

ROCHESTER GAS AND ELECTRIC COMPANY  
GINNA NUCLEAR POWER PLANT

STEAM GENERATOR HYDRAULIC SNUBBER  
REPLACEMENT PROGRAM

AUGUST 15, 1988

REVISION 3

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# GINNA STATION STEAM GENERATOR SNUBBER REPLACEMENT PROGRAM

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1. The first part of the report is a general description of the project and its objectives. It also includes a brief history of the project and a list of the people involved.

2. The second part of the report is a detailed description of the methods used in the project. It includes a list of the equipment used and a description of the procedures followed.

3. The third part of the report is a description of the results of the project. It includes a list of the data collected and a description of the analysis performed.

4. The fourth part of the report is a discussion of the results and a conclusion. It includes a list of the conclusions drawn from the results and a list of the recommendations for future work.

## 1.0 INTRODUCTION

This report describes a proposed modification to the existing steam generator upper lateral support configuration at Ginna Station, and the analyses which demonstrate the acceptability of resulting loads from postulated seismic and other design basis events.

### 1.1 Existing Design

Restraining supports exist for both the upper and lower portion of each steam generator (SG). The lower portion of each SG is restrained laterally and vertically by a set of supports independent of, and not affected by, the proposed modification. The upper portion of each of the two steam generators is restrained against lateral seismic and pipe break loads by eight, large (532,000 lb. capacity) hydraulic snubbers as shown in Figure 1. These snubbers are connected between the building structure and a ring girder which is attached to four lugs welded to the SG shell. The snubbers are installed in four pairs with one pair approximately parallel to the hot leg on the reactor side of the steam generator, and the other pairs placed approximately 90° apart.

### 1.2 Program Overview

The intent of the proposed upper lateral support modification is to replace six of the eight hydraulic snubbers per SG with rigid

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structural members (bumpers), thereby minimizing the number of hydraulic snubbers in service for this application. The redesigned SG upper support configuration will retain two hydraulic snubbers on each steam generator ring girder. These snubbers, along with the rear bumpers, will restrain the steam generator against dynamic motions and loadings along the axis of the hot leg. Restraint of motions and loadings normal to the hot leg will be provided by the replacement bumpers in that direction. The redesigned SG upper support configuration is shown in Figure 2.

The replacement support hardware consists of individual structural assemblies which will be installed wherever an existing hydraulic snubber is removed. A typical assembly is shown in Figure 4. Each assembly is structurally rigid under compression but will allow freedom of movement in the tensile direction. Each assembly is individually adjustable in the field to ensure that clearances at each bumper position are adequate for Reactor Coolant Loop (RCL) expansion yet do not exceed those permitted by the RCL analysis. The bumper assembly, and its individual components, is sized to withstand the new design loads. Detailed design of the rigid structural members has been performed by RG&E. Fabrication has been performed by a qualified supplier having a Quality Assurance Program meeting the requirements of ANSI N.45.2.



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### 1.3 Anticipated Benefits

The required maintenance, in-service inspection and testing of the existing snubbers are performed during annual refueling outages. Surveillance activities are performed periodically throughout the year. By replacing selected snubbers with bumpers, annual maintenance activities and, consequently, annual radiation exposures to maintenance personnel can be minimized. The hydraulic snubbers replaced with bumpers will be refurbished, and stored for use as spares. It is expected that spare parts procurement, as well as utilization of shop facilities and rigging equipment, can be optimized as a result of this snubber replacement program.

### 1.4 Primary System Qualification

The steam generator hydraulic snubber replacement program has resulted in changes in the response of the primary system. The effect of these changes upon the RCL equipment, piping and piping support system has been analyzed by Westinghouse. An independent review by a consultant with broad experience in RCS support design has also been performed. The use of rigid structural members (bumpers) in the SG upper lateral support system will change the degree of stiffness with which the SGs are restrained against dynamic loads. These new stiffnesses have been calculated and are included in the reanalyses. Loadings from a design basis pipe break (DBPB) postulated to occur in an





auxiliary line (RHR, SI accumulator or pressurizer surge line) branch connection have also been developed using the new upper lateral support stiffnesses, to assess the effect of the new SG upper support configuration on the reactor coolant system. Pipe breaks in the Main Steam and Feedwater piping at the corresponding SG nozzles have also been considered.

The analysis results indicate that RCL stresses and deflections have not changed significantly from previous analyses. The details of the RCL piping system analysis, for the revised SG upper lateral support configuration, are provided in Section 3.1 of this report.

The primary equipment supports were also re-evaluated for new support loads generated from the revised RCS piping system analysis based on the proposed SG upper lateral support configuration. The evaluation was conservatively performed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code - 1974 Edition, subsection NF and Appendix F. A detailed discussion of the primary equipment support evaluation is provided in Section 3.2 of this report. Results of the evaluation are summarized in Table 6.

#### 1.5 Intent of Report

This report is intended to present the structural qualifications for the redesigned steam generator upper lateral support



configuration. It contains the supporting data to conclude that the maximum stresses in the RCS, and the primary equipment supports, are less than the Code allowable values.

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## 2.0 DESIGN LOADS AND CRITERIA

### 2.1 Design Basis Loads

#### 2.1.1 Loading Conditions

The SG hydraulic snubber replacement program will assure that adequate support capacity is maintained with respect to the design basis loads.

The RCL, with the modified steam generator upper lateral support configuration, was analyzed for the following loading conditions:

- a. Deadweight
- b. Internal Pressure
- c. Thermal expansion
- d. Seismic events (OBE and SSE)
- e. Postulated pipe ruptures at SG secondary-side nozzles (Main Steam, Feedwater)
- f. Postulated pipe ruptures at RCL auxiliary line nozzles (Pressurizer Surge, SI Accumulator, Residual Heat Removal)

The loads are combined in accordance with Tables 1, 2, and 3.

The loading conditions were evaluated with the RCS at full-power conditions. This is consistent with generic analyses of this

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type, representing the higher probability event, and occurs when higher piping stresses from design RCL pressures exist and code allowable stresses are lower. A discussion of analysis at other than full power operation is also provided in this report.

#### 2.1.2 Postulated Pipe Ruptures

##### a. RCS Pipe Ruptures

The probability of rupturing primary system piping is extremely low under design basis conditions. Independent review of the design and construction practices used in Westinghouse PWR Plants by Lawrence Livermore National Laboratory (reference 2) has provided assurance that there are no deficiencies in the Westinghouse RCL design or construction which will significantly affect the probability of a double-ended guillotine break in the RCL. Westinghouse topical report, WCAP-9558, Rev. 1 (reference 1), provided the technical basis that postulated design basis flaws would not lead to catastrophic failure of the Ginna stainless steel RCL piping. This WCAP documented the plant specific fracture mechanics study in demonstrating the leak-before-break capability. It has been reviewed by the NRC and its conclusions were approved for application to Ginna by letter dated September 9, 1986 (NRC approval of RG&E response to Generic Letter 84-04).





In the analyses supporting the proposed modification, terminal-end pipe breaks are postulated in the RCL at auxiliary line branch connection nozzles to the Residual Heat Removal (RHR) system, the Safety Injection (SI) Accumulator piping and the Pressurizer Surge piping. The terminal end break at the SI accumulator line nozzle defines the limiting pipe break design basis loads for the SG upper lateral support system under emergency conditions.

b. Secondary System Pipe Ruptures

Existing postulated pipe break locations in the secondary systems were reviewed. Some intermediate break locations have been eliminated from consideration as described below. Existing postulated terminal-end breaks at Main Steam and Feedwater nozzles on each SG continue to be assumed.

i. Main Steam Line Ruptures

The previous controlling design load for the SG upper lateral support system was an arbitrary intermediate pipe break in the horizontal Main Steam line near the top of the SG (See Figure 3). NRC Generic Letter 87-11, "Relaxation in Arbitrary Intermediate Pipe Rupture Requirements", provides guidance for elimination of arbitrary intermediate breaks and has been applied in this program.

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Previous Ginna Seismic Upgrade Program analyses (recently reviewed in NRC Inspection No. 50-244/87-11), using ANSI B31.1 criteria, have been revised as necessary to reflect changes resulting from this snubber replacement program. Consistent with Generic Letter 87-11, these analyses have established that no intermediate pipe breaks need to be postulated in the Main Steam (MS) piping.

#### ii. Feedwater Line Pipe Ruptures

A terminal-end pipe break is postulated at the steam generator feedwater inlet nozzle and now defines the limiting pipe break design basis loads for the SG upper lateral support system under faulted conditions. All other Feedwater break locations are less limiting and, in addition, are not postulated because of the application of Generic Letter 87-11 guidance.

### 2.2 General Criteria - Seismic Upgrade Program

The design codes and criteria utilized in the analysis are consistent with those used for RG&E's Seismic Upgrade Program. That program was initiated in response to IE Bulletins 79-02, 79-14, and the Systematic Evaluation Program (SEP). This program was reviewed during SEP and was approved by the NRC as documented



in the SEP SERs for Topic III-6, "Seismic Design Considerations" and the SEP Integrated Assessment. NRC Inspection No. 50-244/83-18 and Inspection No. 50-244/87-11 provided a review of RG&E work performed in response to IEB's 79-02 and 79-14. Since 1979, RG&E has upgraded critical safety-related piping and supports, resulting in the reevaluation and modification of virtually all supports originally covered by the IEB's.



### 3.0 PRIMARY SYSTEM ANALYSIS

#### 3.1 Piping Analysis

##### 3.1.1 Mathematical Models

The RCL piping model consists of mass and stiffness representations for the two RCLs and the reactor vessel. Each RCL includes the primary loop piping, a steam generator and a reactor coolant pump. The primary equipment supports are represented by stiffness matrices.

The static, thermal and seismic analyses of the RCS were performed using a two-loop model (See Figure 5) to obtain component and support loads and displacements. This model is identical to the one used previously in the Ginna Piping Seismic Upgrade Program except for the following:

- a. The new SG upper lateral support design is represented by stiffness matrices in two directions. One matrix provides stiffness along a direction corresponding to the hot leg direction and snubber axes. The second provides stiffness perpendicular to the direction corresponding to the hot leg direction and snubber axes. This permits component support loads in the snubbers and bumpers to be calculated directly.

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- b. Each existing pinned-end, tubular support column under the SG's and the RCP's is represented by a stiffness matrix based on stiffness values which account for the embedment of the supporting structural frame in the reinforced concrete slab. This is a representation of the existing configuration and eliminates the need for translation of loads from global to local coordinates.

### 3.1.2 Methodology

The seismic analysis is performed using the envelope response spectra method. Peak-broadened floor response spectra for two-percent and four-percent critical damping (OBE and SSE, respectively) were used in conformance with Regulatory Guides 1.60 and 1.61. The use of four-percent critical damping for SSE was developed and justified by testing. The testing programs are described in WCAP-7921, which has been accepted by the NRC (reference 9). The modification in the SG upper lateral supports will not affect the conclusion of the damping testing program. Responses to the three directions of earthquake loading were evaluated in accordance with the Ginna Piping Seismic Upgrade Program by combining all three directional earthquakes by the square-root-sum-of-the-squares (SRSS) method. The Westinghouse epsilon-method of closely-spaced modes combination was used in the analysis. The combination equations are presented in Appendix A. This method of combination of modal responses and spatial components is consistent with the NRC guidelines in

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Regulatory Guide 1.92. This method has been used on numerous other Westinghouse PWR's (such as Vogtle and South Texas) as discussed in their respective FSAR's. The NRC has approved the use of this method via the SER's associated with modal response combination on those Westinghouse plants.

#### 3.1.2.1 Branch Line Postulated Ruptures

The dynamic time-history pipe rupture analyses of the RCL were performed using a one-loop model (Figure 6). The steam generator upper lateral supports are modeled with snubber-in-compression support stiffness in one direction and the combined effect of snubber-in-tension plus bumper-in-compression support stiffnesses in the opposite direction. The steam generator column supports and reactor coolant pump column supports are modeled with tension and compression stiffness in the opposite directions. The reactor coolant pump tie-rods are modeled to be active in tension only. The steam generator lower lateral support stiffness matrices used were chosen to be consistent with the calculated dynamic motions.

Pipe breaks are postulated in the primary system at the loop branch connections of the pressurizer surge, RHR and SI accumulator piping systems. The calculated time-history forcing functions were applied to the RCL analytical model at the lumped-mass points and where each auxiliary line joins the RCL to obtain the corresponding transient loads. The applied forces associated



with these pipe breaks include the following three components:

- a. blowdown forcing functions at various locations in the primary piping
- b. A thrust force at the break location.
- c. A jet impingement force at the break location.

The blowdown forcing functions, which represent the traveling compression blowdown waves due to internal fluid system loads, are calculated (in the x, y, and z coordinate directions) at each change in direction or change in flow areas. Thirteen such locations occur in each one-loop model and are shown schematically in Figure 7. These time-varying forces are applied at eight mass locations shown in Figure 8. A representative blowdown forcing function time-history plot (for a single coordinate direction at one location) is shown in Figure 9. This is the standard methodology used for Westinghouse RCL pipe breaks and is described in WCAP-8172-A (Reference 13), which has been accepted by the NRC.

The thrust force is a time-varying blowdown force at applied the break location. It is calculated using the same methodology used for the above internal fluid system blowdown loads and is oriented along the centerline axis of the auxiliary line nozzle.

The jet impingement load is calculated using the simplified methods of Appendixes B and D of Reference 12. The jet impingement load is taken as  $KC_T P_o A$  (Equations D-1 and D-3 of Ref. 12)



where:  $K = 1.0$  (maximum value from Figure B-1)  
 $C_T = 1.3$  (Figure B-6, for pressure and enthalpy)  
 $P_o =$  initial pressure  
 $A =$  pipe cross-sectional flow area

This step function jet impingement force is added to the thrust force to obtain the total applied force at the break location.

