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NUREG-0792

Seismic Design Margin Evaluation of Systems and Equipment Required for Safe Shutdown of North Anna, Units 1 and 2, Following an SSE Event

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

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ABSTRACT

The Advisory Committee on Reactor Safeguards recommended that the NRC staff review in detail the capability and available seismic design margin of fluid systems and equipment used in North Anna Units 1 and 2 to achieve safe shutdown following an SSE event.

The staff conducted a series of plant visits and meetings with the licensee to view and discuss the seismic design methodology used for systems and equipment and their supports.

The report is a descriptior and evaluation of the seismic design criteria, design conservatisms, and seismic design margin for North Anna, Units 1 and 2.

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SEISMIC DESIGN MARGIN EVALUATION OF SYSTEMS AND EQUIPMENT REQUIRED FOR SAFE SHUTDOWN OF NORTH ANNA, UNITS 1 AND 2, FOLLOWING AN SSE EVENT

1 INTRODUCTION

In 1977, the Advisory Committee on Reactor Safeguards (ACRS) recommended that the NRC staff review in detail the design of fluid systems and equipment at the North Anna Power Station, Units 1 and 2, which are required to (1) achieve safe shutdown and (2) continue shutdown heat removal after a seismic event (see Appendix A). This review was aimed at demonstrating to the ACRS that the seismic design margin in these systems and equipment is adequate for a seismic event of greater magnitude than that for which the plant is designed. This report addresses a design margin evaluation for the site-design safe-shutdown earthquake (SSE) event only. However, it should be noted that design margin exists for any postulated event loading because "design margin evaluation" (as used in this report) is based on an industry standard or code-allowable limit that always provides for considerable margin to failure.

During the NRC Operating License (OL) review, the staff concluded that all safe-shutdown systems and equipment met staff seismic requirements, as well as additional design requirements. These systems and equipment items were considered acceptable without the review covered in this report. However, the staff undertook the additional review at the request of the ACRS.

The staff conducted a series of plant-site visits and meetings with the licensee to view and discuss specific systems, equipment, and their supports. In response to the ACRS request for additional review, the staff presented a summary of its findings to ACRS on March 9, 1978 (see Appendix B). As a result of its initial evaluation and the additional work performed, the staff concluded that the seismic design margin for the systems and equipment was adequate and so notified the ACRS.

During the March 9 meeting, ACRS members raised specific questions about the seismic design margin of heating, ventilating, and air conditioning (HVAC) ductwork supports. The ACRS also requested more information on the design margin for the drilled-in expansion anchor bolts that have been used for safe-shutdown system equipment.

In a letter dated March 14, 1978 (see Appendix A), Raymond Fraley, executive director of the ACRS, asked the staff to prepare a report summarizing the seismic design margin evaluation. This report has been prepared in response to that request.

The report discusses seismic design criteria, design conservatisms, and margin evaluation; copies of the ACRS letters and staff presentations to the ACRS are included as appendices.

In addition, under a March 1980 contract, the staff asked Oak Ridge National Laboratory (ORNL) to evaluate its realistic seismic design margins of as-constructed ASME Class 1 components* (pumps, valves, and piping) for sustained and SSE loadings. This effort was deemed necessary to determine realistic seismic design margins which consider all possible conservatisms built into the various phases of seismic design and analysis, into the safety factors in industry codes, into the design safety factors of off-the-shelf components, and into material properties.

The results of this study are reported in NUREG/CR-2137 (Ref. 1). The ORNL findings supplement the assurance in this report that the seismic design margin in the system and components is adequate for a seismic event of greater magnitude than that for which the plant is designed.

2 SEISMIC DESIGN CRITERIA AND CONSERVATISMS

A safe-shutdown earthquake with an intensity 0.12 g on rock or 0.18 g on soil was used as the design basis for seismic Category I components of the North Anna Power Station. The floor response spectra used for the design of these components were generated by the frequency response method. The expected variations of structural properties and damping values on the floor response spectra were accounted for by widening the response spectra peaks by ±15 percent. The damping values used in conjunction with these floor response spectra were generally lower than those recommended in Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants" (Ref. 2). The combination of the design response spectra and damping values have resulted in responses that were equal to or more conservative than those obtained by the use of Regulatory Guides 1.60 (Ref. 3) and 1.61. Thus, the seismic design criteria used for Category I components are conservative and satisfy General Design Criteria 1 and 2.

3 SEISMIC DESIGN MARGIN EVALUATION

To comply with the ACRS request (as discussed in the introduction), a detailed seismic design margin evaluation was performed for the Category I equipment and components in systems which are required to achieve safe shutdown following a seismic event. These systems and equipment are:

- Auxiliary feedwater system
- Portions of main steam system
- Portions of component cooling water system
- Portions of service water system
- Portions of chemical and volume control system
- Instrument air supply system

*Components so classified by the American Society of Mechanical Engineers (ASME)

- o Emergency diesel generator
- o Switchgear
- o Batteries
- o Battery charger
- o [illegible]rter

The seismic design margin used for this study is defined as:

$$\text{Seismic design margin} = \frac{\text{Allowable stress or load}}{\text{Calculated stress or load}}$$

The allowable stress is based on the applicable industry standards or codes that have built-in margins of safety based on ultimate strength. The total load to which a system or component may be exposed is determined from static/dynamic elastic stress analysis of the system or component. Operating loads, dead weight load, and SSE loadings were considered in the margin evaluation.

