary readout unit and circuit to ascertain their proper operation by measuring the actual contact temperature and by displacing the transducer through a known deflection. Readings shall be verified using calibrated standards traceable to the National Bureau of Standards.

When instruments are installed and wiring completed, all circuits, instruments, and readout devices shall be checked for proper operation as described above. Calibrated standards shall be used to verify proper system functioning.

The above described activities shall be performed according to procedures reviewed and approved by project engineering.

Complete documentation shall be maintained on all tests, repairs, modifications, and other corrective actions required to verify system operation.

9.5 HOT FUNCTIONAL TEST, UNITS 1 AND 2

9.5.1 The HFT shall be carried out based on information provided by Consumers Power Company startup and testing group. *

9.5.2 The sequence of temperature versus time during the HFT shall be as shown in Appendix 1, Sheet 9.

9.5.3 Temperature and distance data shall be recorded as follows: *

Readings shall be taken at the beginning, middle, and end of each temperature hold and at the midpoint of all transitions as the temperature rises and falls (refer to Appendix 1, Page 1-9). A minimum of one set of readings shall be taken each 12 hours.

9.5.4 All equipment failures shall be reported to the project engineer. The failure shall be corrected if possible. Because each HFT goes through two cycles of heating and cooling, all instrument failures shall be corrected between the first and second cycles if possible, without unacceptable delay of the HFT.

9.5.5 A complete set of data shall be transmitted to the project engineer after the first RCS heating and cooling cycle is complete. This shall include the temperature of the RCS coolant at the inlets and outlets. The location of the RCS coolant temperature sensors shall be given and the data shall be referenced to the date and time of day. These temperatures shall be recorded simultaneously with the thermocouple and distance readings required by this procedure.

9.5.6 When the Unit 2 HFT is completed, the test will be reviewed by project engineering. At that time, all failures and sequence of data recording shall be reviewed. If it is believed that the system should be modified in any way to provide reliable data, these modifications shall be made before starting the Unit 1 HFT. If it is believed that more or less data are required, the test procedure shall be modified to accommodate these requirements. All procedural modifications shall be reviewed and approved by project engineering.

9.5.7 Project engineering shall be informed of the status of the installation and testing at all times. Project engineering shall be advised before the testing is scheduled to begin. A representative of project engineering shall be present at the start and for the duration of the HFT.

10.0 WORK TO FOLLOW

10.1 ENGINEERING

When project engineering receives the HFT data, the temperatures will be compared to those predicted by analysis for operating conditions. These predicted temperatures may vary at different locations on the RPV. The distances measured during HFT will then be proportioned to operating temperatures. This will verify the specified gap in existence at operating temperature, and will confirm the gap required at cold shutdown.

When the cold shutdown gap is verified, the information will be added to the applicable drawing and the shims will be installed to bring the ULS faceplate to the required gap.

10.2 CLEAN UP

When HFT is complete, all transducers and wiring shall be removed from the reactor cavity. Any temporary attachments for supports shall also be removed. The area shall be left in a clean condition as determined by Consumers Power Company startup and testing.

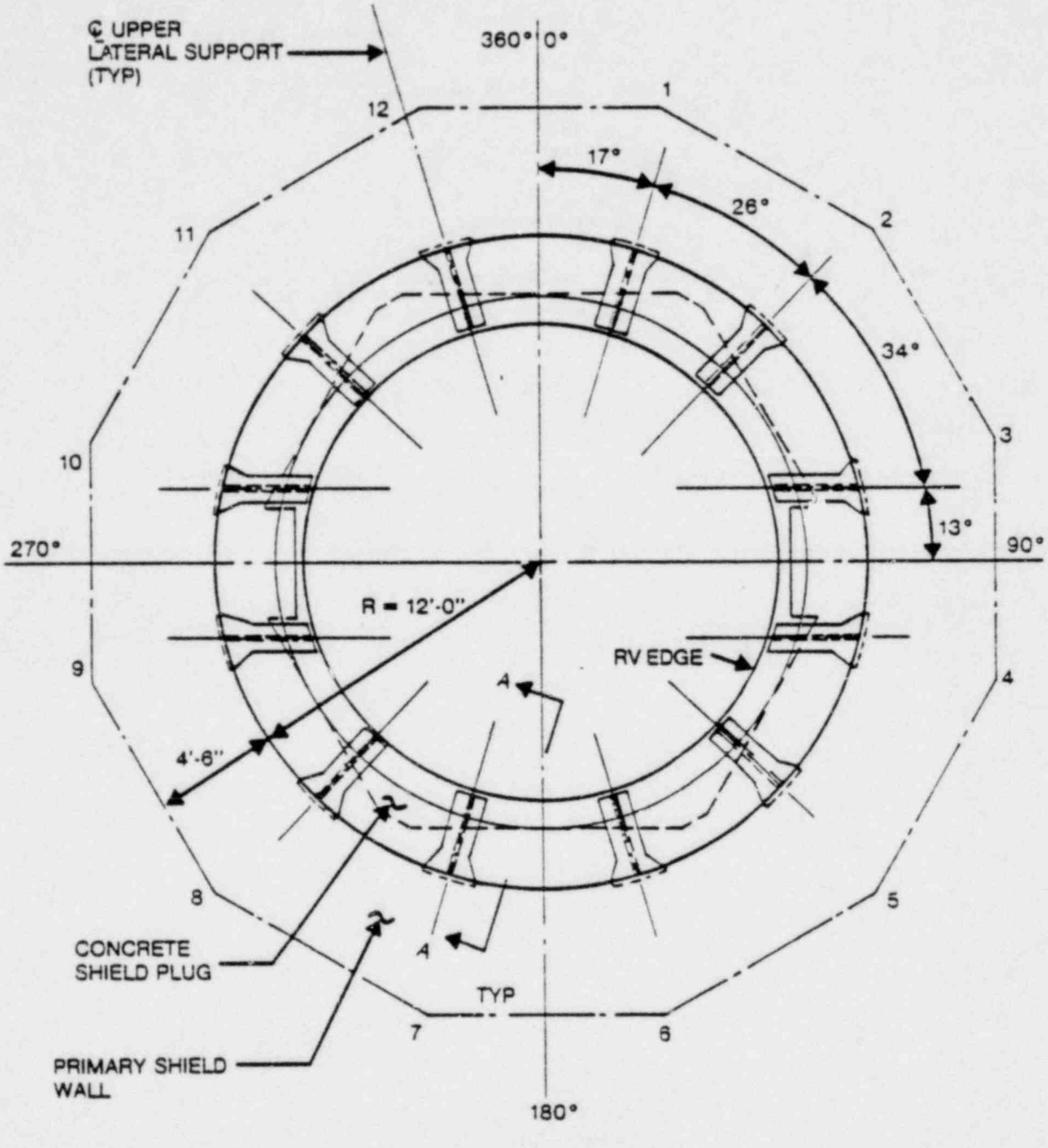
10.3 OTHER CONSIDERATIONS

Gap and temperature measurement during Unit 1 HFT shall be carried out in a similar manner as Unit 2. Project engineering will review both the data collected during Unit 2 HFT and the test operation. Changes in procedures for setting gaps and changes in equipment will be made, if necessary.