#### 3.1.2.2 Main Steam and Feedwater Postulated Ruptures

Applied forces due to pipe breaks postulated to occur on the secondary side of the steam generator at the Main Steam outlet nozzle and Feedwater inlet nozzle are represented by step-function forces. These forces are calculated as the absolute sum of thrust force and jet impingement force for each break location.

For the postulated pipe break at the Main Steam outlet nozzle, the pipe is not constrained and there is no jet impingement load on the steam generator from the severed pipe. The thrust force for this pipe break is calculated using the simplified methods of Appendix B in Reference 12. The steady-state force is taken as  $C_T P_o A$  (Equation B-2 of Ref. 12) where:

$C_T = 1.26$  (thrust coefficient for saturated-superheated steam from Equation B-4)

$P_o =$  Initial pressure

$A =$  pipe cross-sectional flow area

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A step forcing function which is equal to this steady-state force is applied to the steam generator in a dynamic model of one primary piping loop (Figure 6).

For the postulated pipe break at the Feedwater inlet nozzle, a jet impingement load is calculated by the simplified methods of Appendix D in Reference 12. The jet impingement load is taken as  $KC_x P_o A$  (Equations D-1 and D-3 of Ref. 12) where:

$K = 1.0$  (maximum value from Figure D-1)

$C_x = 1.0$  (maximum value from Figure B-7, for  $fL/D \geq 1$ )

$P_o$  = initial pressure

$A$  = pipe cross-sectional flow area

The pipe hydraulic friction term ( $fL/D$ ) is larger than 1.0 since there are several elbows upstream of the postulated break location in the Feedwater piping.

The thrust force for this pipe break is calculated by the same simplified methods used for the postulated Main Steam outlet nozzle break. In this case,  $C_x = 1.0$  based on Figure B-7 of Ref. 12. The pipe hydraulic friction term ( $fL/D$ ) is larger than 1.0 since there are J-tubes and a circular feedwater ring header on the steam generator side of the break. A step-function force which is equal to the sum of the jet impingement load and the thrust force which results in a total coefficient of 2.0, is

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applied to the steam generator in a dynamic model of one primary piping loop.

### 3.1.3 Computer Programs

Piping analyses are performed on the "WESTDYN" Westinghouse computer program (reference 5). WESTDYN performs 3-dimensional, linear, elastic analyses of piping systems subjected to internal pressure and other loadings (static and dynamic). The program is capable of combining loads in accordance with the applicable code class of either ASME Section III or ANSI B31.1. Separate computer runs analyze each loading condition (deadweight, thermal, sustained loads, occasional loads, pipe break and seismic). The primary output from WESTDYN displays information about each analysis performed, including forces, moments, and displacements at each point. The WESTDYN computer code has been utilized on numerous Westinghouse plants and was reviewed and approved by the NRC in 1981 (reference 8). The code is verified for this application and a controlled version is maintained by Westinghouse.

### 3.1.4 Support Stiffnesses

To accurately represent the equipment supports in the piping analyses, the modified support system stiffness characteristics were developed for input to the piping analysis computer model. Individual spring constants in the local directions of

restraint were developed for the modified SG upper lateral support configuration and the other RCL primary equipment supports. The stiffness calculations considered the stiffness characteristics of all structural elements in the load path including the supporting concrete, structural members, as well as the tension and compression stiffnesses of the remaining hydraulic snubbers.

Two separate analyses (identified as Case 1 and Case 2) are performed for the RCL in the hot condition (i.e. full power operation). Both analyses use the response spectra method where seismic loads are dynamically applied in all three coordinate directions (x,y,z). Both analyses also use the same RCL model (Figure 5) except that some of the support stiffnesses for Case 1 and Case 2 are different. The RCL primary equipment support stiffnesses used in Analysis Cases 1 and 2 reflect the differences between RCS loops A and B in the following areas:

i) SG Upper Lateral Support System

No changes to the locations where lateral support is provided to the upper portions of each SG are being proposed. Only the type of support element (snubber or bumper) at each location is being changed and their different stiffnesses are accounted for as described later in this section. However, these upper lateral support locations are



arranged around the periphery of each SG differently for RCS Loops A and B.

SG "A" is modeled with 4 upper lateral support locations. As shown in Figure 2, these consist of a pair of snubbers on the reactor-side of the "A" SG and 3 pairs of bumpers spaced 90° apart.

SG "B" is modeled with 5 upper lateral support locations. As shown in Figure 2, these consist of a pair of snubbers on the reactor-side of the "B" SG, 2 single bumper locations on the back-side of the SG, and 2 pairs of bumpers located perpendicular to the RCL hot leg.

At both SGs, the upper lateral support bumpers provide compression-only support. The upper SG snubbers are capable of acting in tension and compression. The SG upper lateral support snubbers and bumpers are modeled as active in both Analysis Cases 1 and 2 using stiffness matrices as described in Paragraph 3.1.1.a of this report.

#### ii) SG Lower Lateral Supports

No changes to the SG lower lateral supports are being proposed. However, to aid in

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understanding how the existing SG lower lateral supports are modeled in Analysis Cases 1 and 2, a brief description is provided here.

The lower portion of each SG is supported laterally by a support frame located at the bottom of the SG shell. Four equally-spaced lower support brackets built into each SG bottom head (see Figure 3) engage these support frames. In the hot condition, thermal expansion of the RCL causes the SG lower support brackets to move to their hot positions in contact with mating surfaces in the support frame. At these mating surfaces, compression-only support is provided. The physical details of the SG lower lateral support show that there are a total of 6 such mating surfaces (per SG) where contact may occur as described below.

For each SG, the selection of the mating surfaces to be modeled as "active" supports (bumpers) depends on the relative motion between the building structure and that steam generator. Analysis Cases 1 and 2 are based on opposite building motions as described below.

In Analysis Case 1, depicted in Figure 10-a, the





building structure was chosen to be moving away from SG "A" and toward SG "B". This relative building motion allows the SG "B" lower lateral support to be "active" (compression-only) at 6 mating surfaces which, for modeling purposes, is identified as configuration "A". This same relative building motion allows the SG "A" lower lateral support to be "active" (compression-only) at 3 mating surfaces which, for modeling purposes, is identified as configuration "C".

In Analysis Case 2, depicted in Figure 10-b, the building structure motion relative to the RCS was chosen to be opposite from Case 1. Therefore, in Analysis Case 2 the building is moving toward SG "A" and away from SG "B". This new relative motion allows the SG "B" lower lateral support to be "active" (compression-only) at 3 mating surfaces (previously identified as configuration "C"). The new relative building motion allows the SG "A" lower lateral support to be "active" (compression-only) at 5 mating surfaces which, for modeling purposes, is identified as configuration "B".

### iii) RCP Lateral Supports



No changes to the RCP lateral supports are being proposed. However, to aid in understanding how the existing RCP lateral supports are modeled in Analysis Cases 1 and 2, a brief description is provided here.

Each RCP is supported laterally by two pinned-end tie-rods attached to the pump casing. Where each tie-rod attaches to the building structure, it is provided with a slotted end hole to accommodate thermal expansion of the RCL. In the hot condition, thermal expansion of the RCL causes the slotted tie-rod ends to move to their hot positions in contact with their corresponding end pins. In this position, tension-only support is provided.

As depicted in Figure 10-a, the motion of the building structure relative to the RCS chosen in Analysis Case 1 corresponds to active (tension-only) lateral support from the "B" RCP tie-rods. Analysis Case 1 utilizes no lateral support from the "A" RCP tie-rods.

As depicted in Figure 10-b, the opposite motion of the building structure relative to the RCS chosen in Analysis Case 2 corresponds to active (tension-



only) lateral support from the "A" RCP tie-rods. Analysis Case 2 utilizes no lateral support from the "B" RCP tie-rods.

As depicted in Figure 10-c, the vertical support columns associated with the "A" and "B" SGs and the "A" and "B" RCPs provide both tension and compression support in Analysis Cases 1 and 2. All these columns are heavy tubular support elements provided with close-fitting, pinned ends. They are firmly anchored to the building structure and are capable of acting in tension and compression. Each vertical support column is considered to be active in both Analysis Case 1 and 2 and is modeled using the stiffness matrices as described in Paragraph 3.1.1.b of this report.

Within the RCL analytical model (Figure 5), the loop A and B hot leg piping restrains their respective SG in tension and compression for both Analysis Cases 1 and 2, regardless of the assumed building motion.

The seismic response spectra results presented in Table 10 show the effect of the two different Analysis Cases 1 and 2 on the calculated SSE loads in the SG upper lateral support snubbers. As shown in Table 10, the load from Analysis Case 1 is the limiting load for RCS Loop A and the load from Analysis Case 2 is the limiting load for Loop B.

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During a seismic event loads may shift between the snubber and the bumper along the axis of the hot leg. This shifting is bounded in the analysis by utilizing three values of the upper support stiffnesses ( $K_{min}$ ,  $K_{max}$ , and  $K_{avg}$ ) in three separate analyses. The bumper is stiffer than the snubber. Thus, the lower bound value is  $K_{min} = K_{snubber}$  (compression). The upper bound value is  $K_{max} = K_{bumper}$  (compression) +  $K_{snubber}$  (tension).  $K_{min}$  is the actual stiffness when the steam generator moves toward the reactor vessel.  $K_{max}$  is the actual stiffness when the steam generator moves away from the reactor vessel. Finally, a third value of  $K_{avg} = 1/2 (K_{min} + K_{max})$  was used to provide data on an intermediate stiffness. The three values are as follows:

$$K_{max} = 19.15 \times 10^6 \text{ lb/in}$$

$$K_{min} = 7.8 \times 10^6 \text{ lb/in.}$$

$$K_{avg} = 13.46 \times 10^6 \text{ lb/in.}$$

Several evaluations were performed using  $K_{min}$  and  $K_{max}$  stiffnesses, and the worst loads on each individual bumper were determined. The results are summarized in Table 8 along with corresponding loads based on the average stiffness value,  $K_{avg}$ . Use of bounding stiffness values produces a decrease in the seismic stress margin at each location as compared with  $K_{avg}$ . Adequate seismic stress margin still exists since the lowest margin, using the bounding stiffness, is 1.73 (SG 1B snubbers).

Based on these changes in seismic margin, and the calculated





margins for loop piping (shown in Table 4) and the primary equipment supports (shown in Table 6), it is concluded that adequate seismic margins exist for the redesigned SG upper lateral supports. The data in Tables 4, 5, 6, and 7 are based on the  $K_{AVE}$  value of SG upper support stiffness.

#### 3.1.5 Piping Evaluation Criteria

The piping evaluation criteria are based on ANSI B31.1-1973 Edition. The original design basis of the seismic Category I piping at Ginna was in accordance with the 1955 and 1967 Editions of USAS B31.1. When USAS B31.1 was updated to the ANSI B31.1, the stress analysis formula and stress intensification factors were revised. The primary stress equations in the initial B31.1

- 1973 Edition were similar to those given in the ASME Section III Code of that time. The stress intensification factors given in this version of B31.1 were expanded to include more fittings. In using ANSI B31.1, the Piping Seismic Upgrade Program updated the analysis to reflect ASME Section III concepts while still retaining the philosophy of B31.1. However, the stress intensification factors for butt and socket welds of the original Edition of B31.1 have been used because of lack of original weld configuration information.

#### 3.1.6 Piping Load Combinations



The piping was evaluated for the load combinations defined in Table 1.

### 3.2 Primary Equipment Supports Evaluation

#### 3.2.1 Methodology

The steam generator upper lateral support system has been redesigned by replacing six of the eight steam generator snubbers in each loop. The revised configuration is shown in Figure 2.

The RCL analysis model was revised to reflect the new support configurations. Computer analyses were performed, as described in Section 3.1, to generate new RCL loads on the primary equipment support system and the primary equipment supports were evaluated for these new loads. The evaluation was performed for supports associated with the reactor vessel, steam generators and reactor coolant pumps. In appropriate cases, finite element models of supports, using the STRUDL program, were utilized to assist in the evaluation. The supports were requalified for the required combinations of pressure, thermal, deadweight, seismic and pipe rupture loads.

#### 3.2.2 Support Loadings and Load Combinations

The loads used in the requalification of the equipment support structures are defined in Table 2. These loads were combined for

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the plant as identified in Table 3. The corresponding load combinations and the allowable service stress limits are also provided in Table 3.

### 3.2.3 Evaluation Criteria

The rigid structural members (bumpers) in the SG upper lateral support system are designed to the requirements of the current edition of the original design code (American Institute of Steel Construction, AISC Manual, 8th Edition). However, to evaluate the equipment supports for normal, upset, emergency and faulted conditions, the provisions of ASME Boiler and Pressure Vessel Code Section III, Subsection NF and Appendix F were used - 1974 edition. The ASME B&PV Code Section III, Subsection NF was used to establish allowable stress criteria for the equipment support evaluation in lieu of the AISC Code because Subsection NF and Appendix F coupled with US NRC Regulation Guide 1.124 establish a more consistent and conservative set of criteria. For example, Subsection NF was developed specifically to address component supports whereas the AISC generally address building structures.

Additionally, the use of Subsection NF, Appendix F, and RG. 1.124 require the use of material properties at service temperature, limit buckling to 0.67 critical buckling, and establish upper bound allowables on tension and shear stress. The evaluation was performed using manual calculations and computer analysis where appropriate.

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#### 3.2.4 Computer Programs

The primary equipment supports were evaluated by hand calculations and, where appropriate, by finite element computer analysis using "STRU DL." STRU DL, part of the ICES civil engineering computer system, is widely used for the analysis and design of structures. It is applicable to linear elastic two-and three-dimensional frame or truss structures, employs the stiffness formulation, and is valid only for small displacements. Structure geometry, topology, and element orientation and cross-section properties are described in free format. Printed output content, specified by input commands, includes member forces and distortions, joint displacement, support joint reactions, and member stresses. The STRU DL computer code has been utilized on numerous Westinghouse plants and was reviewed and approved by the NRC in 1981 (reference 8). The code is verified for this application and a controlled version is maintained by Westinghouse.