3.1 Category I Mechanical and Class IE Electrical Components

Most of the components required to achieve safe shutdown following a seismic event are in the balance-of-plant (BOP) scope of supply. In response to staff Comment 3.74 in the plant Final Safety Analysis Report (FSAR) (Ref. 4), the licensee has provided seismic design margin evaluation for safety-related components.

The staff reviewed the structural design/analysis of these safety-related components in detail at the office of Stone and Webster Engineering, the architect-engineer for the North Anna plant, to evaluate seismic design margin for BOP equipment. The staff also made several site visits to view these systems and safety-related components and determined that there is no interaction between nonseismic systems and the safety-related equipment required to achieve safe shutdown. (System separation and missile protection criteria are used for these safety systems and equipment.)

During the NRC review, the staff performed an in-depth evaluation of those components with the lowest calculated seismic design margin to more accurately characterize the actual available margin to failure. This review generally indicated that hold-down anchor bolts are the limiting components (as listed in Table 1) which have the lowest margin of all safety-related equipment. Subsequent in-depth evaluation revealed many additional conservatisms. Using a conservative load distribution, the hold-down anchor bolt margin was calculated by selecting the most highly loaded bolt from a large group of such bolts. The stress value in the most highly loaded bolt was compared with the design allowable value, which is given in the FSAR as 0.9 Sy (Sy is the yield stress of material). Other bolts in the same group have a much larger margin than that of the "limiting" bolt. Table 1 shows equipment, number of bolts, material type, and the smallest seismic design margin. Table 2 gives separate stress contributions resulting from sustained loads and SSE loads, the associated allowable stress, and the seismic design margin for portions of piping systems.

Table 1 Equipment seismic design margin evaluation

Equipment	Limiting Component	Material	Maximum Calculated Stress,[1] ksi	Allowable Stress of 0.9 Sy,[2] ksi	Seismic Design Margin
Auxiliary feed-water turbine-driven pump	1 drilled-in anchor bolt out of 4 bolts, 3 shear pins	ASTM A 307, Grade A, steel	29.1	32.4	1.11[3]
Battery racks	1 frame member	ASTM A 36	27.0	32.4	1.20[3]
Control and relay room A/C coil assembly support	1 drilled-in anchor bolt out of 4 bolts	AISI 12 L14 steel	Manufacturer's load capacity data used with a safety factor of 4.0. Data further modified by STD-MS-13-3 (Figure 2) to account for tension and shear interaction.		1.05[4]
20 kVA static Inverter	1 drilled-in anchor bolt out of 6 bolts	AISI 12 L14 steel			1.08[4]

[1]Maximum calculated stress and maximum reaction load include operating loads, dead weight load, and SSE loadings.

[2]Sy = yield stress

[3]Seismic design margin = $\frac{\text{Allowable stress}}{\text{Calculated stress}}$

[4]Seismic design margin = $\frac{\text{Allowable load capacity}}{\text{Maximum reaction load}}$

Note: Other equipment limiting components have a much larger seismic design margin than 1.20 and are reported in Ref. 4 (FSAR response to staff comment 3.74).

Table 2 Seismic design margin evaluation for piping systems

Piping System	SSE Stress Contribution, ksi	Sustained Load Stress Contribution, ksi	Total Calculated Stress,[1] ksi	Allowable Stress, ksi	Seismic Design Margin[2]
Auxiliary feedwater	1.65	1.10	2.75	21.6	7.85
Main steam line	12.81	9.85	22.66	33.8	1.49
Component cooling water	7.05	9.02	16.07	27.0	1.68
Service water	4.02	2.10	6.12	27.0	4.41

[1]Total calculated stress includes operating loads, dead weight load, and SSE loadings.
[2]Seismic design margin = $\frac{\text{Allowable stress}}{\text{Calculated stress}}$

NUREG/CR-2137 shows that when the seismic design margin is close to 1.00 (allowable stress equals calculated stress), nominal margins which represent the reserve strength to yielding and breaking failure are significantly higher; these are listed in Table 3.

Table 3 Reserve strength to yielding and breaking failure for tensile loadings

Failure Criteria	Nominal Margins[1]			
	ASME Code, for Pressure Boundary Integrity		AISC Manual, for Supports	
	OBE (Level B)	SSE (Level D)	Basic	Seismic
Break	3.0 to 10.4	1.43 to [illegible].2	2.6 to 3.1	2.0 to 2.3
Yield	1.1 to 4.8	0.55 to 2.4	1.67	1.25

[1]Nominal margins indicate the reserve strength that is available when the seismic margin is 1.0.

In addition, this study evaluates typical Class 1 components for the North Anna plant in detail to determine realistic seismic design margins. Table 4 summarizes the margins for these components.

Table 4 Seismic and nominal margins of typical components

Item	Margin		
	Seismic	Nominal on yield	Nominal on break
Pump			
Motor feet bolts	2.42	5.21	9.47
Pump feet bolts	2.89	7.02	12.8
Baseplate bolts	1.19	2.50	4.55
Valve			
Tail Link	3.84	6.10	-
Cylinder bolts	1.61	2.85	-
Valve body	1.40	2.23	-
Piping			
Fabricated branch connection Point 151	1.07	1.4	-

Seismic Category I instrumentation and electrical equipment is seismically qualified by testing and analysis methods. The NRC Seismic Qualification Review Team (SQRT) also visited the plant site to review the seismic qualification performed for Category I electrical equipment and instrumentation. The SQRT seismic qualification review program consists of reviewing test methods, procedures, documentation of test results, and such seismic input parameters as amplitude, duration, frequency content, and directional considerations. Qualified equipment is capable of performing its safety function during and after a seismic event.