10.4 EQUIPMENT REMOVAL

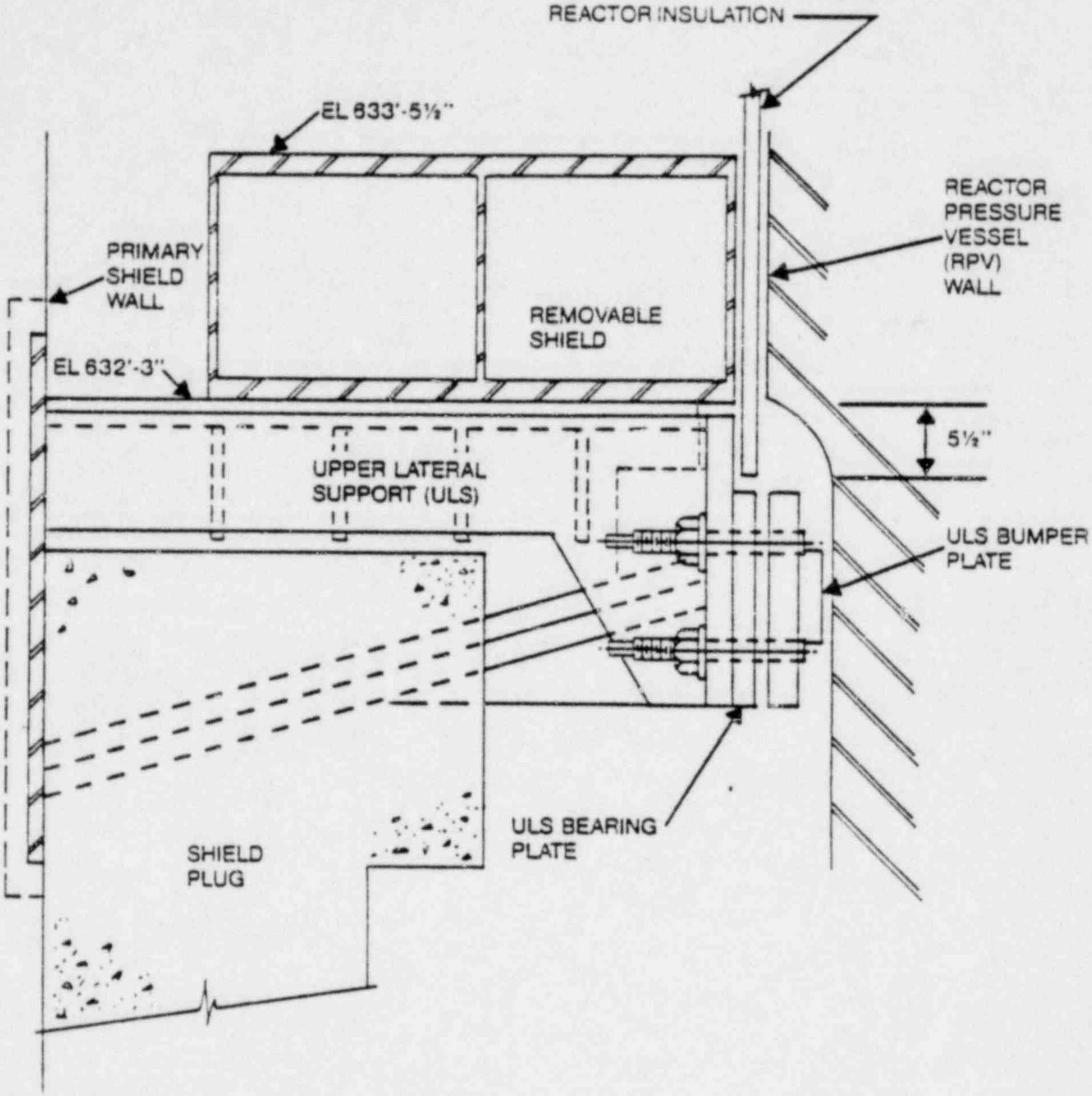
All equipment and wiring used for the gap and temperature measurement shall be removed from the containment building at a time to be designated by Consumers Power Company startup and testing.