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## 4.0 EVALUATION AND RESULTS

### 4.1 Reactor Coolant Loop Piping

Table 4 provides the level of stress in the RCL piping and the allowable stresses from the Design Code (reference 4). The results show that the stresses in the piping are within allowable limits. A comparison between the maximum stress in the RCL piping for the current and redesigned support configuration shows that there are only very small changes in the calculated stresses.

### 4.2 Application of Leak-Before-Break

With the redesigned steam generator upper lateral support configuration, revised loads (forces and moments) in the RCL piping have been generated. The revised loads are compared with those loads in Generic Letter 84-04 (reference 7) in Table 5. The calculated axial stress (19.42 ksi) is 60% of the allowable axial stress (32.4 ksi). Based on the comparison, it is verified that the leak-before-break conclusions of WCAP-9558, Rev. 1 remain valid for the redesigned support configuration.

### 4.3 Main Steam Line Break Locations

The terminal-end break in the main steam line piping at the steam generator nozzle is a design basis pipe break. The maximum

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1. The first part of the report is a general introduction to the subject of the study. It discusses the importance of the problem and the objectives of the investigation. It also mentions the scope of the study and the methods used.

2. The second part of the report is a detailed description of the experimental work. It includes a description of the apparatus used, the procedure followed, and the results obtained. The results are presented in the form of tables and graphs, and are discussed in detail.

3. The third part of the report is a discussion of the results and a conclusion. It discusses the significance of the results and compares them with the results of other workers. It also draws a conclusion from the study.

calculated stress intensity at intermediate locations for combined pressure, deadweight, thermal and OBE loadings is 27.1 ksi. This is less than the threshold stress intensity of 0.8 ( $1.2 S_h + S_A$ ) or 29.6 ksi. Therefore, there are no high-stress intermediate break locations in the main steam lines inside containment.

#### 4.4 Primary Equipment Supports

The stress margins for RCL equipment supports resulting from the RCL analysis considering the redesigned steam generator upper lateral support configurations are summarized in Table 6 for all loading combinations. The stress margin is defined as the ratio of the allowable support stress to the actual support stress. Loading evaluations performed with the redesigned support configuration demonstrate that all RCL equipment support stresses satisfy stress limits with an adequate margin of safety. Seismic margin is assessed by the stress margin for the load combination, (DW + TN + SSE). These stress margins are summarized in Table 7 for the existing and redesigned steam generator upper lateral support configuration. The results demonstrate that a significant margin of safety exists for the redesigned steam generator upper lateral support.

#### 4.5 Primary Component Nozzle Load Conformance

The RCL piping loads on the primary nozzles of the reactor

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vessel, the steam generators, and the reactor coolant pumps were evaluated. The conformance evaluation consisted of load component comparisons, and load combination comparisons, in accordance with each of the respective Equipment Specifications or with applicable nozzle allowable limits. It was concluded that all RCL piping loads acting on the primary component nozzles were acceptable.

#### 4.6 Evaluation of Auxiliary Lines

The RCL piping and primary equipment displacements were compared to the corresponding displacements used in the previous analyses. They are found to be less than the previous analysis results or within  $\pm 1/16$  inch. Due to the flexibility of the attached piping systems (designed to be flexible to accommodate thermal growth of the RCL) and the gaps which normally exist between the pipe and the supporting structure, an increase in anchor motions at the loop connection point of up to  $1/16$  inch will not cause significant changes in piping stress.

Therefore, auxiliary piping systems attached to the RCL are not affected by the redesigned steam generator upper support configuration.

#### 4.7 Building Structural Evaluation

##### 4.7.1 Evaluation of Local Areas

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Corbels and embedments were evaluated for tension loads and their capacity was found to exceed that of the hydraulic snubbers.

Corbels were also evaluated for the rigid structural member (bumper) bearing loads, and were found to be loaded to no more than 60% of allowable.

All evaluations were performed with respect to ACI-349, and Appendix B of ACI-349.

#### 4.7.2 Secondary Shield Walls

The elevation of the SG upper lateral supports is the same as the Reactor Building Operating Floor. There is no localized bending, since the floor slab acts as a stiffening ring.

Resulting tensile stresses are low, with a maximum of about 40% of allowable. All evaluations were done with respect to ACI-349.

#### 4.7.3 Conclusion

In conclusion, the existing containment building structures are adequate for the new design basis loads associated with the new snubber/bumper SG upper lateral support configuration.





## 5.0 ADDITIONAL CONSIDERATIONS

### 5.1 Overtemperature Events

The design basis overtemperature event is the loss-of-load transient. RCL equipment support stress margins for this transient are adequate as shown in Table 6. An evaluation has also been performed for the overtemperature conditions following a feedwater line pipe break. The maximum load on any individual bumper was found to be 23.4 kips. This is significantly less than the 820 kips maximum capacity of each bumper. The corresponding RCL piping stresses were also found to be much less than the code-allowable thermal stress.

### 5.2 Cold Shutdown

#### 5.2.1 RCS Analysis

In addition to the plant design basis full power (i.e. hot condition) evaluation described in paragraph 3.1, a seismic analysis was performed for the cold shutdown condition. This analysis also uses the response spectra method where seismic loads are dynamically applied in all three coordinate directions. The same RCL model was also used (Figure 5) except that the primary equipment supports were modeled differently because of the different thermal expansion in the RCL piping and components.



The revised support stiffnesses reflect the differences between the hot and cold conditions in the following areas:

i) SG Upper Lateral Support System

As described in paragraph 5.2.2, thermal contraction of the RCL piping will move each SG inward toward the centerline of the reactor vessel creating cold shutdown gaps of approximately 2 inches at the new rigid structural member (bumper) locations on the backside (i.e. the support locations farthest from the reactor vessel centerline) of each SG. Therefore, the backside upper lateral support bumpers at each SG are not considered to be active in the cold shutdown condition. The SG upper lateral support snubbers located on the reactor-side of each SG are always active in the cold shutdown condition.

Initially, the RCS cold shutdown seismic analysis is performed considering the SG upper lateral support bumpers oriented in directions perpendicular to the RCL hot legs to be not active. In these directions, cold shutdown seismic displacements at the upper portion of each SG would exceed the 0.4-inch diametrical cold shutdown gaps described in paragraph 5.2.2. However, due to the presence of bumpers at these locations cold shutdown seismic displacements at the upper

portion of each SG are actually limited by the size of the gaps. Consequently, RCS piping displacements, loads and stresses are limited. The dynamic RCL responses obtained in the initial cold shutdown seismic analysis (which assumed no gap closure) are proportioned downward based on the ratio of the cold shutdown gaps in these directions to the initial dynamic displacements calculated at the SG upper support locations. The contact loads on these bumpers are discussed in paragraph 5.2.2.

ii. SG Lower Lateral Supports

The thermal contraction of the RCL piping will also create gaps of approximately 2 inches at the backside (i.e. the support frame location farthest from the reactor vessel centerline) position on each SG lower lateral support frame. Therefore, the backside SG lower lateral support location is not considered to be active in the cold shutdown condition.

In the cold shutdown condition, at lower lateral support frame locations perpendicular to the RCL hot leg, gaps of approximately 0.5 inches exist between the mating surfaces of the SG lower

support brackets and the support frame. At these points the seismic deflections predicted by the RCL model (Figure 5) are too small to close the gaps, due mainly to the stiffening effect of the RCL piping. Therefore, the SG lower lateral support locations approximately perpendicular to the RCL hot leg are not considered to be active in the cold shutdown condition.

iii) RCP Lateral Supports

When cooling to the cold shutdown condition, thermal contraction of the RCL piping will pull each RCP inward toward the reactor vessel creating gaps of approximately 1.5 inches between the slotted ends of each RCP lateral support tie-rod and its corresponding end pin. Therefore, the RCP lateral supports (tie-rods) are not considered to be active in the cold shutdown condition.

The vertical support columns associated with the "A" and "B" SGs and the "A" and "B" RCPs are active in the cold shutdown condition.



The RPV supports are also active in the cold shutdown condition.

#### 5.2.2 Primary Equipment Supports

The RCL piping model (described in paragraphs 3.1.1 and 3.1.3) was analyzed for displacements resulting from thermal changes between temperatures corresponding to full power operation and cold shutdown. A combination of computer analyses (using the RCL piping model), manual calculations (i.e. for the SG shell) and field measurements, are used to predict the gaps which will exist at RCL support locations in the cold shutdown condition.

The SG upper lateral supports (bumpers) are adjusted during plant startup such that, at power operation, the gap between these bumpers and the steam generators will be very small (less than 1/16 of an inch). When cooling to cold shutdown conditions it is calculated that the total diametrical gap between each steam generator and the associated SG upper lateral supports (bumpers) is approximately 0.4 inches in the directions perpendicular to the RCL hot leg (i.e. across steam generator 1A at bumper reference locations 2 and 3, and across steam generator 1B at bumper reference locations 4 and 5 as shown in Figure 2).

At these bumpers, contact loads are estimated by relating the maximum kinetic energy (prior to contact) to the maximum strain energy in the contacted bumper. A simplified single-degree-of-





freedom model is used where the dynamic characteristics are obtained from the initial cold shutdown seismic analysis (which assumes no gap closure). The effective mass was chosen to be 70% of the total SG mass since the RCL hot leg provides restraint to the lower portion of the SG. The coefficient of restitution was chosen to be 0.8 based on a damping value of 7%.

As shown in Figure 2, the revised steam generator upper support configuration will retain existing snubbers at locations approximately parallel to the hot leg direction and they will provide seismic restraint in that direction during cold shutdown. These snubbers will prevent seismically-induced motions from closing the 2-inch cold shutdown gaps at steam generator 1A bumper reference location 1 and at steam generator 1B bumper reference locations 6 and 7 shown on Figure 2.

Other primary equipment supports have been evaluated for seismic loads in the cold shutdown condition. These loads have been calculated and are well within the capacity for the corresponding support component. The loads, support capacities and their comparison (expressed as load margins) are presented in Table 9.



## 6.0 QUALITY ASSURANCE

### 6.1 Rochester Gas and Electric Corporation

The overall project is being conducted under the RG&E Quality Assurance Program. The replacement rigid structural members (bumpers) has been fabricated by a supplier having a Quality Assurance Program meeting the requirements of ANSI N45.2. RG&E has specified material traceability, welder qualification, non-destructive examination and other requirements applicable to the new bumpers.

### 6.2 Westinghouse Electric Corporation

The structural qualification work performed by Westinghouse has been independently reviewed at Westinghouse as a safety-related calculation and meets 10CFR50, Appendix B, Quality Assurance requirements. The detailed results of the analyses are maintained in Westinghouse Central Files in accordance with Westinghouse Quality Assurance procedures (ref. 10 and 11).

### 6.3 Altran Corporation

An independent, third party review is being performed by Altran Corporation and Dr. Thomas C. Esselman. Dr. Esselman and his associates have conducted a thorough review of the assumptions, design bases, analyses and other design documents produced by Westinghouse.



## 7.0 CONCLUSIONS

Based on the results of the evaluation of the reactor coolant system with the redesigned SG upper lateral support configuration the following conclusions are made:

- a. The combination of hydraulic snubbers and rigid structural members (bumpers) which comprise the revised steam generator upper lateral support system maintain adequate restraint of each steam generator under the design basis loads.
- b. The maximum stresses in the RCS piping and primary equipment supports are within Code allowables.
- c. The maximum displacements in the RCS piping have been accounted for in analyses of auxiliary piping systems attached to the RCS, and do not significantly affect those analyses.
- d. The reactor coolant loop piping and equipment supports continue to have acceptable margins of safety for all design basis events.
- e. The Containment Building structures are adequate to carry the loads imposed by the new snubber/bumper SG upper lateral support configuration.

Therefore, the proposed modified configuration meets all conditions necessary to assure safe operation of the plant in accordance with the licensed design bases.





## 8.0 REFERENCES

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Table 1  
RCS PIPING  
LOAD COMBINATIONS AND STRESS LIMITS

<u>Condition</u>	<u>Loading Combination</u>	<u>ANSI B31.1 Equations</u>
Normal	Design Pressure + Deadweight	11
Upset	Design Pressure + Deadweight + OBE	12
Emergency	Design Pressure + Deadweight + SSE	12
Faulted	Design Pressure + Deadweight + (SSE + DBA)**	12
Max. Thermal	Max. Thermal Stress Range*** + OBE Displacement	13
Normal & Max. Thermal	Design Pressure + Deadweight + Max. Thermal Stress Range + OBE Displacements	14

\*\*SRSS combination of SSE and DBA loads

\*\*\*Loss-of-load overtemperature transient condition

The piping stress equations are:

$$\frac{PD}{4t} + .75 i \frac{M_A}{Z} \leq 1.0S_h \quad \text{Equation (11)}$$

$$\frac{PD}{4t} + .75 i \frac{(M_A + M_D)}{Z} \begin{matrix} 1.2S_h \text{ (Upset)} \\ \leq 1.8S_h \text{ (Emergency)} \\ 2.4S_h \text{ (Faulted)} \end{matrix} \quad \text{Equation (12)}$$

$$i \frac{M_C}{Z} \leq S_a \quad \text{Equation (13)}$$

$$\frac{PD}{4t} + .75 i \frac{M_A}{Z} + i \frac{M_C}{Z} \leq S_h + S_a \quad \text{Equation (14)}$$

Where:

$M_A$  = Resultant moment due to dead load and other sustained loads.

$M_D$  = Resultant moment due to occasional loads.