During the discussion at the March 9, 1978 meeting, ACRS members raised specific questions about the seismic design margin of the HVAC ductwork supports and requested more information regarding the margin for drilled-in anchor bolts. In response to these concerns, the staff has reviewed these areas in more depth; the results of this review are included in Sections 3.2 and 3.3 below.

3.2. Category I HVAC Ductwork Support Design Procedure and Margin

The configuration of HVAC ductwork supports is normally based on experience, space limitations, and the design guidelines of the architect-engineer.* These supports are designed to be in the rigid range of the amplified response spectra and are spaced about every 8 feet. Stone and Webster design criteria require that the ductwork support stiffness in any direction be about 100 times the supported duct weight. This will result in a support first-mode frequency of at least 30 hertz. In addition, the support stiffness is verified during the design process.

Finally, the STRUDL computer program** has been used to analyze each ductwork support frame member in the North Anna HVAC system. For loads based on a maximum normal ground acceleration of 0.12 g, the stresses on frame members have been found to be relatively small. The design margin for an SSE event for ductwork-support frame members is in excess of +2.0. Figure 1 shows some typical ductwork support configurations in the plant.

3.3. Drilled-In Anchor Bolts Used for Equipment

Seismic equipment is generally anchored to reinforced concrete foundations with anchor bolts. Structural anchor bolts consist of embedded ASTM A 307, Grade A, bolts and drilled-in expansion anchor bolts. The drilled-in anchor bolts are made of high-tensile strength steel; their material properties and the corrosion protection processes used are given in Table 5.

Tensile and shear-strength tests have been performed for a spectrum of concrete strengths for anchor bolts of the type used at North Anna. Tables 6 and 7 give average ultimate-tensile and shear-strength data derived from tests of various sizes of anchor bolts used with several concrete strengths.

Based on the data in Tables 6 and 7, the manufacturer of the bolts (Hilti Fastening Systems, Inc.) has recommended that a safety factor of 4.0 be used to determine the design-allowable strength for these anchor bolts. In addition, Stone and Webster has developed its own curve, STD-MS-13-3 (see Figure 2), to account for tension and shear interaction. This curve results in an additional margin of safety over and above the bolt manufacturer's recommended safety factor of 4.0. Therefore, the staff concludes that these anchor bolts have a design margin of at least 4.(or more.

To provide additional affirmation of the accuracy of the catalog data presented by the anchor bolts manufacturer, Teledyne Engineering Services (TES) has performed both experimental and analytical work on anchor bolts made by different manufacturers. This work was done for a group of 14 utilities, in response to Inspection and Enforcement (I&E) Bulletin 79-02, "Pipe Support Base Plate Design Using Concrete Expansion Anchor Bolts," which was issued in March 1979. TES has

*Stone and Webster has performed generic studies to determine the applied loads on ductwork supports. Loads are based on an appropriate soil type, duct geometry, and ground acceleration.