APPENDIX 1

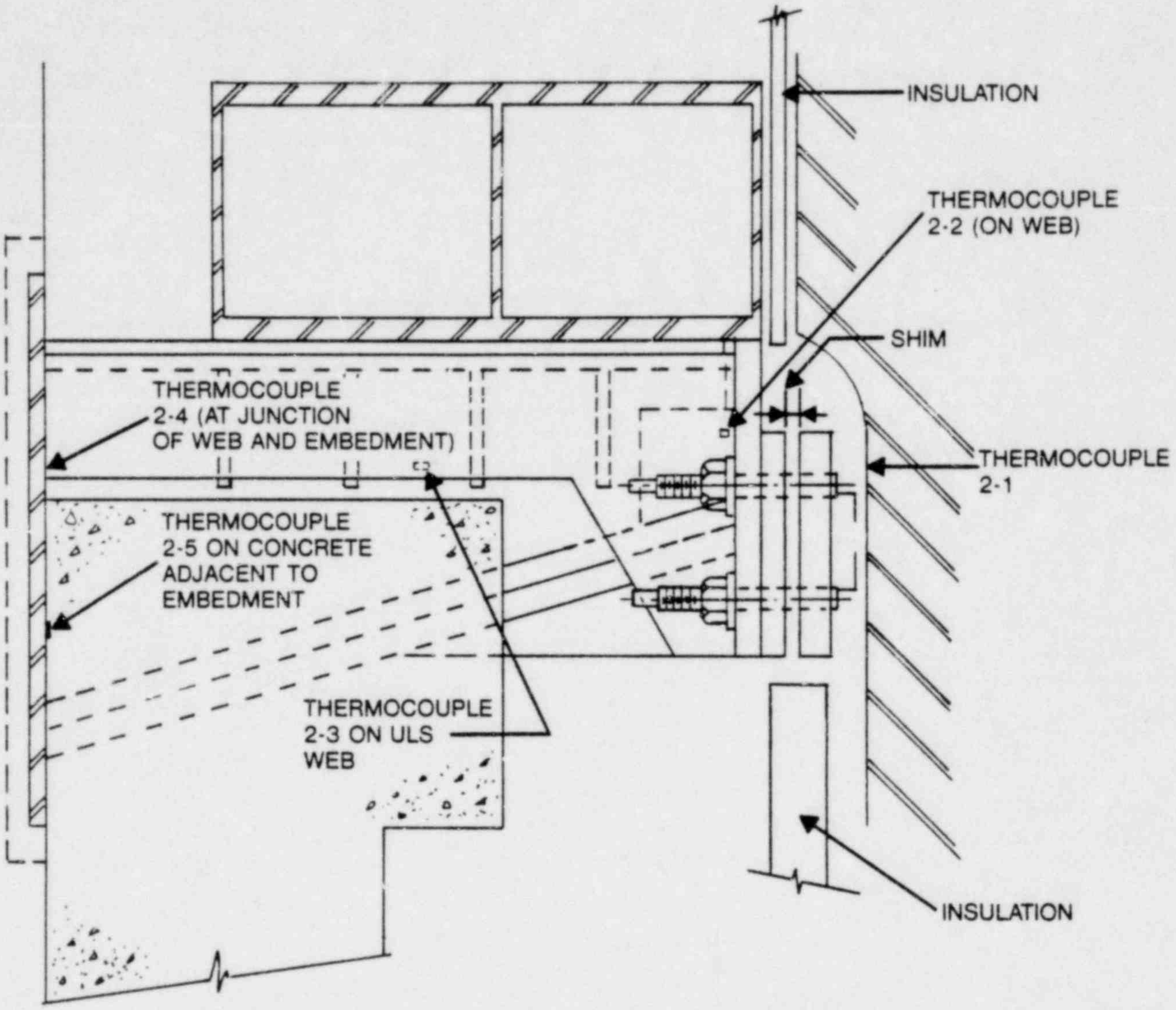


UPPER LATERAL SUPPORT PLAN
AND NUMBERING SYSTEM

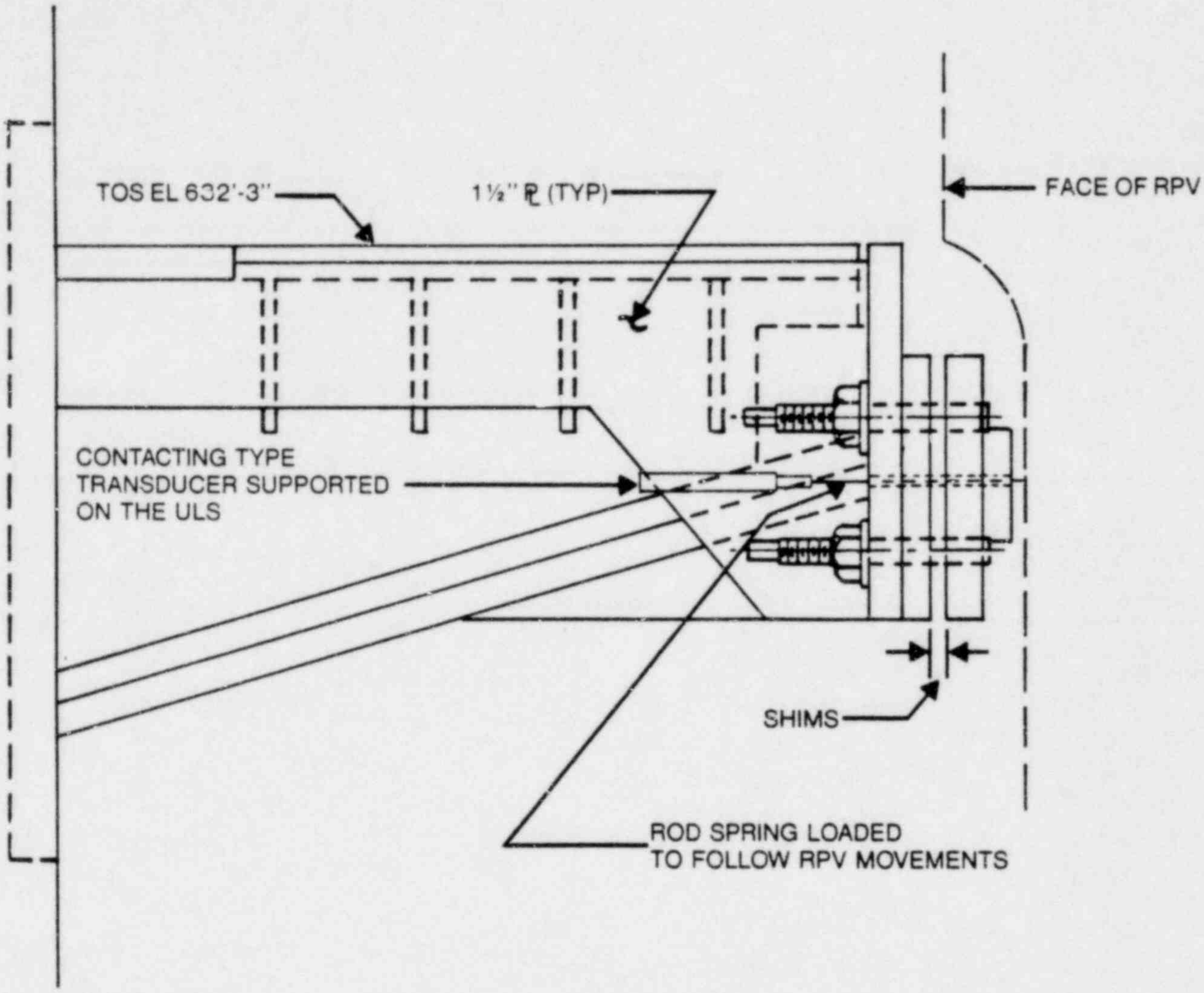
UNIT 1 SHOWN, UNIT 2 OPPOSITE HAND



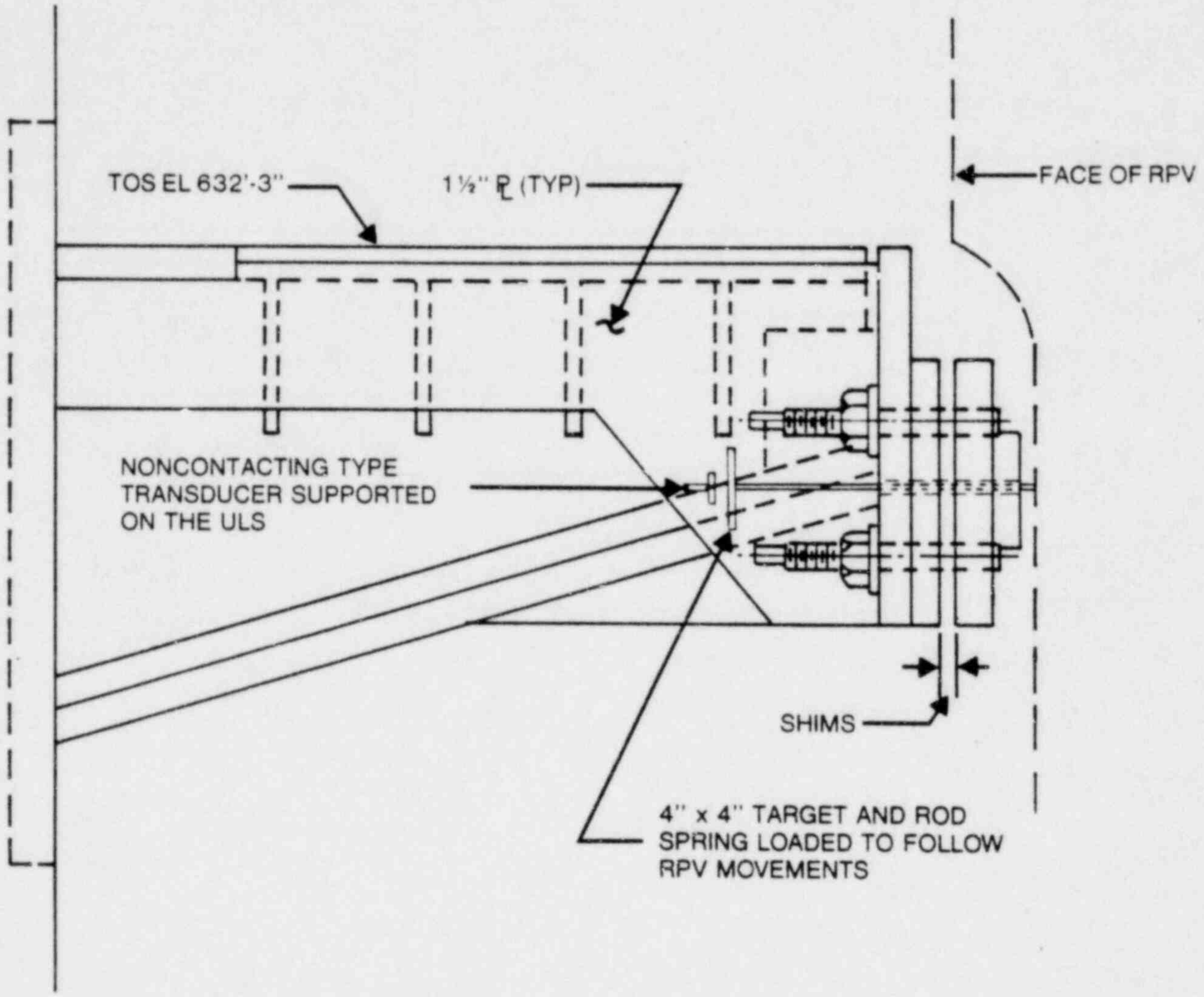
SECTION A-A
NOMENCLATURE



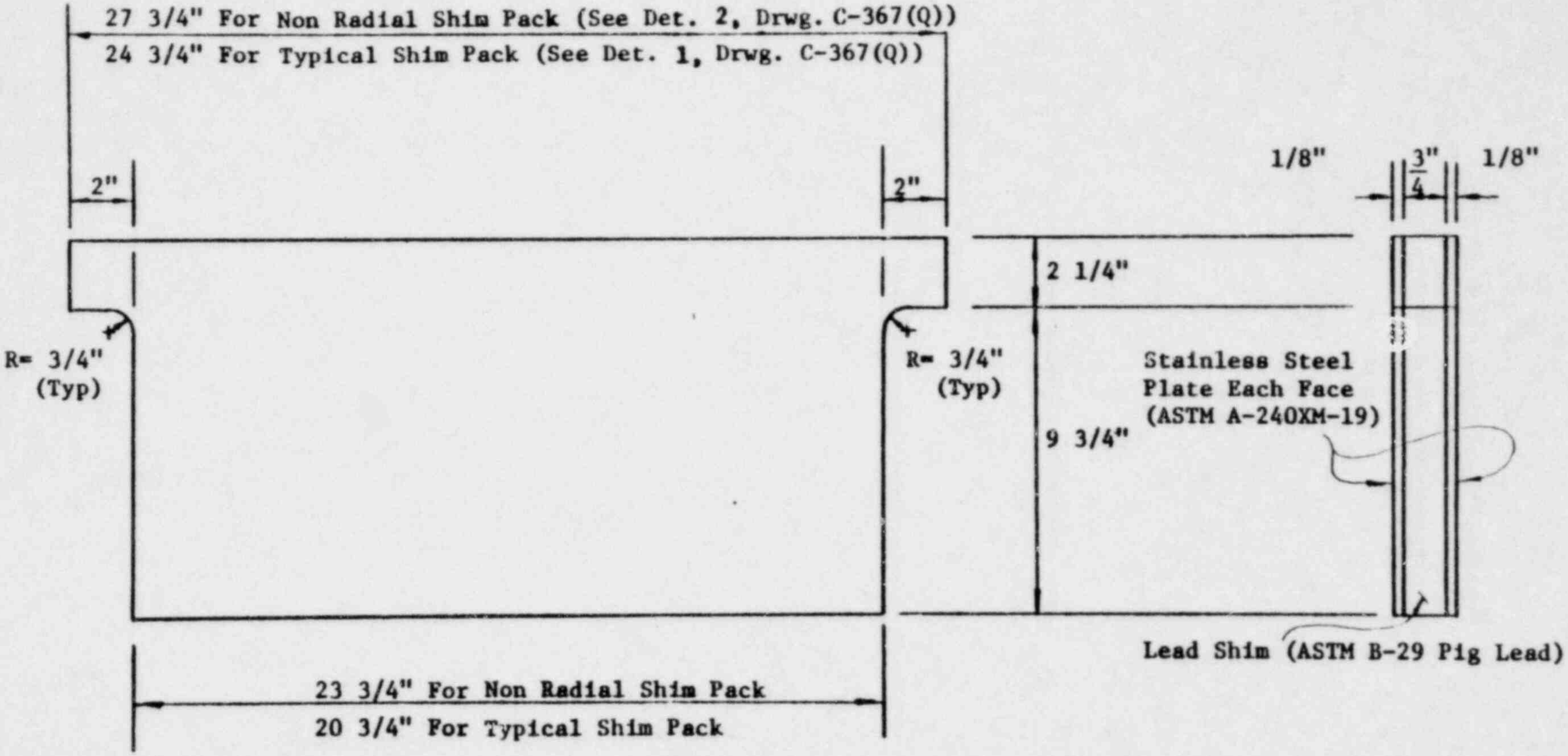
SECTION A-A
THERMOCOUPLE LOCATIONS
SHOWN FOR ULS NO. 2
(5 UNITS PER ULS)