$M_C$  = Resultant moment due to range of thermal expansion loadings.

$P$  = Internal Design Pressure.

$D$  = Outside diameter of pipe.

$t$  = Nominal wall thickness of pipe.

$Z$  = Section modulus

$S_h$  = Material allowable stress at maximum temperature.

$S_a$  = Allowable stress range for expansion stress.

$i$  = Stress Intensification Factor.



TABLE 2

DEFINITION OF LOADING CONDITIONS  
FOR PRIMARY EQUIPMENT SUPPORTS EVALUATION

<u>Loading Condition</u>	Abbreviations
1. Sustained Loads	DW, Deadweight +P, Operating Pressure +TN, Normal Operating Thermal
2. Transients	SOT, System Operating Transient
a. Over-temperature Transient	TA
3. Operating Basis Earthquake	OBE
4. Safe Shutdown Earthquake	SSE
5. Design Basis Pipe Break	DBPB
a. Residual Heat Removal Line	RHR
b. Accumulator Line	ACC
c. Pressurizer Surge Line	SURG
6. Main Steam Line Break	MS
7. Feed Water Pipe Break	FW





TABLE 3

LOAD COMBINATIONS AND ALLOWABLE STRESS LIMITS  
FOR PRIMARY EQUIPMENT SUPPORTS EVALUATION

<u>Plant Event</u>	<u>System Operating Conditions</u>	<u>Service Loading Combinations</u>	<u>Service Level Stress Limits</u>
1. Normal Operation	Normal	Sustained Loads	A
2. Plant/System Operating Transients (SOT) + OBE	Upset	Sustained Loads + SOT + OBE	B
3. DBPB	Emergency	Sustained Loads + DBPB	C
4. SSE	Faulted	Sustained Loads + SSE	D
5. DBPB (or MS/FWPB) + SSE	Faulted	Sustained Loads + (DBPB or MS/FWPB) + SSE	D

## Note:

1. The pipe break loads and SSE loads are combined by the square-root-sum-of-the-squares method.
2. Stress levels as defined by ASME B&PV Code Section III, Subsection NF, 1974 Edition.



TABLE 4

MAXIMUM REACTOR COOLANT LOOP PIPING STRESSES  
(Based on K )  
AVG

ANSI B31.1 Code Equation(2)	(1) Configuration RCL Piping	Current Configuration Stress (ksi)	Redesigned Configuration Stress (ksi)	ANSI B31.1 Code Allow- able Stress (ksi)	Percentage of Allowable
(11)	HL	7.2	7.1	16.8	43%
	XL	6.9	6.9	16.8	41%
	CL	6.9	6.9	16.8	41%
(12) Design and Upset	HL	9.8	8.0	20.1	40%
	XL	9.8	8.9	20.1	41%
	CL	10.0	9.4	20.1	41%
(12) Emergency	HL	11.7	8.6	30.2	29%
	XL	12.1	10.6	30.2	35%
	CL	12.5	11.5	30.2	38%
(12) (Faulted)	HL	*	19.7	40.3	49%
	XL	*	11.5	40.3	29%
	CL	*	17.8	40.3	45%
(13) See Note 3	HL	9.7	9.7	27.5	36%
	XL	5.3	5.3	27.5	20%
	CL	7.4	7.4	27.5	27%
(14)	HL	16.8	16.8	44.4	38%
	XL	11.1	11.1	44.4	25%
	CL	13.1	13.1	44.4	35%

## NOTES:

- (1) HL - Hot Leg, XL - Crossover leg, CL - Cold leg  
 \* Pipe rupture loads were not considered. No faulted stresses were calculated for current design.
- (2) Load combinations are shown in Table 1.
- (3) Loss-of-load overtemperature transient effects are included.



TABLE 5

COMBINED LOADS FOR LOOP PIPING LEAK-BEFORE-BREAK  
(Based on K )  
AVG

<u>Load Combination</u>	<u>Axial Force (kips)</u>	<u>Bending Moment (in-kips)</u>	<u>Combined Axial Stress (ksi)</u>
Normal	1939	16760	16.88 (calculated)
SSE	251	2820	2.54 (calculated)
Normal + SSE	2190	19580	19.42 (calculated)
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Normal + SSE	1800	45600 (2)	32.4 (allowable) (See Note 2)

Notes: (1) Allowable based on WCAP-9558, Rev. 1.  
(2) Umbrella bending moment in NRC Generic Letter  
84-04 is 42,000 in-kips.



TABLE 6

## RCS PRIMARY EQUIPMENT SUPPORTS STRESS MARGIN SUMMARY

(Stress Margin = Allowable/Actual)  
 (Based on K )  
 AVG

Service Level	Normal	Upset	Emergency	SSE	Faulted
Load Combination	DW+TN	DW+TA+ OBE	DW+TN+ DBPB	DW+TN+ SSE	DW+TN+ [ (SSE <sup>2</sup> +PIBK <sup>2</sup> ) ]
SG Upper Supports					
Bumpers	See Note 3	2.53	3.24 (ACC)	2.41	1.79 (FW)
Snubbers	See Note 3	3.17	6.26 (ACC)	2.25	1.11 (FW)
SG Lower Supports					
Lateral Columns	See Note 3 3.51	1.67 1.65	1.57 (SURG) 3.11 (ACC)	1.77 3.29	1.21 (SURG, 2.19 (MS)
Reactor Coolant Pumps					
Lateral Columns	See Note 3 5.15	4.55 1.87	18.12 (ACC) 2.76 (ACC)	8.10 1.87	7.46 (ACC) 1.87 (ACC)
Reactor Vessel					
Lateral Vertical	See Note 3 3.05	4.33 1.29	1.31 (ACC) 2.09 (ACC)	5.94 4.53	1.41 (ACC) 3.45 (ACC)

- Notes: 1) The load symbols are defined in Table 2.  
 2) PIBK includes DBPB and MS/FW breaks  
 3) Under normal conditions no significant loads are imposed on these lateral support elements.





TABLE 7  
STEAM GENERATOR UPPER SUPPORTS  
SEISMIC LOAD MARGINS  
(Based on K )  
AVG

LOOP NO.	BUMPER ID	<u>SEISMIC LOADS (DW+TN+SSE)</u>			<u>SGUS CAPACITY</u>		<u>SEISMIC LOAD MARGIN</u>	
		(kips)			(kips)		(Allowable/Actual)	
		EXISTING SGUS(1)	REDESIGNED SGUS	% CHANGE	EXISTING	REDESIGNED	EXISTING	REDESIGNED
1A	SN-1	582.0	410.4	-30	1064	1064	1.83	2.59
	1	582.0	335.4	-42	1064	1640	1.83	4.89
	2	582.6	410.5	-30	1064	1640	1.83	3.99
	3	582.6	410.5	-30	1064	1640	1.83	3.99
1B	SN-2	514.2	472.3	-8	1064	1064	2.07	2.25
	4	470.0	453.3	-4	1064	1640	2.26	3.61
	5	448.0	386.5	-14	1064	1640	2.37	4.24
	6	312.2	309.9	-1	532	820	1.70	2.64
	7	287.2	340.0	+18.4	532	820	1.85	2.41

(1) See Note Attached.



NOTE TO TABLE 7

The original seismic support load calculations included an additional contribution which is not required in the revised support load calculations. In the original case, the total seismic support plane load at the upper support was first calculated by dynamic analysis in global coordinates and then rotated to the local coordinates of the support members. In the revised case, the individual support members were modeled directly in the dynamic model so that a rotation from support plane loads to member loads were not required. The rotation of coordinates must be done conservatively, since there are no signs associated with the total seismic force components in global coordinates. Therefore, the original design loads are more conservatively calculated than the revised design loads.



TABLE 8

STEAM GENERATOR UPPER SUPPORTS  
SEISMIC LOAD MARGINS  
(Using  $K_{avg}$  and  $K_{max}/K_{min}$ )

<u>LOOP NO.</u>	<u>BUMPER ID</u>	<u>SEISMIC LOADS (DW+TN+SSE)</u> (kips)			<u>SGUS CAPACITY</u> (kips)	<u>SEISMIC LOAD MARGIN</u> (Allowable/Actual)	
		<u>Kavg</u>	<u>Kmax/Kmin</u>	<u>% CHANGE</u>	<u>REDESIGNED</u>	<u>Kavg</u>	<u>Kmax/Kmin</u>
1A	SN-1	410.4	533.5	+30	1064	2.59	1.99
	1	335.4	436.0	+30	1640	4.89	3.76
	2	410.5	533.7	+30	1640	3.99	3.07
	3	410.5	533.7	+30	1640	3.99	3.07
1B	SN-2	472.3	614.0	+30	1064	2.25	1.73
	4	453.3	589.3	+30	1640	3.61	2.78
	5	386.5	502.5	+30	1640	4.24	3.26
	6	309.9	402.9	+30	820	2.64	2.03
	7	340.0	442.0	+30	820	2.41	1.86



Table 9

RCS PRIMARY EQUIPMENT SUPPORTS LOAD MARGIN SUMMARY  
COLD SHUTDOWN SEISMIC ANALYSIS  
(Load Margin = Capacity/Load)

<u>Support Component</u>	<u>Load (kips)</u> (See Note 8)	<u>Capacity</u> (kips)	<u>Load Margin</u>
SG Snubbers (See Note 1)	385.1	1064.0	2.76
SG Upper Lateral Supports (Bumpers) (See Note 2)	912.0	1640.0	1.80
SG Columns (See Note 3)	495.6	1349.0	2.72
SG Lower Lateral Supports (See Note 4)	-	-	-
RCP Columns (See Note 5)	256.6	397.0	1.55
RCP Tie Rods (See Note 6)	-	-	-
RPV Support (Vertical) (See Note 7)	623.1	3000.0	4.81
RPV Support (Horizontal) (See Note 7)	364.3	1300.0	3.57

NOTES:

1. One pair of existing snubbers remain in place at each SG (A and B) in direction of RCL hot leg. Load and capacity corresponds to the pair of snubbers (532 kips capacity, each)
2. Cold shutdown seismic loads are calculated for new bumpers oriented approximately perpendicular to RCL hot leg. Load and capacity corresponds to a pair of bumpers (820 kips capacity, each).
3. Each SG (A and B) has four support columns with 1349.0 kips capacity, each, in compression. Load given is worst case single column compression load.
4. Each SG (A and B) has a lower lateral support frame at the bottom of the SG shell. During Cold Shutdown, lateral support from the frame is disengaged due to contraction of the RCS.

5. Each RCP (A and B) has three support columns with 397.0 kips capacity, each, in tension. Load given is worst case single column tension load.
6. Each RCP (A and B) has two tie-rods. During cold shutdown all RCP tie-rods are disengaged as a result of contraction of RCS.
7. There are six RPV supports (one at each of four major nozzles) and two at separate vessel support brackets. Loads and capacities are for the worst case single RPV support in each direction.
8. Loads include deadweight and SSE.



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Table 10

## STEAM GENERATOR UPPER SUPPORTS

## LIMITING SEISMIC LOADS (Analysis Cases 1 and 2)

<u>RCS Loop No.</u>	<u>Snubber Location</u>	<u>Snubber Capacity, Kips (See Note 2)</u>	<u>Limiting Seismic Loads (DW+TN+SSE), Kips</u>	
			<u>Analysis Case 1</u>	<u>Analysis Case 2</u>
1A	See Note 1	1064	410.4 (See Note 4)	386.4 (See Note 3)
1B	See Note 1	1064	380.3 (See Note 3)	472.3 (See Note 4)

Notes:

1. See Figure 2 for snubber locations.
2. Capacity corresponds to a pair of snubbers of each location (532 kips capacity, each).
3. The smaller load for each Analysis Case is shown for comparison purposes and is not the limiting load.
4. These seismic loads are also presented in Table 7.



# APPENDIX A COMBINATION OF SEISMIC MODAL RESPONSES

For seismic Category I components in NSSS scope, the method used to combine modal responses is described below. The total unidirectional seismic response for NSSS equipment is obtained by combining the individual modal responses using the SRSS method in reference 10. For systems having modes with closely spaced frequencies, this method is modified to include the possible effect of these modes. The groups of closely spaced modes are chosen such that the difference between the frequencies of the first mode and the last mode in the group does not exceed 10 percent of the lower frequency. Combined total response for systems which have such closely spaced modal frequencies is obtained by adding to the SRSS of all modes the product of the responses of the modes in each group of closely spaced modes and a coupling factor,  $\epsilon$ . This can be represented mathematically as:

$$R_T^2 = \sum_{i=1}^N R_i^2 + 2 \sum_{j=1}^S \sum_{k=M_j}^{N_j-1} \sum_{\ell=k+1}^{N_j} R_k R_\ell \epsilon_{k\ell} \quad (\text{Equation A-1})$$

where:

- $R_T$  = Total unidirectional response
- $R_i$  = Absolute value of response of mode  $i$
- $N$  = Total number of modes considered
- $S$  = Number of groups of closely spaced modes
- $M_j$  = Lowest modal number associated with group  $j$  of closely spaced modes
- $N_j$  = Highest modal number associated with group  $j$  of closely spaced modes
- $\epsilon_{k\ell}$  = Coupling factor defined as follows:

$$\varepsilon_{k\ell} = \left\{ 1 + \left[ \frac{\omega_k' - \omega_\ell'}{(\beta_k' \omega_k + \beta_\ell' \omega_\ell)} \right]^2 \right\}^{-1}$$

and,

$$\omega_k' = \omega_k [1 - (\beta_k')^2]^{1/2}$$

$$\beta_k' = \beta_k + \frac{2}{\omega_k t_d}$$

where:

$\omega_k$  = Frequency of closely spaced mode K

$\beta_k$  = Fraction of critical damping in closely spaced mode K

$t_d$  = Duration of the earthquake

An example of this equation applied to a system can be supplied with the following considerations. Assume that the predominant contributing modes have frequencies as given below:

Mode	1	2	3	4	5	6	7	8
Frequency	5.0	8.0	8.3	8.6	11.0	15.5	16.0	20

1245

1246

1247

1248

1249

1250

1251

1252



There are two groups of closely spaced modes, namely modes 2, 3, 4 and 6, 7.