**The program is in the public domain and is acceptable to the NRC staff.

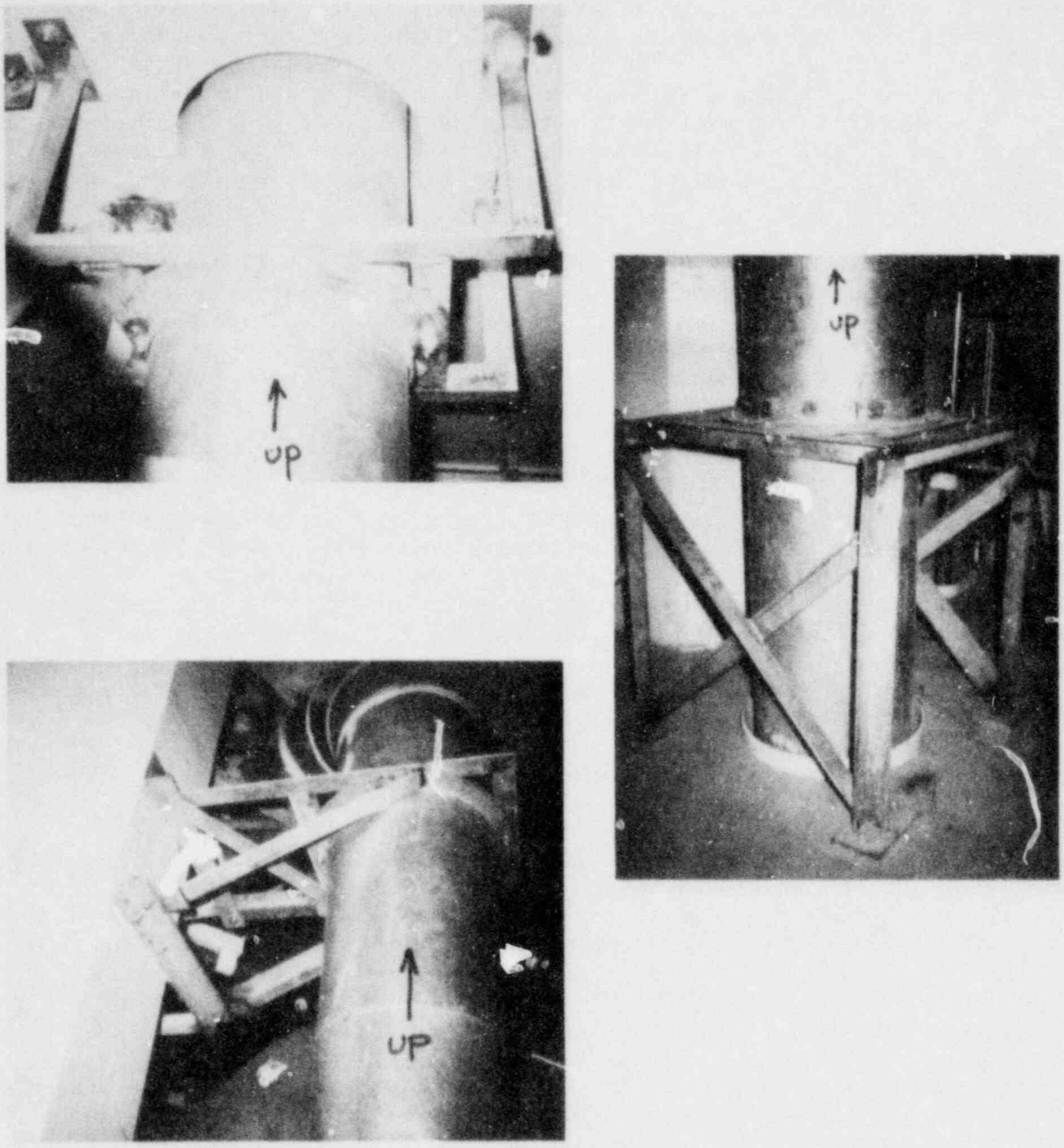
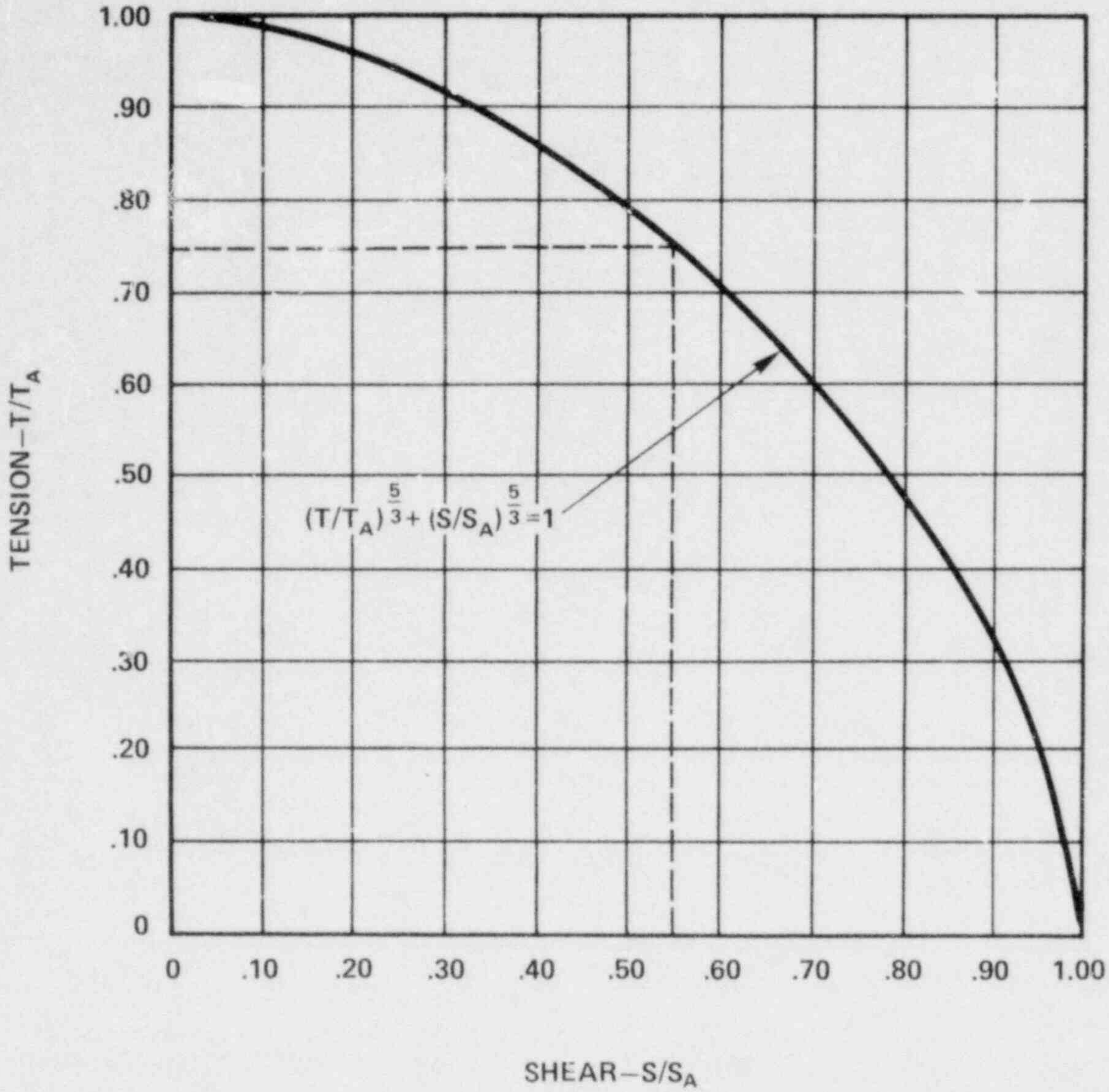


Figure 1. Some typical ductwork support configurations.