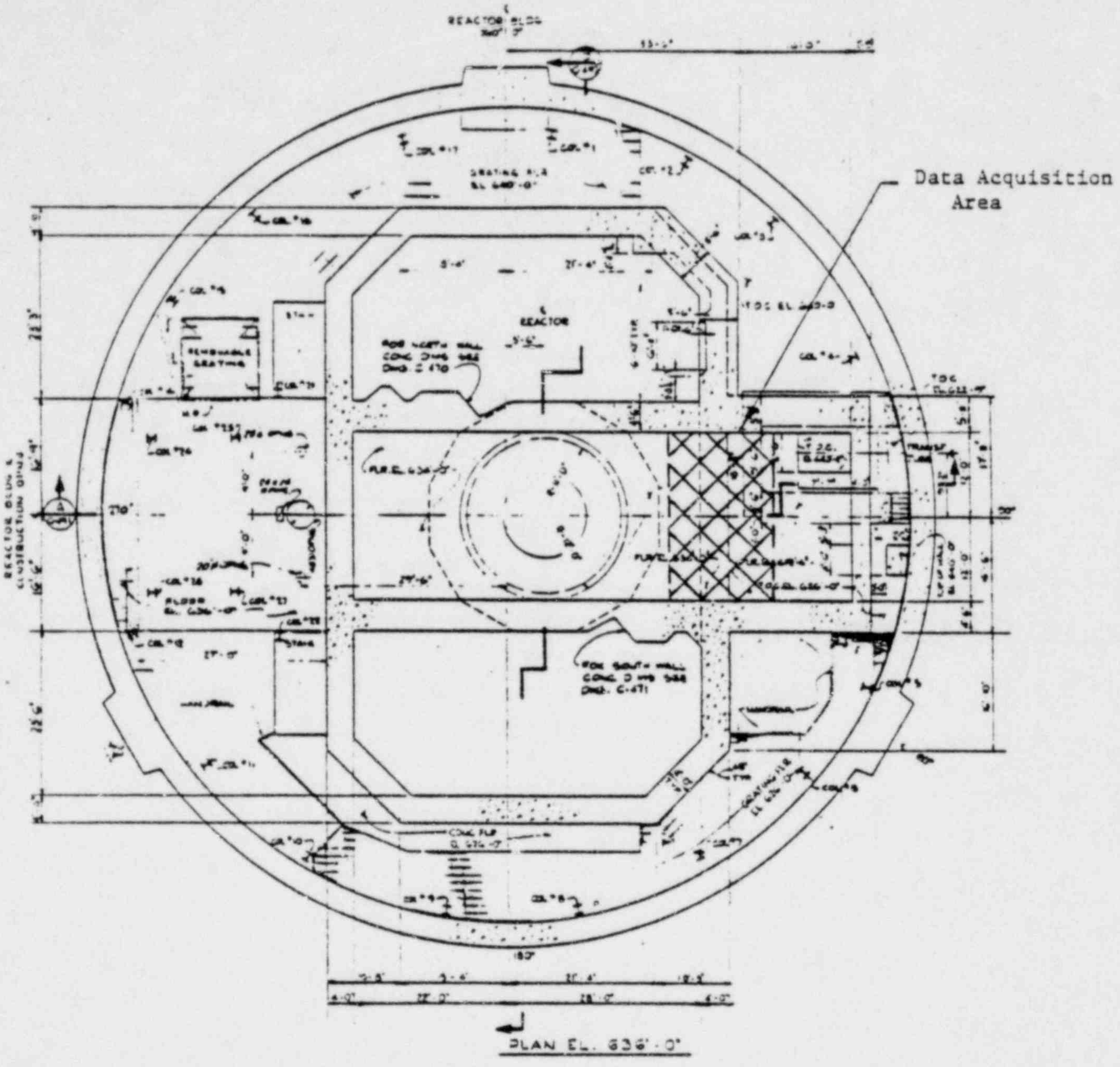
SECTION A
CONTACTING TYPE
TRANSDUCER
(2 UNITS PER ULS)



SECTION A-A
NONCONTACTING TYPE
TRANSDUCER
(2 UNITS PER ULS)