Therefore:

$S = 2$ , Number of groups of closely spaced modes

$M_1 = 2$ , Lowest modal number associated with group 1

$N_1 = 4$ , Highest modal number associated with group 1

$M_2 = 6$ , Lowest modal number associated with group 2

$N_2 = 7$ , Highest modal number associated with group 2

$N = 8$ , Total number of modes considered

The total response for this system is, as derived from the expansion of Equation A-1:

$$R_T^2 = [R_1^2 + R_2^2 + R_3^2 + \dots + R_8^2] + 2R_2R_3\epsilon_{23} + 2R_2R_4\epsilon_{24} \\ + 2R_3R_4\epsilon_{34} + 2R_6R_7\epsilon_{67}$$

The first term in brackets represents the SRSS summation of each of the eight sample modes. The next four terms account for the additional effects due to interaction between sample modes 2, 3, 4, 6 and 7.

The above method of modal combination is known as Westinghouse grouping method. A more conservative grouping method known as Westinghouse ten percent grouping method was used in the seismic response spectrum analyses. The groups of closely spaced modes are chosen such that the difference between two frequencies is no greater than the percent. Therefore,



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11





$$R_T^2 = \sum_{i=1}^N R_i^2 + 2 \sum \epsilon_{kl} R_k R_l$$

where

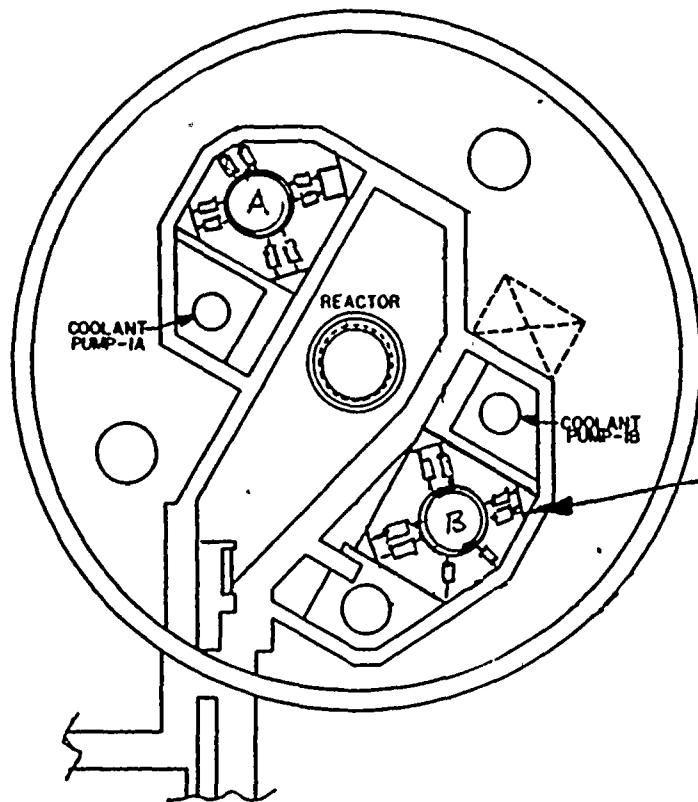
$$\frac{|\omega_k - \omega_l|}{\omega_l} \leq 0.1$$

All other terms for the modal combination remain the same. The ten percent grouping method is more conservative than the grouping method because the same mode can appear in more than one group.