TO DETERMINE COMBINED SHEAR AND TENSION LOAD ON EACH BOLT, ENTER CHART WITH THE RATIO OF ACTUAL TENSION TO ALLOWABLE TENSION AND FIND THE RATIO OF ACTUAL SHEAR TO ALLOWABLE SHEAR.

Figure 2. Tension and shear interaction curve (STD–MS–13–3).

Table 5 Material properties of and corrosion protection process used for stud and flush types of drilled-in anchor bolts

Type	Size in.	Material Properties	Requirements Met
Stud:			
Stud (bolt)	1/4 - 1/2	AISI 11L41	ASTM A 108[1]
	5/8 - 1-1/4	AISI 1144	ASTM A 108[1]
Expansion wedges		AISI 1075, spring steel	
Nuts		Commercial manufacture	ASTM A 307
Washers		SAE material	ASA B27.2-1949
Flush			
Anchor (bolt)[1,2]		AISI 12L14, steel	ASTM A 108[1]

[1]Meets chemical requirements.

[2]Anchor bolt meets the dimensional requirements of Federal Specification FF-S-325, Group II, Type 4, Class 1.

[3]Each anchor bolt component is zinc plated to meet the requirements of Federal Specification QQZ-325B, Type 1, Class 3. The stud-type anchor bolt component is then chromate plated for extra protection against corrosion.

Table 6 Test data for stud type of drilled-in anchor bolts for average ultimate tensile and shear loads

Anchor Bolts		Actual Concrete Strength					
		2178 psi		4027 psi		6119 psi	
Diameter, in.	Embedment, in.	Tension	Shear	Tension	Shear	Tension	Shear
1/4	1-1/8	975	1653	1455	2612	1755	2389
	1-1/2	1875	1653	2225	2612	2935	2389
	1-3/4	2275	1653	2700	2612	3300	2389
	2	2525	1653	3125	2612	3350	2389
	2-1/4	2680	1653	3310	2612	3350	2389
	2-1/2	2800	1653	3350	2612	3350	2389
3/8	1-5/8	2245	3748	2355	5107	2810	6266
	2	2725	3748	3025	5107	3650	6266
	2-1/2	3075	3748	3900	5107	4450	6266
	3	3300	3792	4300	5419	5000	6266
	3-1/2	3425	3792	4600	5419	5275	6266
	4	3520	3792	4750	5419	5375	6266
	4-1/2	3580	3792	4800	5419	5400	6266
1/2	2-1/4	4545	7444	5510	8316	6845	9341
	2-3/4	5800	7444	7200	8316	9800	9341
	3-1/2	7000	7444	9450	8316	13200	9341
	4-1/2	7275	8897	11225	10232	14550	11522
	5-1/2	8250	8897	12050	10232	15150	11522
	6	9000	8897	12300	10232	15300	11522
5/8	2-3/4	5410	11198	6600	11562	7700	13500
	3-1/2	6250	11198	9100	11562	9560	13500
	4-1/2	7000	11198	12000	11562	14500	13500
	5-1/2	7550	13378	14300	15437	20300	15437
	6-1/2	8025	13378	16000	15437	21000	15437
	7-1/2	9000	13378	17000	15437	21000	15437
3/4	3-1/4	8155	13257	10150	17133	10860	18102
	4	9700	13257	13400	17133	13700	18102
	5	11700	13257	16500	17133	17600	18102
	6	13800	15195	18000	18466	22500	21009
	7	15800	15195	21000	18466	23600	21009
	8	16000	15195	23000	18466	23600	21009
	9	16000	15195	23500	18466	23600	21009

Table 6 (continued)

Anchor Bolts		Actual Concrete Strength					
Diameter, in.	Embedment, in.	2178 psi		4027 psi		6119 psi	
		Tension	Shear	Tension	Shear	Tension	Shear
1	4-1/2	14000	27355	16000	26879	20500	32112
	5	15500	27355	18900	26879	24400	32112
	6	17600	27355	24650	26879	32200	32112
	7	18200	27355	27500	26879	35000	32112
	8	18200	27355	27500	34491	35000	36394
	9	18200	27355	27500	34491	35000	36394
	10	18200	27355	27500	34491	35000	36394
1-1/4	5-1/2	19000	36750	23000	35680	31200	45195
	6-1/2	21600	36750	27000	35680	36500	45195
	7-1/2	23600	36750	31100	35680	42000	45195
	8-1/2	25100	39843	34600	35680	44400	47098
	9-1/2	26200	39843	37800	35680	44400	47098
	10-1/2	26800	39843	40900	35680	44400	49596

Note: Tension values have been obtained from best-fit curves through mean values of test data. Shear values are minimum mean values at each embedment based on failure across the threaded section of the anchor. The recommend safe working load is 25% of the average ultimate load.