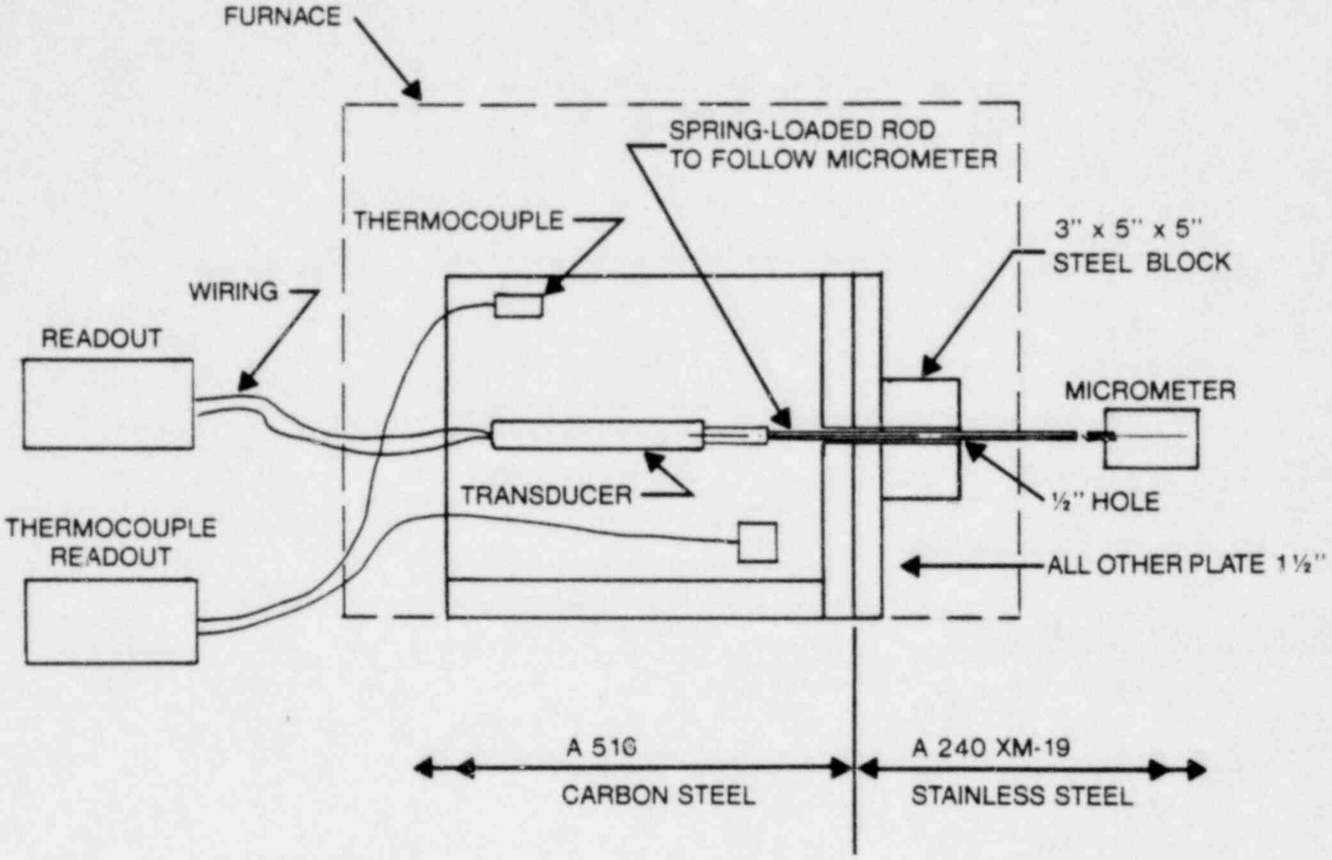
LEAD SHIM
For Test Shim Pack



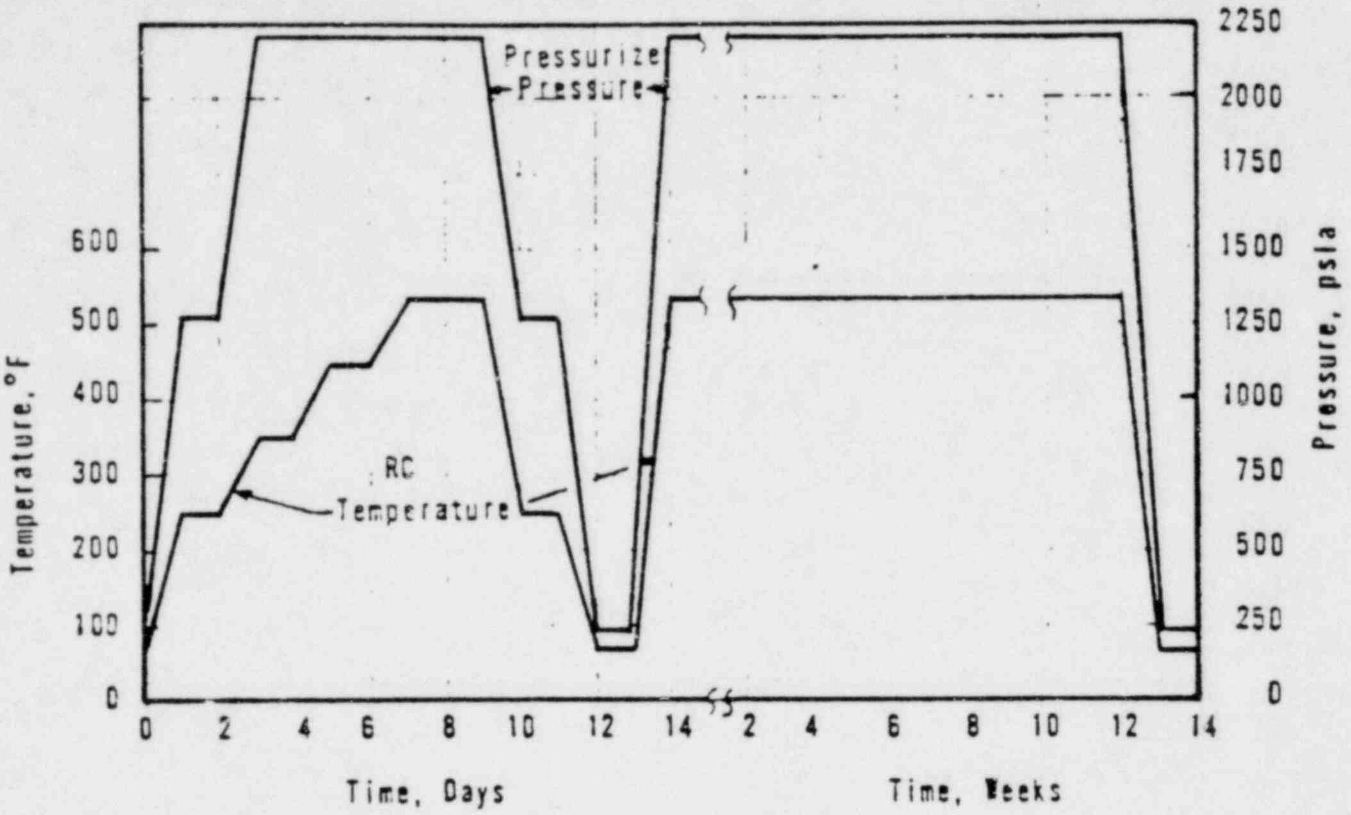
DATA ACQUISITION AREA

LOCATION

(UNIT 1 SHOWN, UNIT 2 OPPOSITE HAND)



SUGGESTED CALIBRATION SETUP



HOT FUNCTIONAL TESTING RC TEMPERATURE AND PRESSURIZER PRESSURE

APPENDIX C:

Unit 1 Anchor Stud Lift-Off Data

TABLE C1

UNIT 1 REACTOR VESSEL ANCHOR STUDS

Lift-Off Data

Stud Number (2)			Date	Hydraulic Pressure (psig) 1	Bolt Stress to Nearest ksi
Sequence	B&W	Teledyne			
1	01 in	37 in	4-08	13,000	88
2	02 in	13 in	4-23	11,900	81
3	03 in	01 in	4-25	13,400	91
4	04 in	25 in	5-19**	9,300	63*
5	01 out	37 out		8,000	54*
6	02 out	13 out		12,500	85
7	03 out	01 out		10,800	73*
8	04 out	25 out	5-12	8,400	57
9	05 out	43 out	5-13	12,500	85
10	06 out	19 out	5-13	12,500	85
11	07 out	07 out	5-13	13,400	91
12	08 out	31 out	5-14	13,800	94
13	05 in	43 in	5-14	12,300	83
14	06 in	19 in	5-14	11,500	78
15	07 in	07 in	5-15	12,000	81
16	08 in	31 in	5-15	11,400	77
17	09 in	40 in	5-16	12,300	83
18	10 in	16 in	5-16	11,700	79
19	11 in	04 in	5-19	13,700	93
20	12 in	28 in	5-19	12,400	84

TABLE C1 (Continued)

21	09 out	40 out	5-20	12,200	83
22	10 out	16 out	5-20	12,500	85
23	11 out	04 out	5-20	13,000	88
24	12 out	28 out	5-21	12,300	83
25	13 out	46 out	5-21	12,800	87
26	14 out	22 out	5-21	11,500	78
27	15 out	10 out	5-21	12,300	83
28	16 out	34 out	5-22	12,600	85
29	13 in	46 in	5-22	11,100	75
30	14 in	22 in	5-22	12,100	82
31	15 in	10 in	5-23	9,300	63*
32	16 in	34 in	5-23	13,100	89
33	17 in	38 in	5-23	11,600	79
34	18 in	14 in	5-27	9,500	64*
35	19 in	02 in	5-27	13,300	90
36	20 in	26 in	5-27	9,600	65*
37	17 out	38 out	5-28	12,500	85
38	18 out	14 out	5-28	12,300	83
39	19 out	02 out	5-29	14,000	95
40	20 out	26 out	5-29	12,100	82
41	21 out	44 out	5-30	12,200	83
42	22 out	20 out	5-30	12,300	83
43	23 out	08 out	6-17	12,300	83
44	24 out	32 out	6-18	12,300	83
45	21 in	44 in	6-18	12,800	87
46	22 in	20 in	6-18	10,900	74*
47	23 in	08 in	6-19	12,300	83
48	24 in	32 in	6-19	12,400	84

TABLE C1 (Continued)

49	25 in	41 in	6-20	12,200	83
50	26 in	17 in	6-20	11,800	80
51	27 in	05 in	6-20	13,000	88
52	28 in	29 in	6-23	12,800	87
53	25 out	41 out	6-23	12,500	85
54	26 out	17 out	6-24	12,700	86
55	27 out	05 out	6-24	8,900	60*
56	28 out	29 out	6-25	12,500	85
57	29 out	47 out	6-25	10,200	69
58	30 out	23 out	6-25	12,200	83
59	31 out	11 out	6-26	12,200	83
60	32 out	35 out		BROKEN	
61	29 in	47 in	6-26	11,900	81
62	30 in	23 in	6-27	12,400	84
63	31 in	11 in	6-27	11,800	80
64	32 in	35 in	6-27	11,600	79
65	33 in	39 in	7-02	11,700	79
66	34 in	15 in	7-02	11,700	79
67	35 in	03 in		BROKEN	
68	36 in	27 in	7-03	12,300	83
69	33 out	39 out	7-03	12,100	82
70	34 out	15 out	7-03	12,300	83
71	35 out	03 out	7-07	12,000	81
72	36 out	27 out	7-07	10,300	70*
73	37 out	45 out	7-07	12,600	85
74	38 out	21 out	7-08	12,500	85
75	39 out	09 out	7-08	12,200	83
76	40 out	33 out	7-08	13,600	92