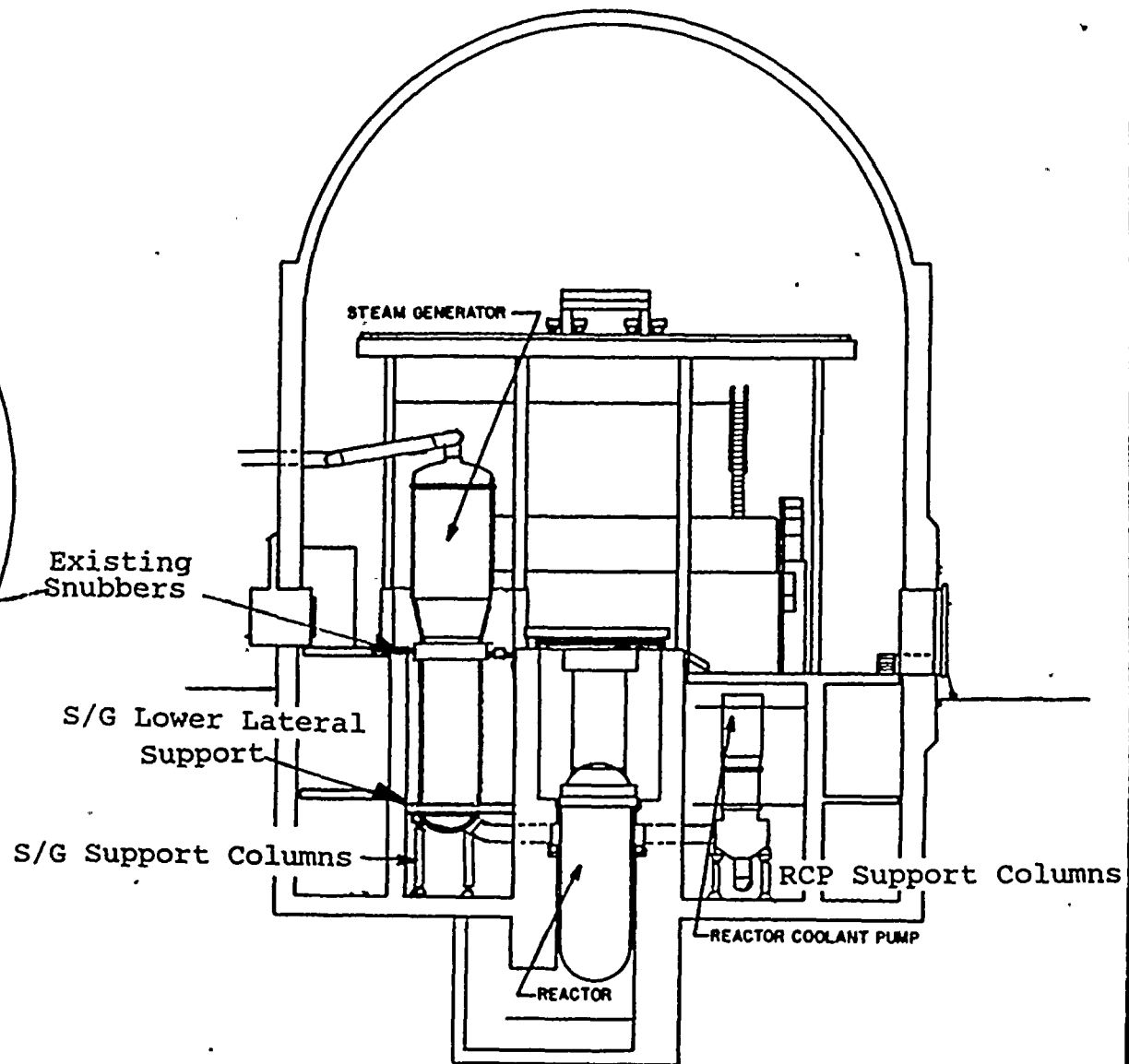




E-1

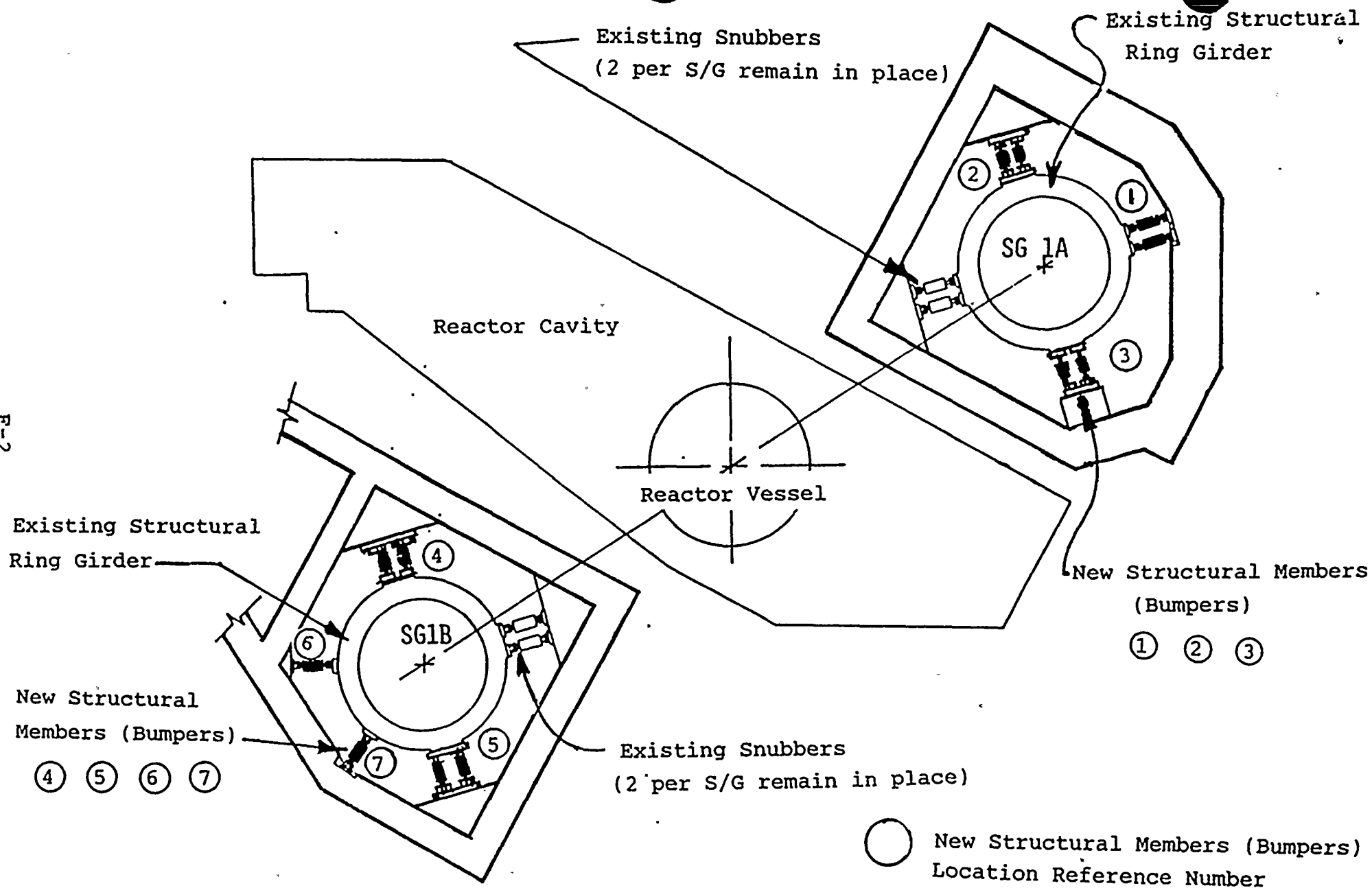


REACTOR BUILDING PLAN



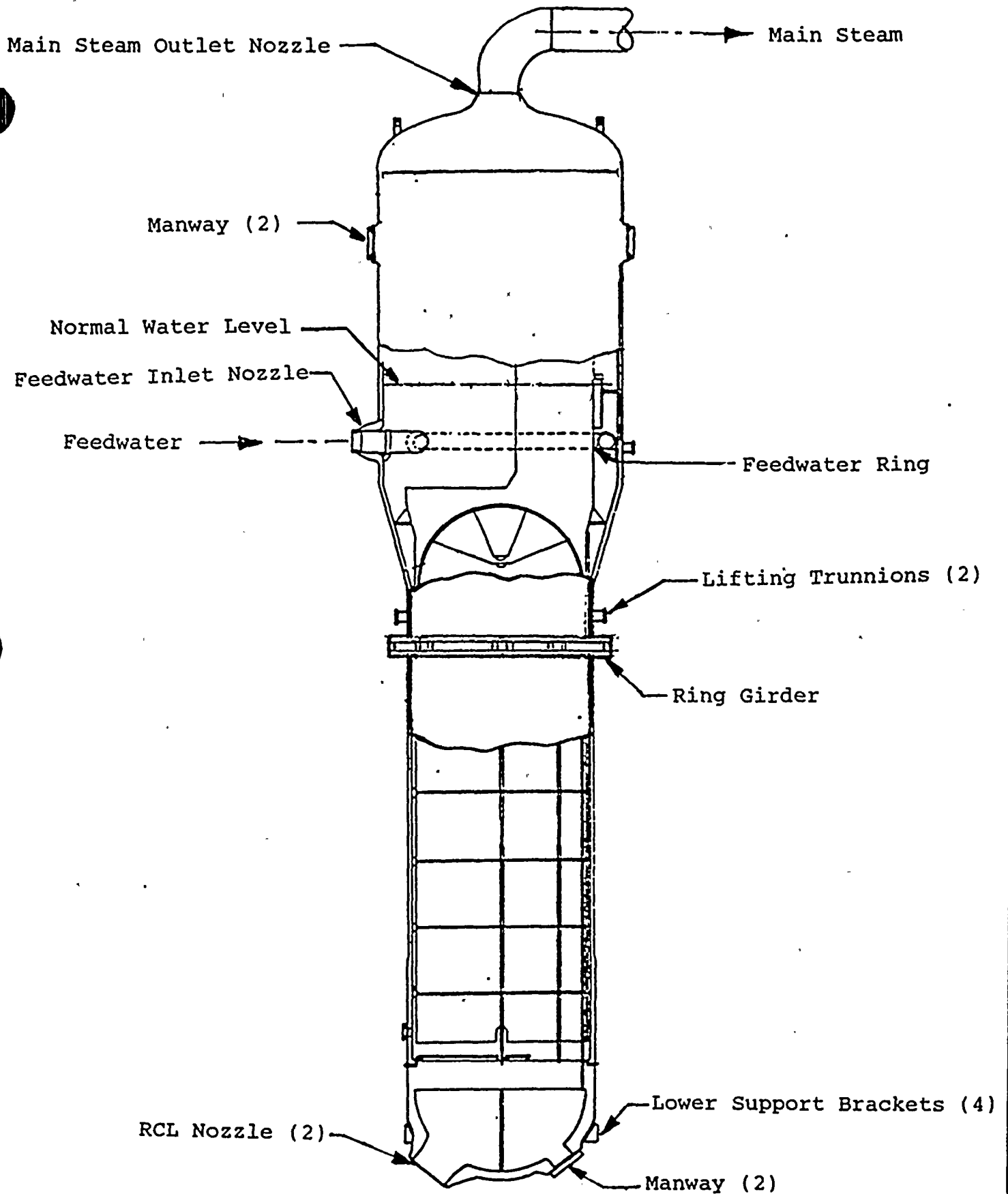
REACTOR BUILDING ELEVATION

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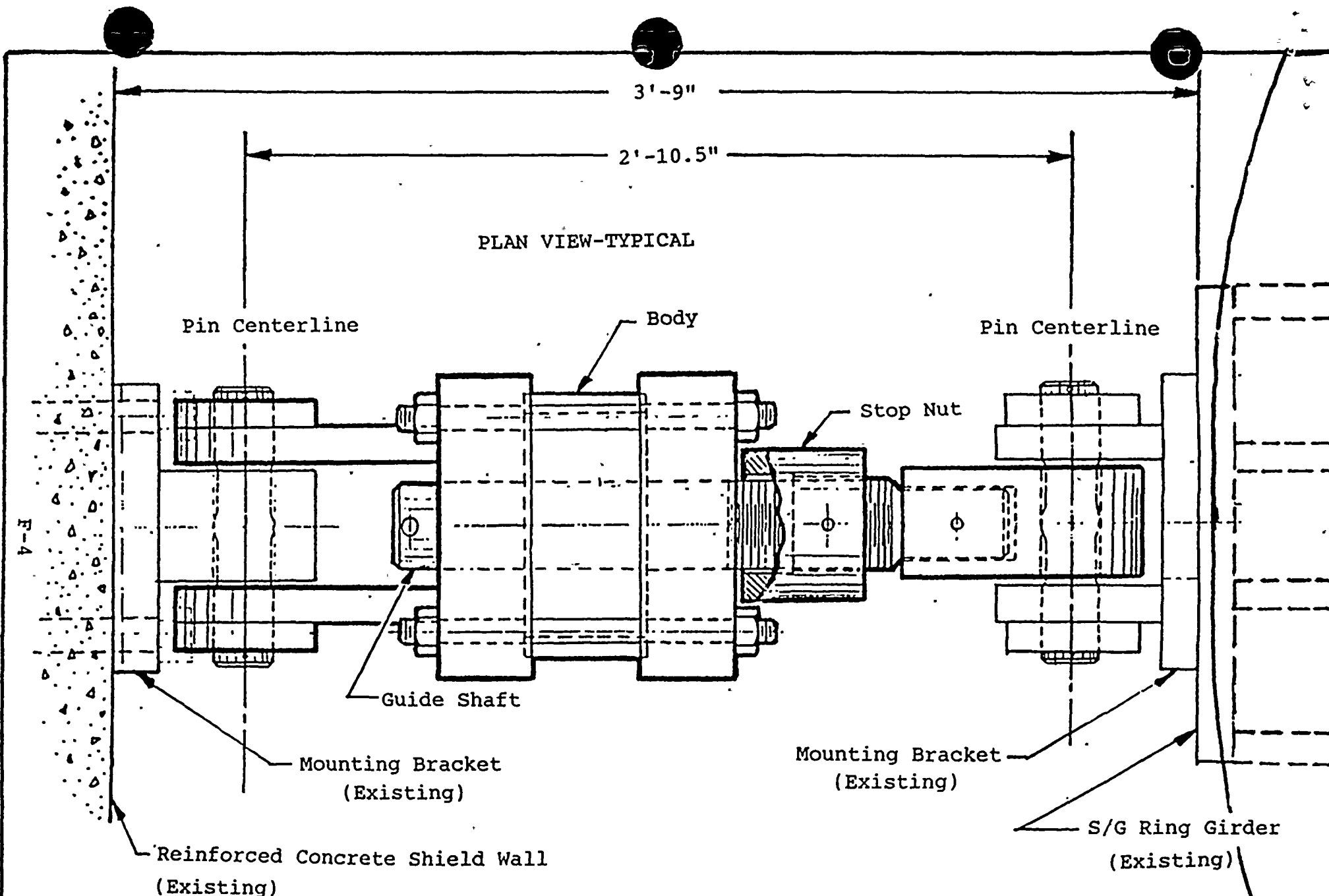
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GINNA STATION STEAM GENERATOR SNUBBER REPLACEMENT PROGRAM

FIGURE 4

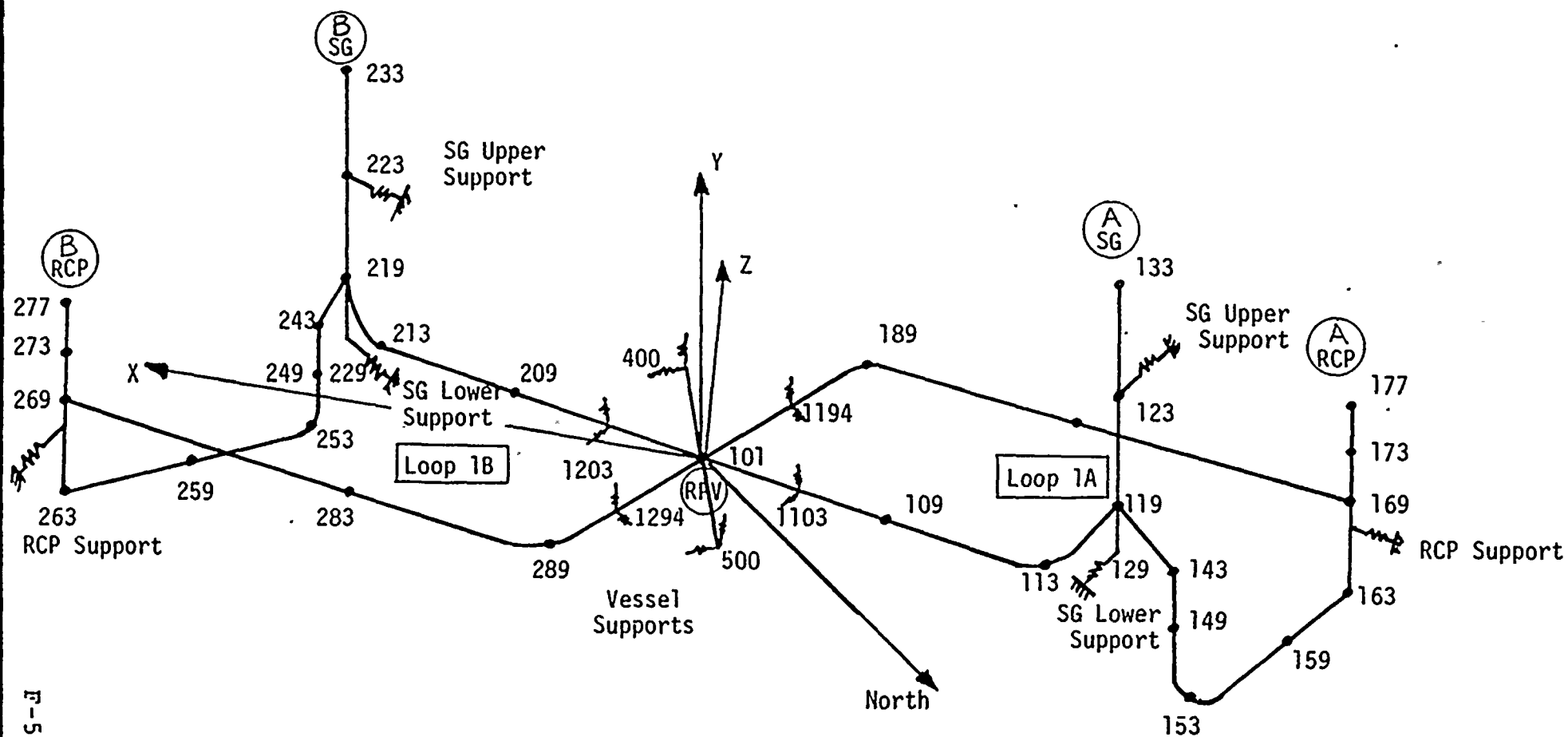
RIGID STRUCTURAL MEMBER (BUMPER)-DETAILS





177  
2  
1885



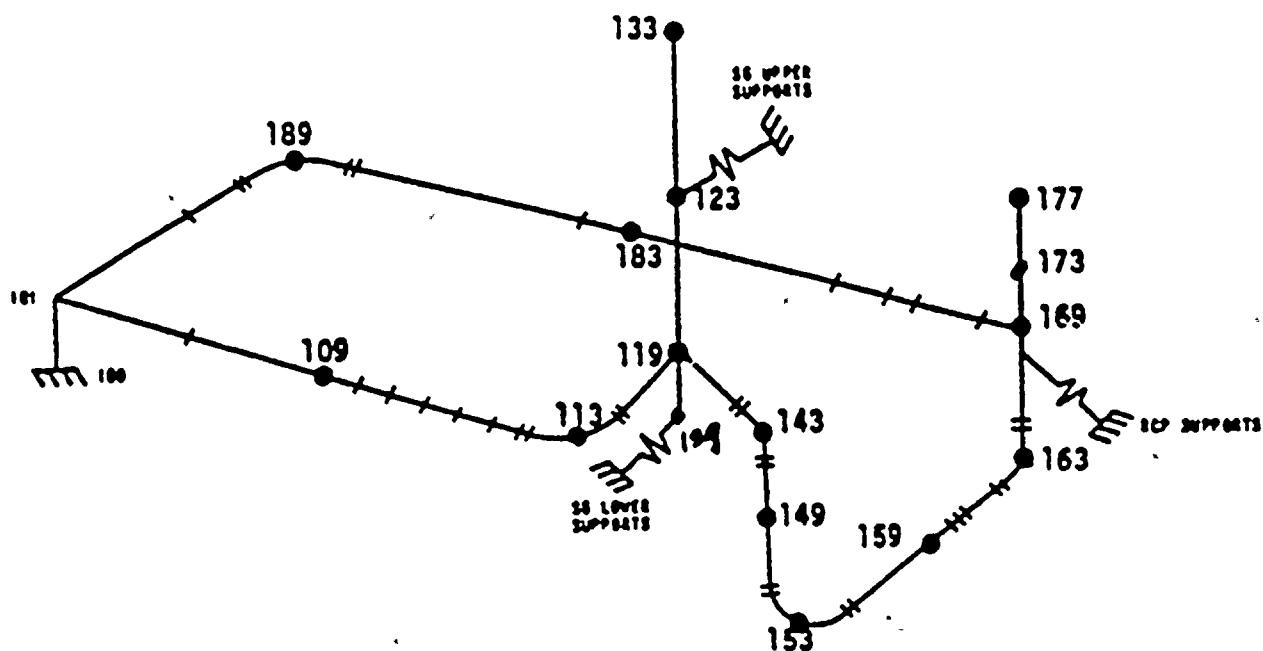


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FIGURE 5

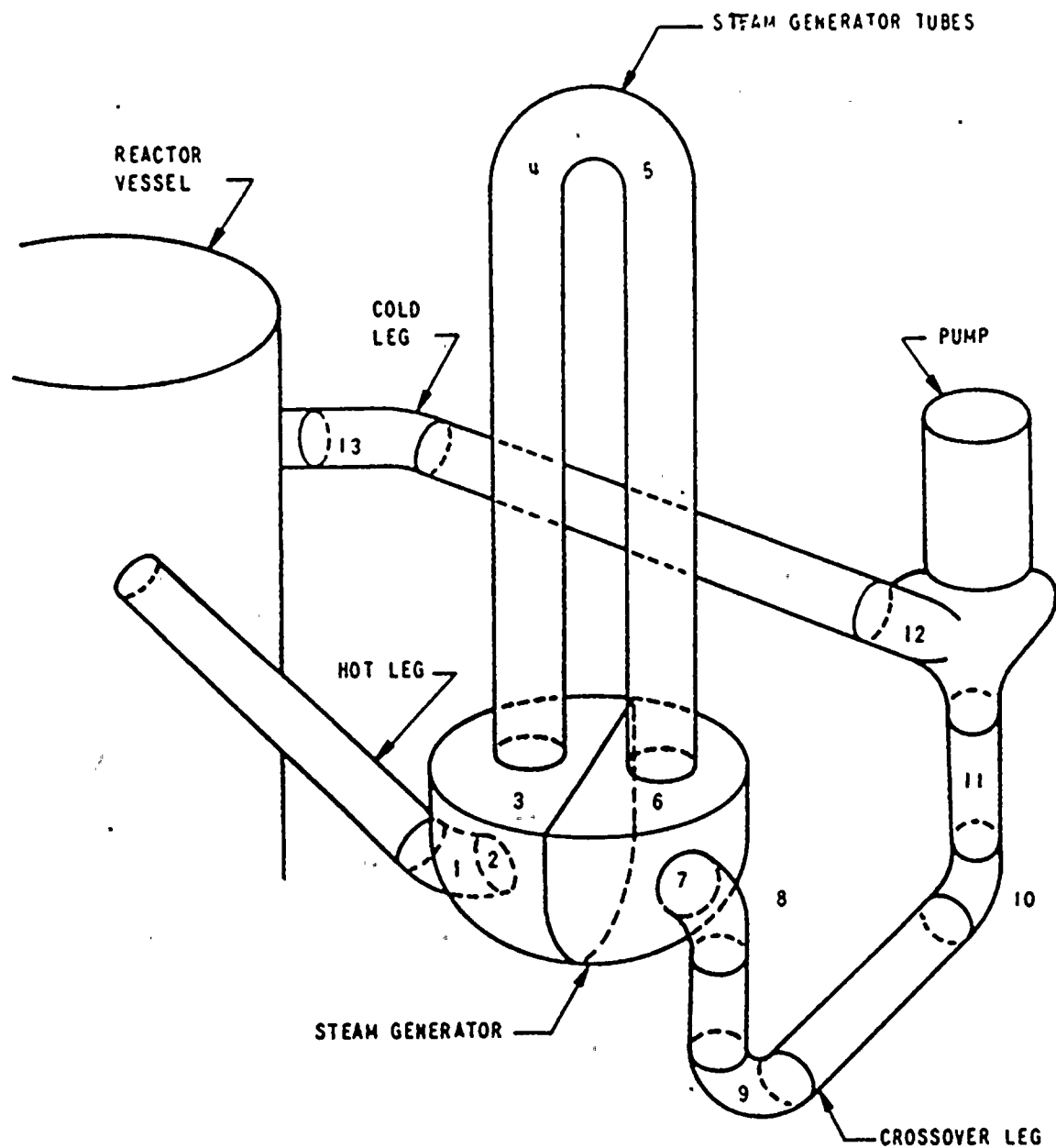
REACTOR COOLANT LOOPS 1A & 1B ANALYTICAL MODEL  
(STATIC AND SEISMIC ANALYSES)