Table 7 Test data for flush type of drilled-in anchor bolts for average ultimate tension and shear loads

Anchor Bolt Dia, in.	Actual Concrete Strength					
	2000 psi		3850 psi		6200 psi	
	Tension	Shear	Tension	Shear	Tension	Shear
1/4	1904	1738	2251	1781	3075	3050
3/8	3174	3970	4942	4225	5650	5900
1/2	3997	5873	6751	6224	10200	9350
5/8	5549	8883	9696	12205	10400	13600
3/4	8857	15195	16034	17609	16400	21200

Note: The recommended safe working load is 25% of the average ultimate load.

published a report, "Generic Response to USNRC I&E Bulletin Number 79-02, Base Plate/Concrete Expansion Anchor Bolts" (Ref. 5).

The TES report is discussed in detail in NUREG/CR-2137. The findings presenting these are:

(1) The TES tests indicate that for properly installed, isolated anchor bolts not near an edge, the manufacturers' catalogs usually give a reasonable estimate of tension and shear load capacities.

(2) A crude statistical evaluation of the data indicates that by using 1/4 of average strength as a design basis, the probability of failure at 2 times the design load is about 0.023 and less than 0.001 at the design load.

(3) The bolt material used in anchor bolts must be of high strength. (For example, 125,000 psi ultimate tensile strength is used to obtain some of the catalog shear loads.)

(4) Use of linear combination for combined tension and shear loads is generally conservative.

(5) Cyclic loadings in the range of loads less than $P_u/4$ did not have any significant effect on subsequent static load capacity. (P_u is the average ultimate static strength.)

(6) Anchor bolts installed near edges or installed close together may not have the strength indicated by the test data. Guidance is given by the American Concrete Institute (ACI) Standard 349-76, which is presumed to be conservative.

Eleven different types of anchor bolts are identified in Table 8. Table 9 compares the manufacturers' data for these bolts with the results of the TES average test loads.

Table 8 Anchor bolt groups and generic types

Group	Designation	Generic Type
A*	Phillips, Snap Off	Shell
B	Phillips, Wedge	Wedge
C	Phillips, Sleeve	Sleeve
D	Phillips, Stud Anchor	Wedge
E	Hilti, Kwik Bolt	Wedge
F	USM, Parabolt	Wedge
G	Wej-It, Stud	Wedge
H*	Rawl, Snap Off	Shell
I	Star, Slug-In	Shell
J	Ramset, Wedge	Wedge
K	Ramset, Sleeve	Sleeve

*TES report indicates these are identical.

Table 9 Comparison of catalog loads with TES average test loads

Bolt Size, in.	Load Type	Ratio of Catalog Loads to TES Average Test Loads, by Group										
		A	B	C	D	E	F	G	H	I	J	K
1/4	Tension	----	----	----	----	1.2	----	1.1	----	----	----	----
	Shear	----	----	----	----	0.8	----	1.5	----	----	----	----
3/8	Tension	----	----	1.0	----	0.9	----	----	----	----	----	----
	Shear	0.9	----	0.9	----	1.1	----	0.8	----	----	----	----
1/2	Tension	1.2	1.1	1.0	----	1.3	0.7	----	1.2	2.9	0.7	0.9
	Shear	----	1.2	0.9	----	1.0	1.1	1.8	----	0.6	1.0	0.6
5/8	Tension	1.2	0.8	1.3	----	0.9	0.8	----	----	2.0	0.7	1.1
	Shear	1.0	0.9	0.8	----	0.8	1.1	1.8	----	0.6	0.9	1.2
3/4	Tension	1.3	1.2	0.9	1.5	1.0	1.2	1.6	1.3	3.7	1.4	0.9
	Shear	----	0.9	0.8	1.0	0.8	1.2	1.1	----	0.3	1.3	1.0
7/8	Tension	1.1	0.9	----	----	----	----	----	----	1.1	----	----
	Shear	1.6	1.3	----	----	----	----	1.0	----	0.4	----	----
1	Tension	----	0.7	----	----	0.8	----	1.2	----	1.6	0.8	----
	Shear	----	0.9	----	----	1.0	----	1.2	----	0.4	0.6	----
1-1/4	Tension	----	----	----	----	1.0	----	----	----	----	----	----
	Shear	----	1.1	----	----	1.1	----	1.0	----	----	----	----
Avg.	Tension	1.20	0.94	1.05	1.50	1.01	0.90	1.30	1.25	2.26	0.90	0.97
	Shear	1.17	1.05	0.85	1.00	0.94	1.13	1.27	----	0.46	0.95	0.93
	Both	1.19	1.00	0.95	1.25	0.98	1.02	1.28	1.25	1.36	0.92	0.95

4 CONCLUSIONS

Based on a detailed review of the seismic design margin of systems and equipment required to achieve safe shutdown following an SSE, the staff has confirmed that there is considerable margin between the stress level or load that would result from the design basis SSE and the stress level or load that would result in failure of the component. The following conservatisms provide additional margin for all North Anna plant systems and equipment required to achieve safe shutdown:

(1) Applicable industry standards or codes used in design-allowable stress have a built-in safety factor based on ultimate strength (that is, material failure strength).

(2) Static/dynamic elastic analysis methods were used in the seismic margin evaluation. Actual material properties, which are conservative, were used rather than minimum allowable stresses.