TABLE C1 (Continued)

77	37 in	45 in	7-09	13,000	88
78	38 in	21 in	7-09	11,500	78
79	39 in	09 in	7-09	12,200	83
80	40 in	33 in	7-10	13,200	90
81	41 in	42 in	7-10	11,800	80
82	42 in	18 in	7-10	12,500	85
83	43 in	06 in	7-11	10,200	69*
84	44 in	30 in	7-11	12,300	83
85	41 out	42 out	7-11	12,200	83
86	42 out	18 out	7-14	10,400	71*
87	43 out	06 out	7-14	11,800	80
88	44 out	30 out	7-14	11,700	79
89	45 out	48 out	7-15	13,100	89
90	46 out	24 out	7-15	10,400	71*
91	47 out	12 out	7-15	11,700	79
92	48 out	36 out		BROKEN	
93	45 in	48 in	7-16	12,500	85
94	46 in	24 in	7-16	11,900	81
95	47 in	12 in	7-16	12,100	82
96	48 in	36 in	7-17	11,700	79

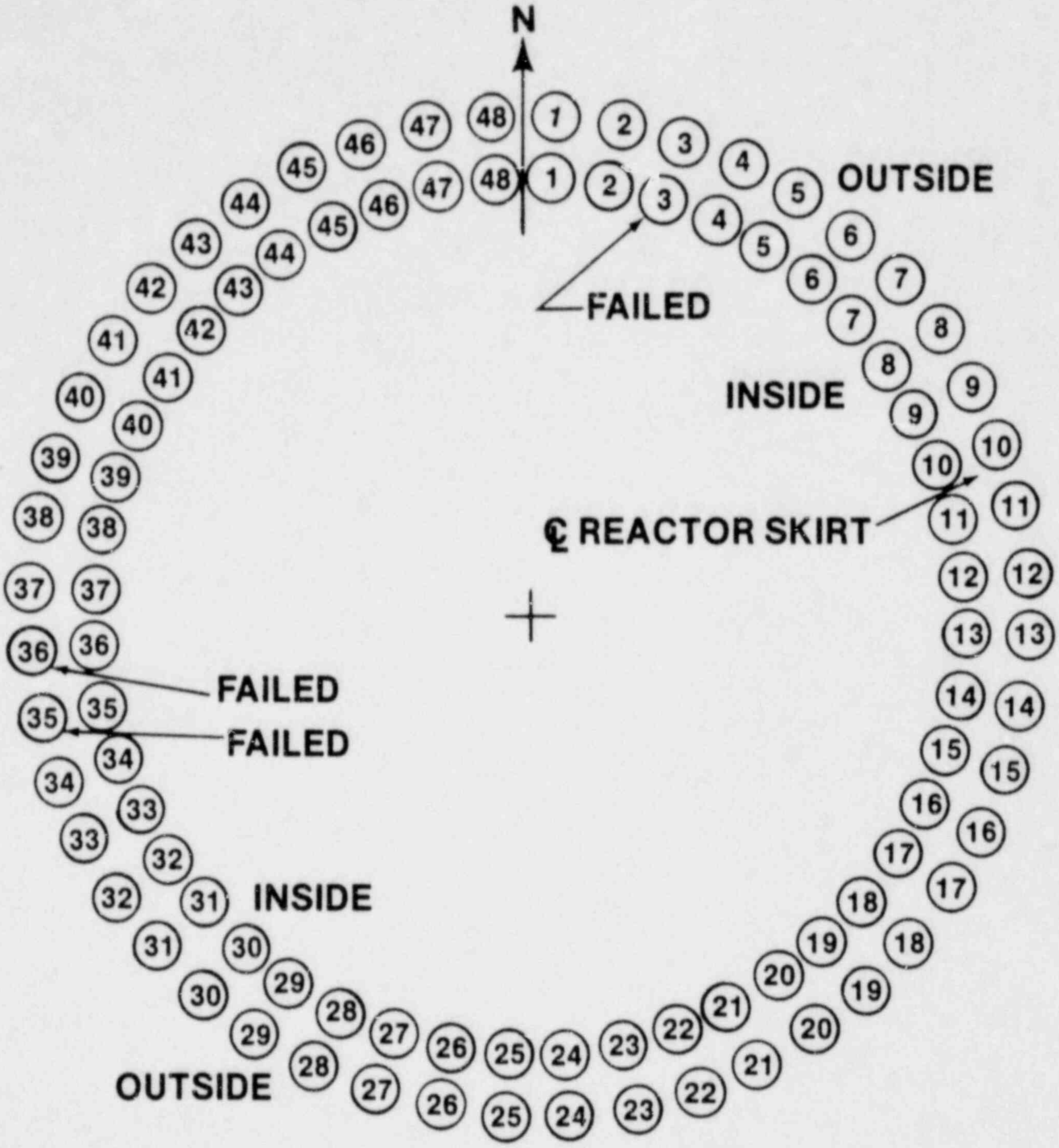
NOTES:

1) Ram area of tensioner = 27.134 sq in, bolt area = 4.00 sq in.

2) Refer to Figure C-1 for the locations of the studs.

*) Proof loaded to 75 ksi after detensioning.

**) Tensioner run up to 14,200 psig/96 ksi on initial attempt without being able to rotate nut. The lift-off data shown is the result of detensioning attempt after 20th in sequence.



POSITION AND NUMBERING OF STUDS IN UNITS 1 AND 2

FIGURE C-1

APPENDIX D:

Justification of the Ductility Ratio for Use in the Design of the ULS

The following provides the justification for the use of an allowable ductility ratio of 10 in the design of the upper lateral support (ULS) brackets:

1. The least radii of gyration ($r_{min.}$) at Sections 1 through 6 (See Figure 5.1 from Section 5.0 of this report) are given in the table below.

Section	1	2	3	4	5	6
$r_{min.}$ (in.)	4.85	4.41	4.48	4.57	5.59	4.97

   The effective buckling length of the brackets, assuming that the end welded to the steel embedment is clamped and the end in contact with the RV can displace without rotation, is 1.2 times the length of the bracket (42 in.); see Reference D1. Using the least $r_{min.}$ from the table above, a conservative (upper bound) effective slenderness ratio (KL/r) for the brackets can be calculated as follows, namely KL/r = (1.2 x 42)/4.41 = 11.4.

2. Reference D2 specifies that the slenderness ratio of a stub-column must not exceed 20. In otherwords, to insure that the column will yield, undergo plastic deformation and go into strain hardening; its slenderness ratio should be equal to or less than 20.

3. The column strength curves established by the structural stability research council for rolled and welded built-up sections (Reference D3) indicates that the strength of columns where $\lambda \leq .15$ will be controlled by yielding rather than buckling, where λ is defined as, $\lambda = \frac{KL}{\pi r}\sqrt{\frac{\sigma y}{E}}$. The parameter λ for the ULS brackets is equal to 0.13 which is less than 0.15.

4. Norris and others (Reference D4) stated that a compression member will develop its full ultimate compressive strength without buckling if its effective slenderness ratio does not exceed 15.

5. One can establish based on the aforementioned arguments that the brackets can develop their ultimate compressive strength without buckling. In this case, the allowable ductility can be as high as $\frac{\varepsilon st}{\varepsilon y}$, where εy and εst are the strains at the initiation of yielding and at the onset of strain hardening, respectively. For structural steels with a yield stress of 50 ksi or less, a lower bound value for $\frac{\varepsilon st}{\varepsilon y}$ is equal to 10, see Reference D5.

6. In addition to what has been outlined above, the AISC nuclear specification (Reference D6) allows a ductility ratio in compression of $\frac{.225}{\lambda 2}$ with a maximum of 10. Using $\lambda = 0.13$, for the brackets, the allowable ductility calculated from the AISC formula is more than 10; in this case, an allowable ductility of 10 should be used.