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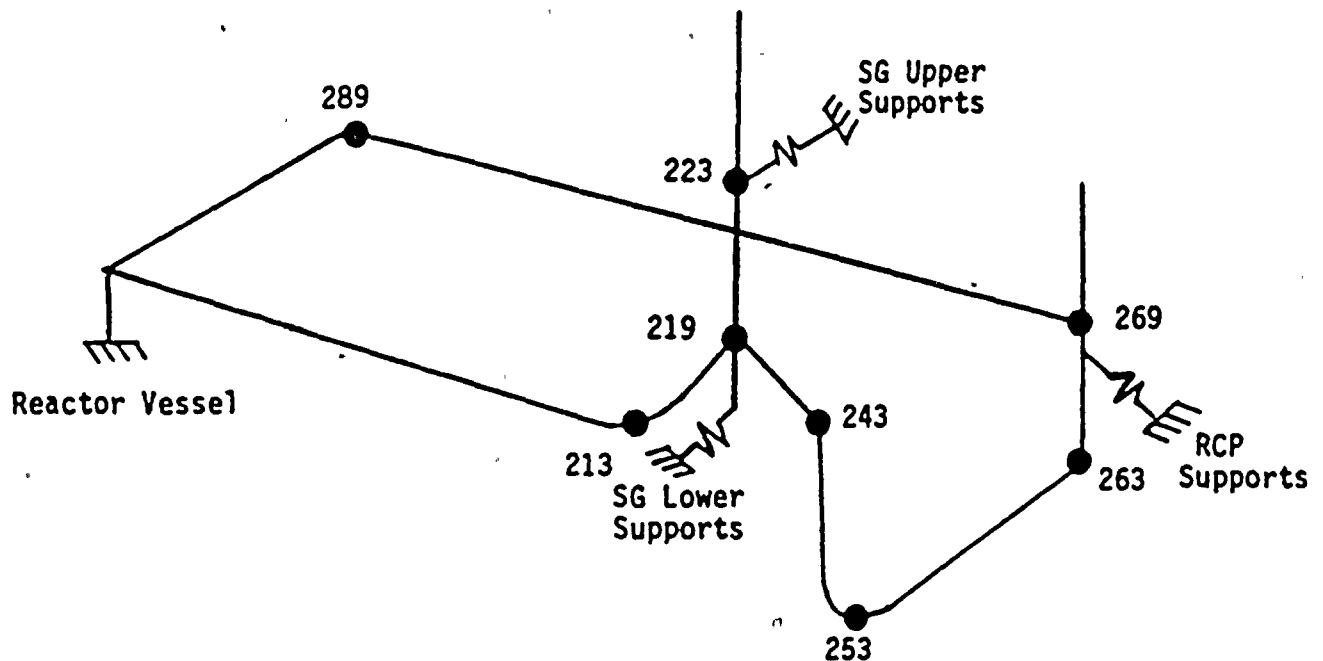
FIGURE 6: REACTOR COOLANT PIPING/SUPPORT SYSTEM-  
ONE LOOP MODEL FOR TIME-HISTORY PIPE  
RUPTURE ANALYSIS



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Figure 7 REACTOR COOLANT LOOP MODEL -  
Hydraulic Force Locations





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Figure 8 REACTOR COOLANT PIPING/SUPPORT MODEL  
(Location of Lumped Masses For the Application  
of Time History Hydraulic Loads)





TITLE

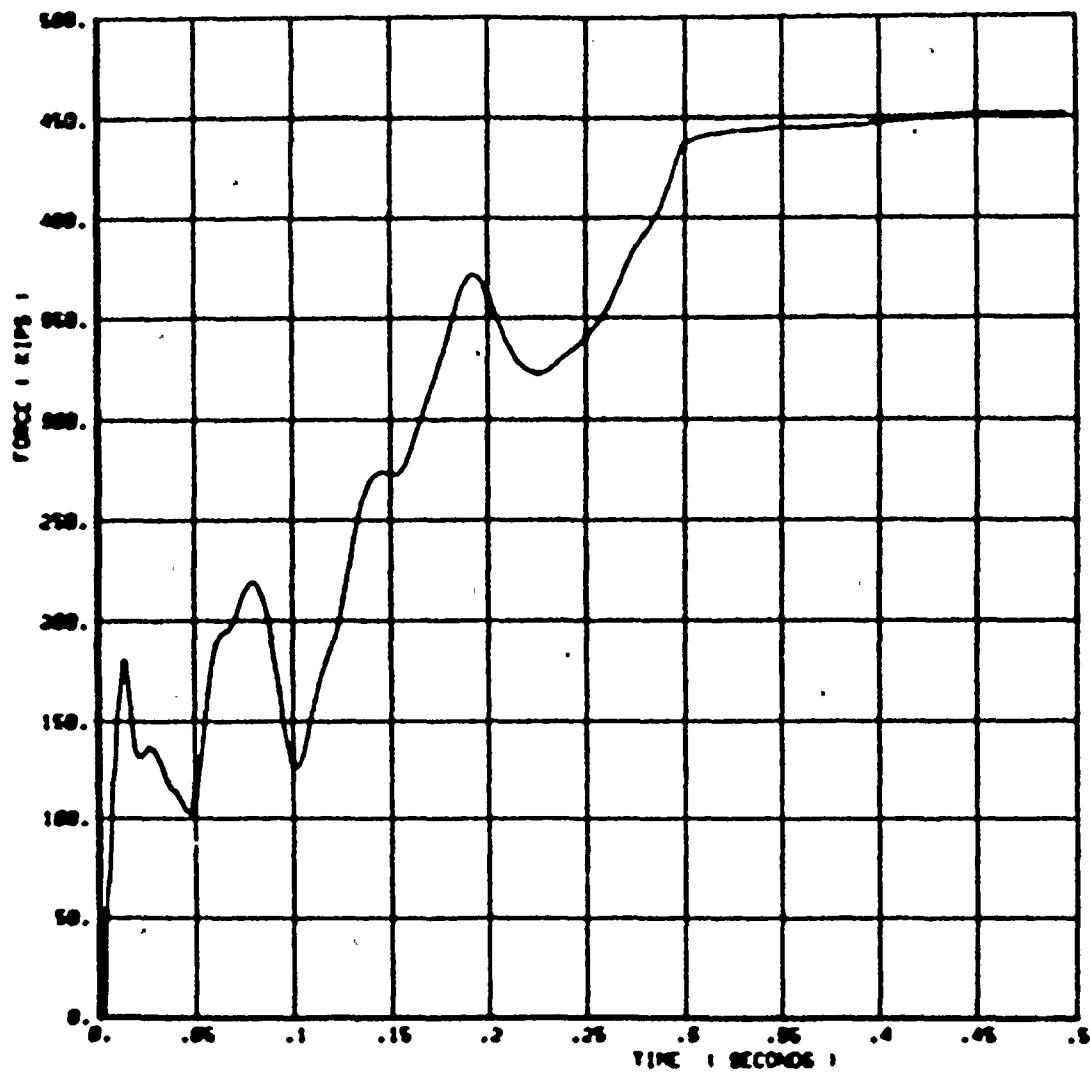
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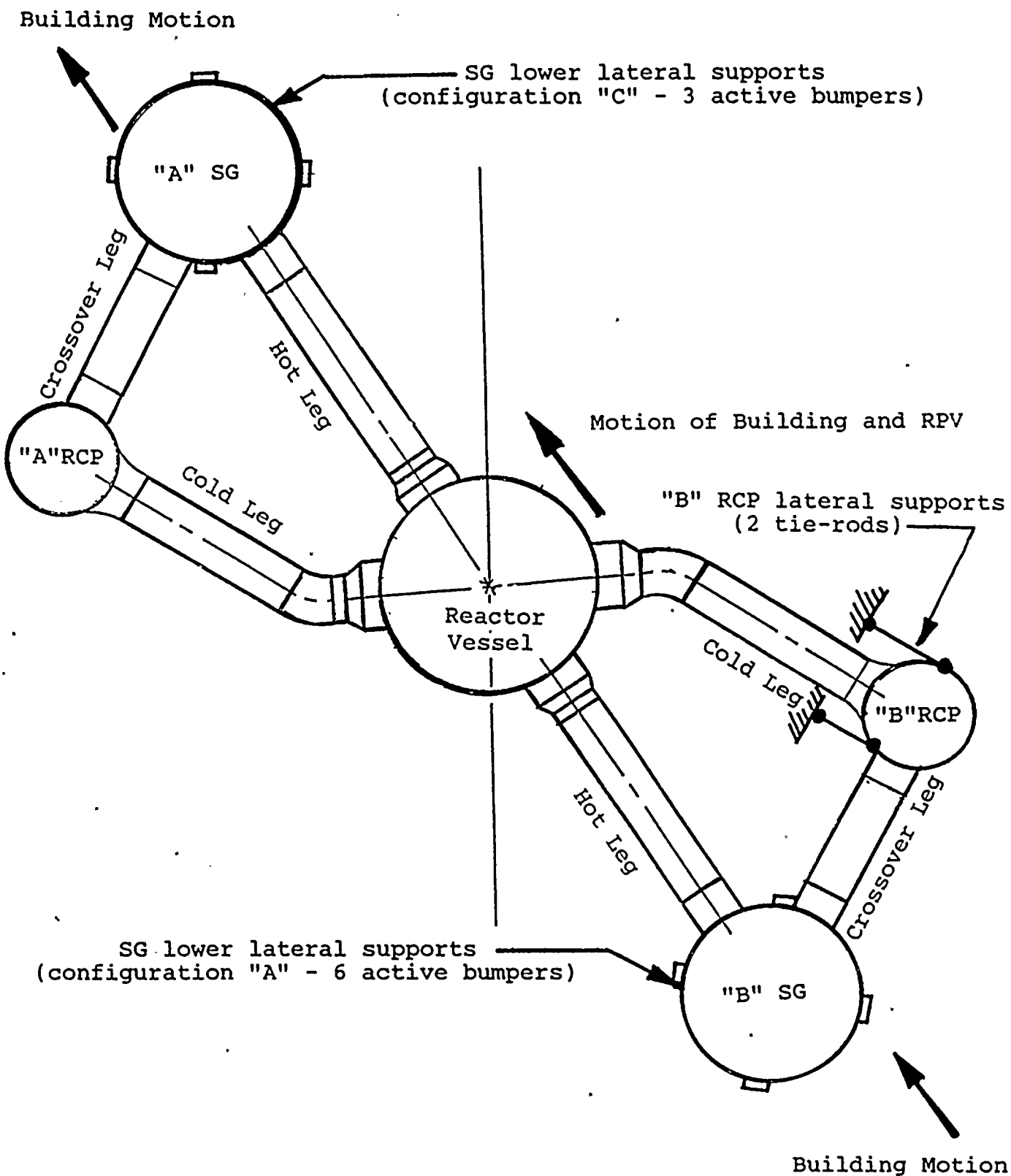
GINNA STATION STEAM GENERATOR SNUBBER REPLACEMENT PROGRAM