(3) For the North Anna plant, a more conservative design criterion of 0.9 Sy* was used for the design of equipment support members instead of the current criterion of ASME Section III, Subsection NF, which permits stresses up to 1.2 Sy.

(4) Conservative seismic design criteria, including the ±15 percent response spectra peak broadening technique, were used, with low damping values.

Therefore, the staff concludes that, as required by General Design Criterion 2, an adequate margin exists in systems and equipment required to reach safe shutdown of North Anna Power Station Units 1 and 2 following an SSE event.

5 REFERENCES

The documents referenced below are available for inspection and copying for a fee in the NRC Public Document Room, 1717 H Street, N.W., Washington, D.C. 20555. Those marked with an asterisk also are available for purchase from the NRC/GPO Sales Program, Washington, D.C. 20555 and the National Technical Information Service, Springfield, Virginia 22161.

(1) Realistic Seismic Design Margins of Pumps, Valves and Piping, USNRC Report NUREG/CR-2137, June 1981.*

(2) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1973.*

(3) U.S. Nuclear Regulatory Commission, Regulatory Guide 1 60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Rev. 1, December 1973.*

(4) Virginia Electric and Power Company, "Final Safety Analysis Report for North Anna Power Station, Units 1 and 2," Part B, Supplement Volume 1, Amendment 63, July 1977, pp. 53-74 - 1 through 25 (Dockets 50-338 and 50-339).

(5) Teledyne Engineering Service, Summary Report, "Generic Response to USNRC I&E Bulletin Number 79-02, Base Plate/concrete Expansion Anchor Bolts," August 1979.*

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*Sy is the yield stress of material.

APPENDIX A

CORRESPONDENCE DEALING WITH NORTH ANNA POWER STATION, UNITS 1 AND 2

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON D. C. 20555

January 17, 1977

Honorable Marcus A. Rowden
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: REPORT ON NORTH ANNA POWER STATION, UNITS 1 AND 2

Dear Mr. Rowden:

At its 201st meeting, January 6-8, 1977, the Advisory Committee on Reactor Safeguards completed its review of the application of the Virginia Electric and Power Company for a license to operate North Anna Power Station, Units 1 & 2. This project was also considered during a Subcommittee meeting h ld in Washington, D.C., on January 5, 1977. The Committee previously completed a partial review of this project at its 198th meeting, October 14-16, 1976, as discussed in its report to you, dated October 26, 1976. During its review, the Committee had the benefit of discussions with representatives and consultants of the Virginia Electric and Power Company, the Westinghouse Electric Corporat.on, the Stone and Webster Engineering Corporation, and the Nuclear Regulatory Commission (NRC) Staff. The Committee also had the benefit of the documents listed.

In its report of October 26, 1976, on North Anna, Units 1 & 2, the ACRS had not completed its review of the adequacy of seismic design bases and seismic design; loss-of-coolant accidents and emergency core cooling; quality assurance and control of on-site fabrication and installation; asymmetric loads on pressure vessel structures arising from certain postulated pipe breaks; and plans for upgrading protection against fires.

The NRC Staff has now completed its review of the Stafford fault zone and concluded that the available geological and seismological information supports the conclusion that the Stafford fault zone is not capable within the meaning of Appendix A to 10 CFR Part 100, and that the available information does not warrant any change in the previously approved seismic design bases for North Anna 1 and 2. Representatives of the U.S. Geological Survey concurred that there exists no definitive information showing significant m[illegible]nt during the last million years and that the fault is not capable. [illegible]onsultants to the ACRS concur with this interpretation. While they generally find the current design bases acceptable for the already constructed North Anna plants, they have recommended that, in view of the uncertainties of knowledge concerning the sources of earthquakes in the Eastern United States, a minimum safe shutdown earthquake (SSE) of 0.2g acceleration should be utilized for new plants for which construction permit applications are submitted in the future.

The Applicant presented partial information concerning the calculated safety factors during safe shutdown earthquake conditions for some of the engineered safety features. The Committee recommends that the NRC Staff review this aspect of the design in detail and assure itself that significant margins exist in all systems required to accomplish safe shutdown of the reactors and continued shutdown heat removal, given an SSE. The Committee believes that such an evaluation need not delay the start of operation of North Anna 1 and 2. The Committee wishes to be kept informed.

The NRC Staff has now completed its review of emergency core cooling system performance and found it to be acceptable. The Committee concurs.

The NRC Staff has conducted and is continuing extensive investigation of construction activities of North Anna Units 1 and 2. These investigations have been separated into four phases:

1. investigation of specific allegations made by three individuals of faulty construction practices;

2. a detailed inspection of certain safety-related piping not directly implicated in the original allegations but which was potentially subject to similar problems;

3. detailed monitoring of the nondestructive preservice baseline examination of selected welds in safety-related piping by the Licensee and his contractors; and

4. inspections of the performance of selected components in specific piping systems during the preoperational testing program.

The NRC Staff has concluded that various items of non-compliance with NRC requirements have occurred and has defined a program to remedy the matter.

The Committee has had the benefit of a review and evaluation of this matter by its own consultant, who supports the adequacy of the NRC investigations and has made several recommendations, including one related to a program to ascertain that significant deficiencies do not exist in safety related piping systems. The ACRS concurs. The Committee wishes to be kept informed regarding resolution of these recommendations.