7. Furthermore, the ASCE Committee on impactive and impulsive loads allows a ductility ratio of $140{,}000/\sigma y \ (\frac{KL}{r})^2$ with a maximum of 10, see Reference D7. Using $\sigma y = 38$ ksi and $\frac{KL}{r} = 11.4$ for the brackets, the allowable ductility ratio calculated from the ASCE formula exceeds 10, in such a case the maximum value of 10 should be used.

8. In order to achieve the established allowable ductility ratio without premature local buckling of plate elements, the AISC specification (Reference 6) does not allow the width/thickness ratio $\frac{w}{t}$ to exceed $76/\sqrt{\sigma y}$ for unstiffened plate elements and $238/\sqrt{\sigma y}$ for stiffened plate elements. The width/thickness ratios for the plate elements of the ULS brackets satisfy these requirements.

9. The presence of bending in the brackets is considered in establishing the axial compression which will intiate yielding. Furthermore, the allowable ductility ratio in bending is 12.5 (See References D6 and D7). Hence, the presence of bending will not cause the allowable ductility to be less than 10.

REFERENCES

D1. Structural Stability Research Council, Guide to Stability Design Criteria for Metal Structures, Third Edition (1976), Pg. 74.

D2. Structural Stability Research Council, Guide to Stability Design Criteria for Metal Structures, Third Edition (1976) - Technical Memorandum No. 3: Stub-Column Test Procedure, Pg. 561.

D3. Structural Stability Research Council, Guide to Stability Design Criteria for Metal Structures, Third Edition (1976), Pg. 68.

D4. Structural Design for Dynamic Loads, by Norris, Hansen, Holley, Biggs, Namyet and Minami (1959), Pg. 13-15.

D5. Plastic Design in Steel, ASCE Manual No. 41 (1971); Chapter 5 - Verification of Plastic Theory, Pg. 42.

D6. AISC Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities, issued for trial use and comments on July 17, 1981.

D7. Report of the ASCE Committee on Impactive and Impulsive Loads, Vol. V of the Proceedings of the Second ASCE Conference on Civil Engineering and Nuclear Power, September 15-17, 1981; Pg. 2-112.

APPENDIX E:

Methodology for the Computation of the Mathematically Equivalent ULS Spring Rates

The following provides the methodology to develop the spring rates for the RV upper lateral support (ULS) brackets:

1. Capacity of the ULS Brackets Under Axial Compression and Bending: Under combined axial compression and bending the axial capacity "Py" is determined from the AISC interaction formulas given in Section 2.4, Reference E1. Since the bracket has a variable cross-sectional properties along its length and the bending moment varies due to the variation of the axial load eccentricities, the axial capacity "Py" was calculated at six different sections (See Figure 5.1 from Section 5.0 of this report). The capacity "Py" used is the minimum obtained. In order to insure that the axial capacity "Py" will be reached without premature local buckling of the bracket's plate elements; the width-thickness ratios of these elements satisfy the requirements of Section 2.7 of the AISC specification (Reference E1).

2. Load-Displacement Relationship of Individual Brackets: Load-Displacement relationship of individual brackets are shown in Figure E-1. The axial capacity "Py" is calculated as described in Item 1 above. The corresponding displacement Δy is calculated as follows:

$$\Delta y = \frac{Py}{E} \sum_{i=1}^{5} \frac{Li}{Ai}$$

   Where

   E = Young's Modulus of Elasticity,
   Ai = Average Cross-Sectional Area of Segment i, and
   Li = Length of Segment i

   The bracket was divided into 5 segments as shown in Figure 5.1 of this report.

The maximum displacement Δmax is equal to $10 \times \Delta y$; using an allowable ductility ratio of 10.

3. Spring Constant Curves (Load-Displacement - Relationship) for ULS Brackets Combination in a Specified Direction: To determine the load-displacement relationship for the ULS brackets combination in the three directions given in Section 11.1.2.4 of this report and illustrated in Figures 11.11 through 11.13; the structural model shown in Figure E-2 was used. For a given direction of motion and from geometry, the first brackets to come in contact with the RV are determined. A structural analysis is then carried out using the model shown in Figure E-2 with the brackets in contact only supporting the RV. From this analysis, the load-displacement relationship of the system is determined. The load and the corresponding displacement of the system to cause contact with additional brackets are then calculated. This load and the corresponding displacement represent a point on the load-displacement curve where stiffness changes. At this point, the new bracket or brackets to come in contact with the RV is added to the model and a new load-displacement relationship is determined. The process is repeated until all the brackets in contact with the vessel yield or the displacement exceed 10 times the displacement of the bracket which yielded first. When a bracket reaches its yield capacity Py, the support provided by the bracket is removed from the model. A load equal to Py representing the capacity of the yielded bracket, however, is applied on the vessel opposite to the direction of motion. The load at which one or more brackets yield and the corresponding displacement represent a point on the load-displacement curve where stiffness changes.

References

E1. *AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings* - 1969 Edition with Supplements 1, 2 and 3.

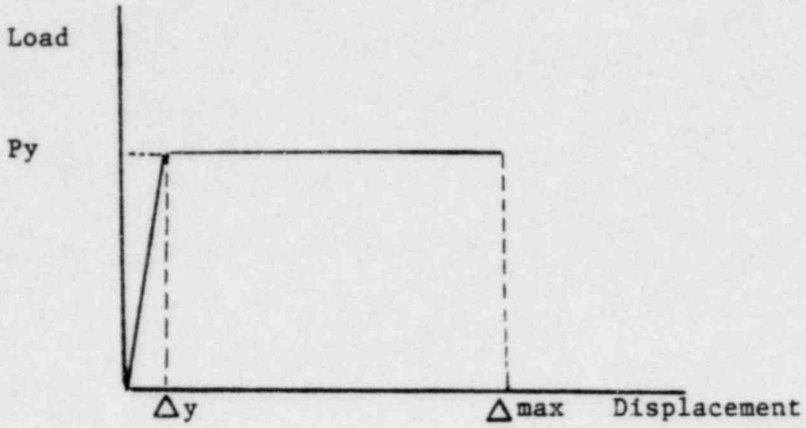


Figure E-1 - Load Displacement - Relationship of Individual Brackets

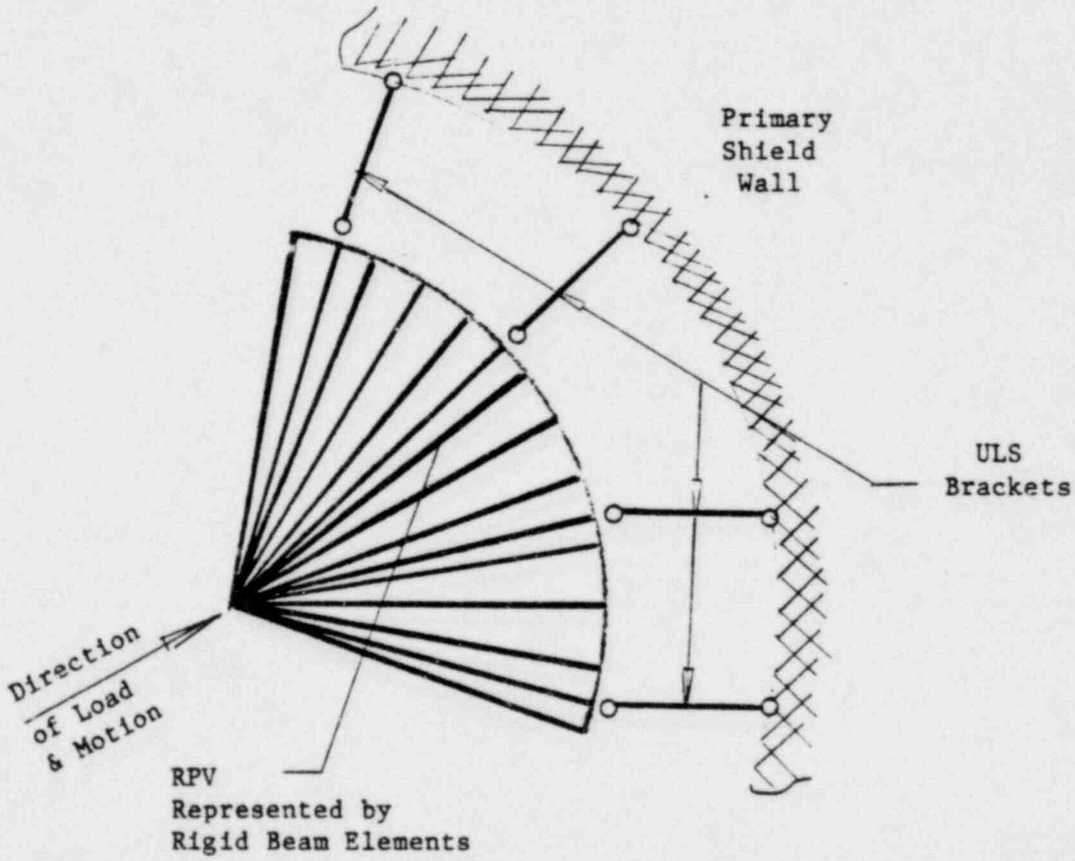


Figure E-2 - Model to Establish Spring-Constant Curves for ULS Brackets

APPENDIX F:

Teledyne Engineering Services Letter (W E Cooper to H W Slager) Dated December 11, 1981, Reaffirmation of Letter Report TR-5255-1.