Figure 9

REPRESENTATION BLOWDOWN FORCING FUNCTION PLOT  
(one coordinate direction at one location)

sheet



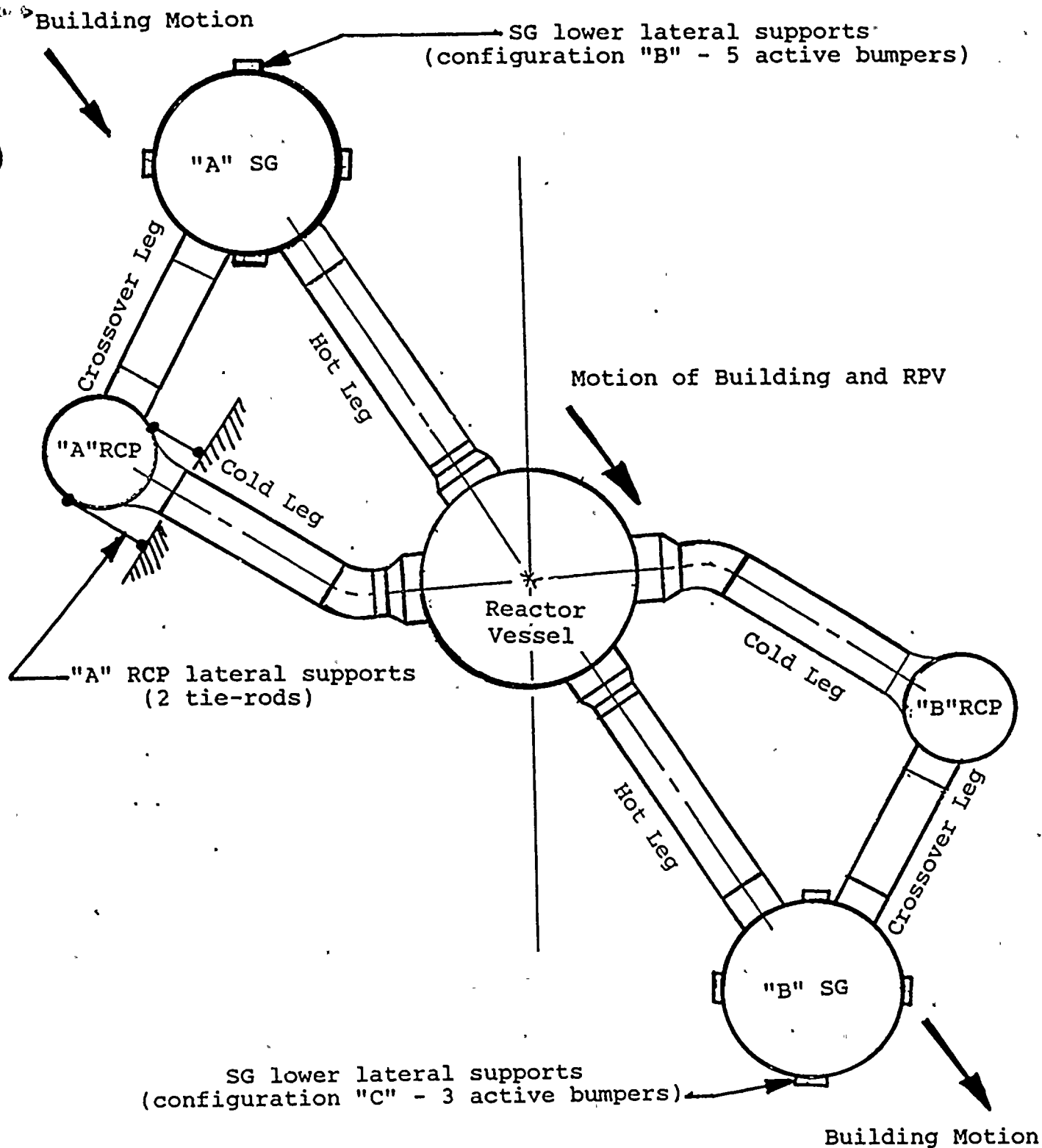


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Figure 10-a REACTOR COOLANT LOOPS A&B - HOT CONDITION  
(Additional active supports for analysis Case 1)

10  
9  
8  
7  
6  
5  
4  
3  
2  
1

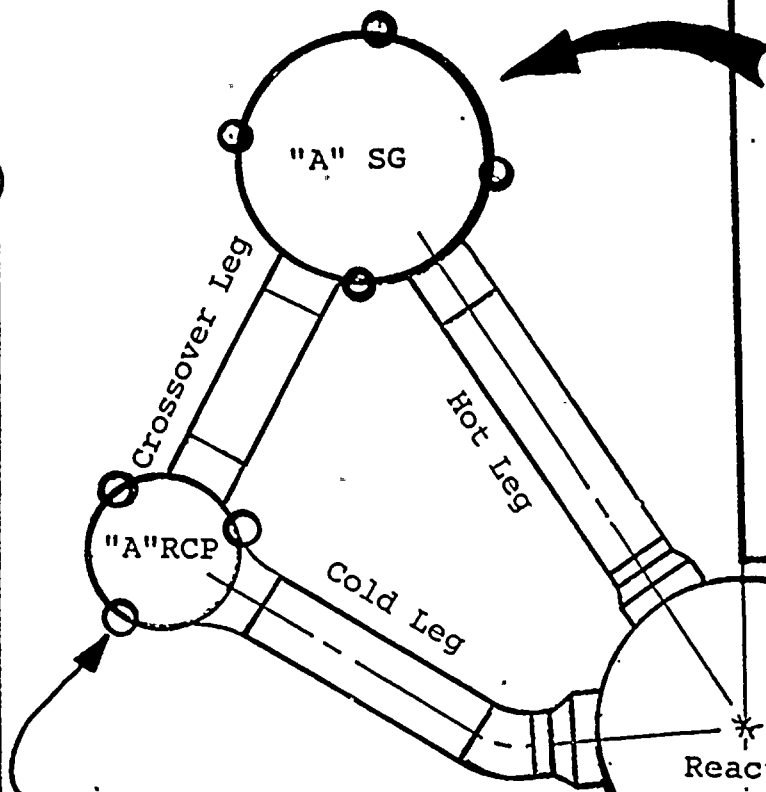




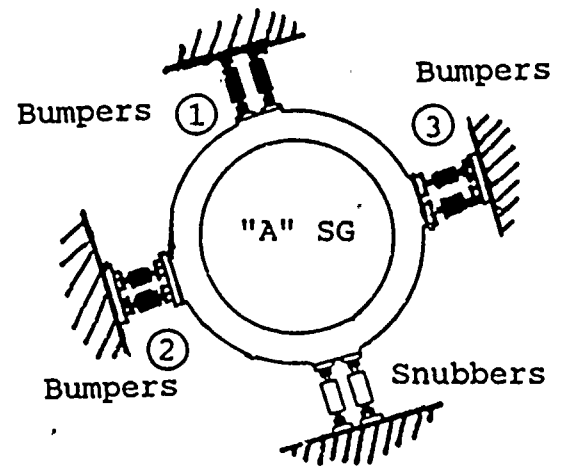
GINNA STATION STEAM GENERATOR SNUBBER REPLACEMENT PROGRAM  
Figure 10-b REACTOR COOLANT LOOP A&B - HOT CONDITION  
 (Additional active supports for analysis Case 2)



20  
21  
22

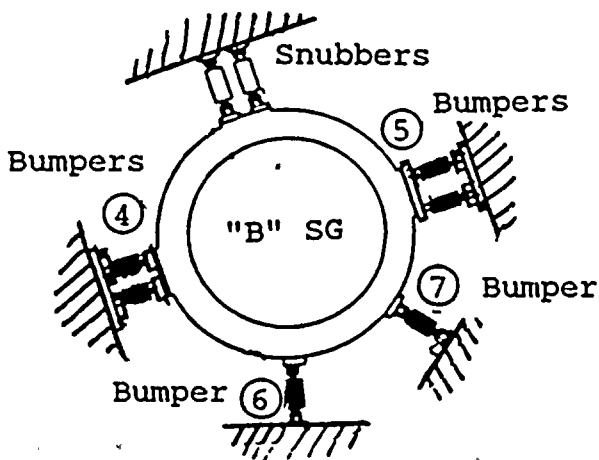
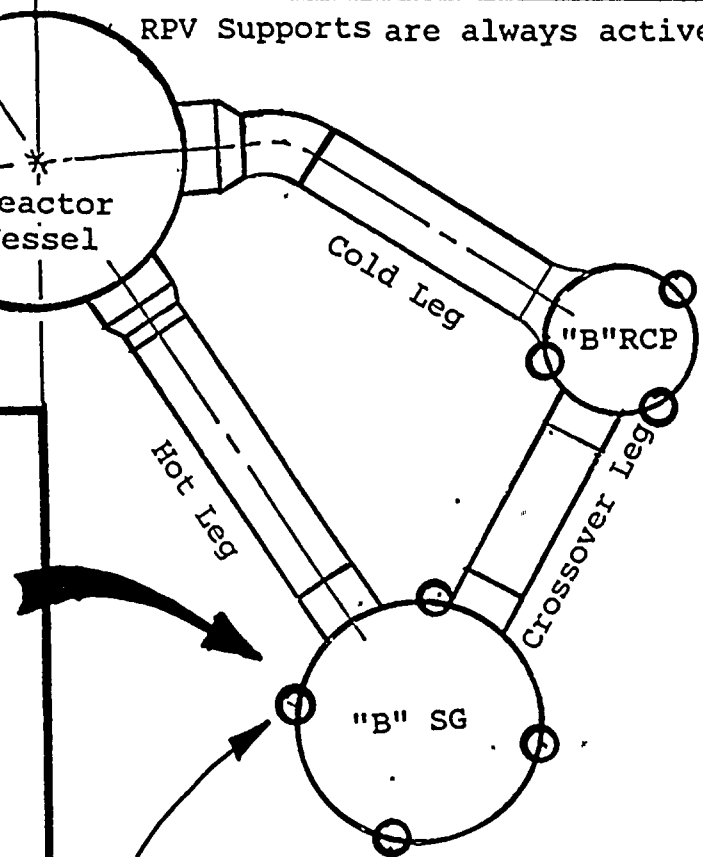


Three vertical support columns per RCP are always active (same for loops "A" and "B")



"A" SG Upper Lateral Support System (2 snubbers and 6 bumpers) are always active.

RPV Supports are always active



"B" SG Upper Lateral Support System (2 snubbers and 6 bumpers) are always active

Four vertical support columns per SG are always active (same for loops "A" and "B")

# GINNA STATION STEAM GENERATOR SNUBBER REPLACEMENT PROGRAM

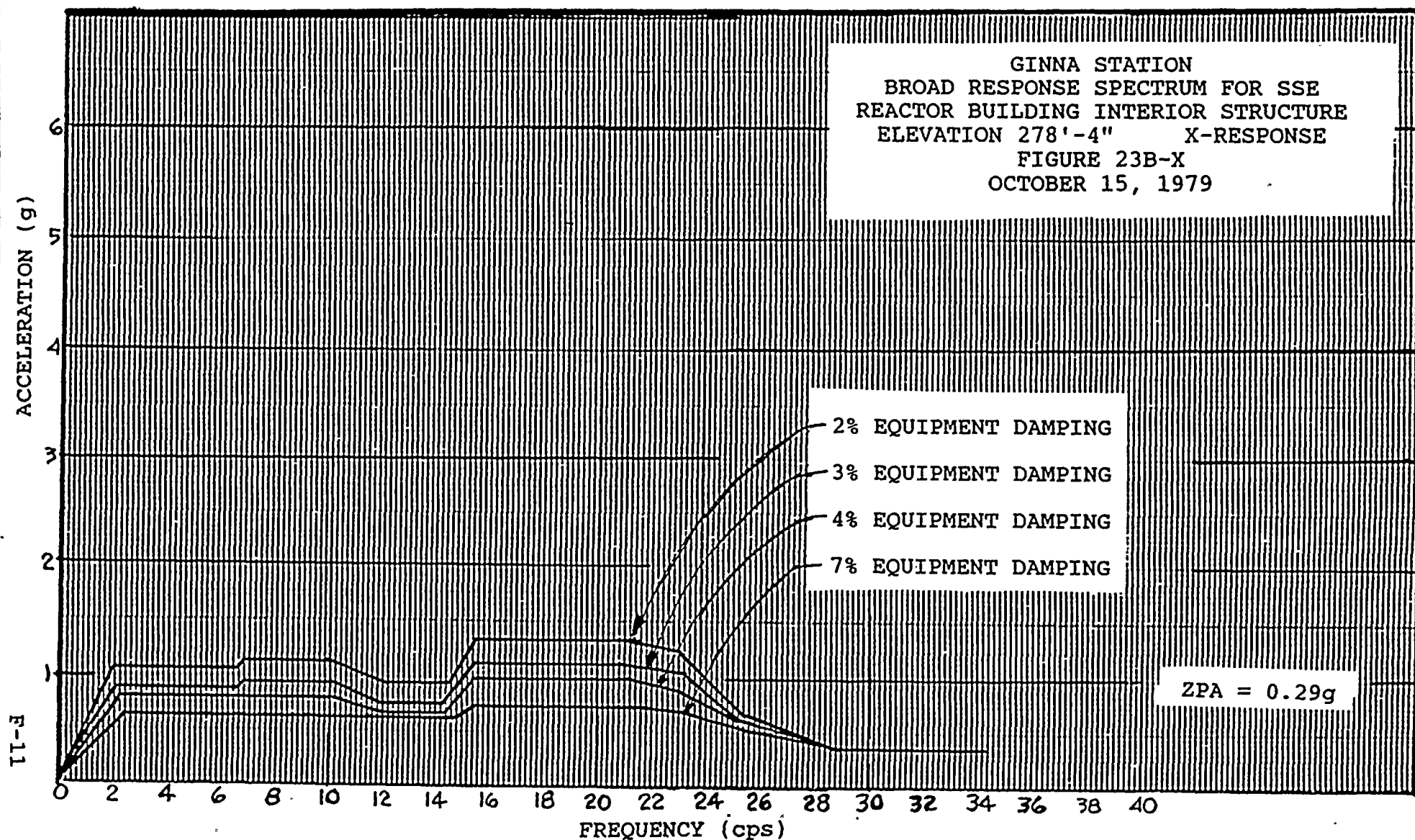
Figure 10-c

REACTOR COOLANT LOOPS A&B - HOT CONDITION  
(Supports which are active for both Cases 1 and 2)

10  
e. v. h. a. 2  
a. v. h. a. 2







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Figure 11 SEISMIC RESPONSE SPECTRUM

12  
2  
1