TELEDYNE
ENGINEERING SERVICES

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December 11, 1981
5355-2

Mr. Harvey W. Slager
Consumers Power Company
1945 W. Parnall Road
P. O. Box CP 10-4672-Q
Jackson, Michigan 49201

<u>Subject</u>: Reaffirmation of Letter Report TR-5255-1, Expanded Criteria for Acceptability for Service for Midland Unit 1 RPV Anchor Studs

Dear Mr. Slager:

TES TR-5355-1 expanded the criteria for acceptability of the subject studs to include Service Levels B, C and D limits in addition to the Service Level A criteria provided by TES TR-3887-2, Rev. 1. At a December 2, 1981 meeting, NRC questioned the expanded criteria and provided the basis for their concern. TES has evaluated all available information and reaffirms the recommendation of TR-5355-1.

The background may be summarized as follows:

1. The RPV is constrained from rotation during a system faulted condition by studs which restrain a flanged RPV support skirt against a pedestal upper ring plate.

2. The studs in question are 2-1/2" in diameter and 7'-4" long and are tensioned between the upper surface of the skirt flange and a lower ring plate near the bottom of the studs.

3. Lateral shear is carried by separate structural elements, so the stud carries no significant lateral shear.

4. The stud is tensioned by a stud tensioner, not by torquing, so the stud carries no significant torsional shear.

5. Three of the 96 studs failed by stress corrosion cracking after installation as a consequence of the combined effects of stud materials, atmosphere, and prestressing.

6. Certain design revisions were adopted which included decreasing the prestress to a small (less than 6 ksi) value to avoid long-term stress corrosion cracking and limiting the service stress to a value proportional to the stress to which the studs were loaded subsequent to the period of initial high prestress. The minimum value of this stress measured during the 1980 detensioning was 75 ksi and the average value was approximately 85 ksi.

7. Because of the previous stress corrosion cracking and because the fracture toughness of such studs is relatable to susceptibility to such cracking one must assume that the stress carrying capability of a stud is limited to that which has been demonstrated. Therefore, the effective yield strength, effective ultimate tensile strength and failure load strength of the stud must be considered to be no higher than that measured, even though that value is much smaller than the minimum specified yield strength.

8. The basic allowable stress, Service Level A, should be taken as one-half of the effective ultimate tensile strength. Increase factors may be applied to the Service Level A values for Service Levels B, C and D.

9. Although satisfaction of ASME Code rules is not required for Midland component supports, ASME Boiler and Pressure Vessel Code, Section III, Subsection NF rules are to be applied for guidance.

10. Regulatory Guide 1.124 is applicable to the Midland component supports.

The above listing is intended to summarize the background in a manner which is consistent with past discussions and which is acceptable to all parties.

The present issue is that of establishing the increase factors applied to the Service Level A values to determine the allowable value for Service Level D. Although there are differences in the increase factors proposed for Service Levels B and C, the differences are slight and the lower of the two values is acceptable. There are also partially compensating differences in the quantities to be multiplied by the increase factors. The differences may be summarized as follows:

Service Level	TES	NRC
A	0.500 S_T	0.500 S_N
B	0.500 S_T	0.575 S_N
C	0.667 S_T	0.625 S_N
D	0.700 S_T	0.625 S_N

where:

S_T = The lowest value measured on any stud during the 1980 detensioning, 75 ksi, or a higher value if confirmed by a specific test on the specific stud at a later time.

S_N = The value measured on a specific stud, whether in 1980 or at a later time.

Specific values for Service Level D for the more highly stressed studs are as follows:

Outer Stud	1980 Value	TES	NRC	Calculated
38	85	52.5	53.1	37.5
37	75	52.5	46.7	44.8
34	85	52.5	53.1	49.2
33	92	52.5	57.5	44.6
32	83	52.5	51.9	43.0
31	94	52.5	58.7	41.9

The tabulated calculated values are those now calculated, and all are sufficiently low as to satisfy either the TES or NRC criteria. However the margin for stud 37 is but 1.04 against the NRC allowable as compared to 1.17 against the TES allowable. Similar values for stud 34 are 1.08 and 1.07, respectively. Margins for all other studs are above 1.18 against either criteria. Subsequent calculations may result in increased values, and the minimum margin against the NRC criteria is but 1.04 as compared to 1.07 for the TES criteria. These numbers are misleading, however, because the TES procedure would permit increasing the margin for stud 34 to 1.17, the value applicable to stud 37, by retesting to 82.4 ksi, a value smaller than that measured in 1980. Any increase in the margin with the NRC criterion would require retesting to values higher than those measured in 1980 with significantly increased probability of stud fracture. The apparently small difference between the TES and NRC criteria really represents a major difference in level of risk involved in satisfactory completion of construction. It is this concern that causes us to try to justify the previous TES position.

The difference between the TES and NRC criteria arises because Subsection NF provides for more than one design procedure for component supports. TES has applied the load rating procedure, a procedure which is completely defined by Subsection NF and Regulatory Guide 1.124. NRC has applied the design by analysis procedure, and has introduced as part of that procedure an incomplete and unpublished action of the ASME Committee. Even if that action were complete and published, however, it would only be applicable to the design by analysis procedure and would not be a requirement when the load rating procedure was applied. Furthermore, we will demonstrate that the present direction of the Committee completing that action is acceptance of an increase factor equal to that used in the TES criteria.

Justification for use of the load rating procedure is provided in TR-5355-1 so will not be repeated here other than reemphasizing that that procedure permits a sampling procedure, whereas each and every Midland stud was tested. It is also noted that there is no Subsection NF prohibition against applying the load rating procedure to component supports which include threaded parts.

The present Subsection NF may be considered by NRC to be incomplete with respect to Levels C and D Service Limits for bolts when the design by analysis procedure is used. TES considers the present rules to be complete and consistent with the increase factors applied by the TES criteria.

ASME Main Committee Action 81-73 at the January 1981 meeting revised the rules for bolts when the design by analysis procedure is followed. Publication has been withheld pending completion of the NF-3000 rewrite. That action applied the same increase factor for Service Level D as for Service Level C, 1.25 which results in the previously stated limit of 0.625 S_N. However, the action taken qualified the Level D factor as an interim value pending revision of Appendix F. (The Working Group on Component Supports had previously approved the action without an increase factor but with words referencing Appendix F.) Appendix F is being revised and the required words are included in F-1335.1 of Draft 11 dated August 1981. This reads:

> "The average tensile stress computed on the basis of the available tensile stress area (independent of any initial tightening force), shall not exceed the smaller of 0.7 S_u or S_y. When high strength bolts or threaded parts having an ultimate strength greater than 100 ksi (689 MP_a) at operating temperature, are used in component applications, the maximum value of the stress at the periphery of the bolt cross section resulting from direct tension plus bending and excluding stress concentrations shall not exceed S_u. The bolt load shall be the sum of the external load and any bolt tension resulting from prying action produced by deformation of the connected parts."

It is our understanding, based upon participation on the Task Group, that there is concern over permitting S_y in some applications, but we have not heard any concern about the 0.7 S_u criterion.

Based on this discussion, TES is of the opinion that the criteria recommended by TR-5355-1 is applicable to the studs in question and is in complete conformance with Code and Regulatory Guide requirements. We recommend that this proposal be applied rather than the alternative proposal of NRC.

Very truly yours,

TELEDYNE ENGINEERING SERVICES

W. E. Cooper

William E. Cooper
Consulting Engineer

WEC/lh