The NRC Staff has reported that the matter of asymmetric loads on pressure vessel structures is essentially resolved. The ACRS has had the benefit of meetings of an Ad Hoc Working Group on this general subject, in Toronto on August 5, 1976, and in Los Angeles on December 1, 1976. The Committee agrees that, subject to final evaluation by the NRC Staff, this matter is in an acceptable status for North Anna 1 and 2.

The Applicant is in the process of studying fire protection measures at the plant in accordance with the guidelines of Appendix A to Auxiliary and Power Conversion Systems Branch Technical Position 9.5-1. The NRC Staff has stated that, as a plant about to come into operation, North Anna 1 and 2 will be given priority in the evaluation of fire protection matters, and that most, if not all improvements will be implemented prior to the start of operation on the second fuel cycle. The Committee finds this approach to be acceptable.

The Committee notes that post-accident operation of the plant to maintain safe shutdown conditions may be dependent on instrumentation and electrical equipment within containment which is susceptible to ingress of steam or water if the hermetic seals are either initially defective or should become defective as a result of damage or aging. The Committee believes that appropriate test and maintenance procedures to assure continuous long-term seal capability should be developed.

The ACRS believes that, if due regard is given to the items mentioned above and in its report of October 26, 1976, and subject to satisfactory completion of construction and preoperational testing, there is reasonable assurance that the North Anna Power Station, Units 1 and 2, can be operated at power levels up to 2775 MWt without undue risk to the health and safety of the public.

Sincerely yours,

M. Bender

M. Bender
Chairman

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

February 17, 1977

Benard C. Rusche, Director
Office of Nuclear Reactor Regulation

SUBJECT: ACRS REPORT ON THE NORTH ANNA POWER STATION, UNITS 1 AND 2, DATED JANUARY 17, 1977

This memorandum is in response to your letter of January 31, 1977 concerning interpretation of the ACRS report of January 17, 1977 on the North Anna Power Station, Units 1 and 2. The Committee considered your request for clarification during the 202nd ACRS meeting. The members discussed the bases for the Committee's report on the North Anna Station and the comm nts noted below are reflected in the meeting minutes.

(1) The Committee concurs with its consultants in the matter of the Stafford fault zone.

(2) The Committee concurs in general with the recommendation of its consultants that a minimum safe shutdown earthquake (SSE) of 0.2g should ordinarily be utilized for new plants for which construction permit applications are submitted in the future, although the Committee believes that flexibility in this nominal floor is appropriate to allow for special site conditions and specific aspects of plant design for which site dependent spectra may be important or for situations where a sound and non-controversial basis exists for setting lesser criteria.

(3) The systems to be investigated are those required to accomplish safe shutdown of the reactors and continued shutdown heat removal. The Committee has recommended that such systems have significant margins in the event of the SSE, so that safe shutdown has a high probability of accomplishment, should a lower probability earthquake having a response spectrum somewhat larger than that of the usual broad band spectrum over part of the frequency range occur. Instances in which "current acceptance limits" may be exceeded in such an evaluation may be considered acceptable on a judgment basis.

R. F. Fraley
Executive Director

cc: L. Gossick, EDO
S. Chilk, SECY

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

March 14, 1978

Mrs. P. M. Allen, President
North Anna Environmental Coalition
112 Hallmark North
Briarcrest Gardens
Hershey, PA 17033

Dear Mrs. Allen:

In response to your letter to Mr. Myer Bender, Chairman, ACRS, dated January 4, 1978, the Committee has asked that the following information be provided to you.

1. The Committee considered the microearthquakes detected by the VEPCO net in the vicinity of the North Anna Power Station in its review and approval of this facility. The additional information reported since the Committee reviewed this project has been brought to the attention of the members. Based on comments from USGS representatives, as noted below, the Committee continues to believe that these microseismic events do not indicate the presence of a significant risk to the North Anna Station.

2. Representatives of the USGS have examined the microseismic history in the vicinity of the North Anna Station, including the information you brought to the Committee's attention, and do not consider this data unusual or indicative of any particular problems.

3. The ACRS has not approved a "design deficiency" for the North Anna Station. The ACRS has examined the features of the North Anna site and the plant seismic design and has concluded that the seismic design values of 0.12g and 0.18g as applied to the North Anna Station are adequate. In its report of January 17, 1977 the Committee concurred in general with the recommendations of its consultants that a minimum safe shutdown earthquake of 0.2g acceleration should ordinarily be utilized for new plants in the Eastern United States for which construction permit applications are submitted in the future, although the Committee believes that flexibility in this nominal floor is appropriate to allow for special site conditions and specific aspects of plant

design for which site dependent spectra may be important or for situations where a sound and noncontroversial basis exists for setting lesser criteria.

4. The review by Mr. J. Knight of seismic design margins in systems required to accomplish safe shutdown and safe shutdown heat removal is continuing. Mr. Knight provided a report to the Committee on the status of this work during its 215th meeting, which you attended. We expect a final written report from Mr. Knight on this item within one or two months.

5. The evaluation of seismic design margins has not yet been completed, as noted above. I understand that the ASLB on North Anna Units 1 and 2 issued its decision regarding an Operating License for this facility during February of this year.

Sincerely,

R. F. Fraley
Executive Director

APPENDIX B

NRC STAFF PRESENTATION TO ACRS, MARCH 9, 1978

NORTH ANNA UNITS 1 AND 2

Seismic Design Margin Evaluation

of Equipment and Systems Required

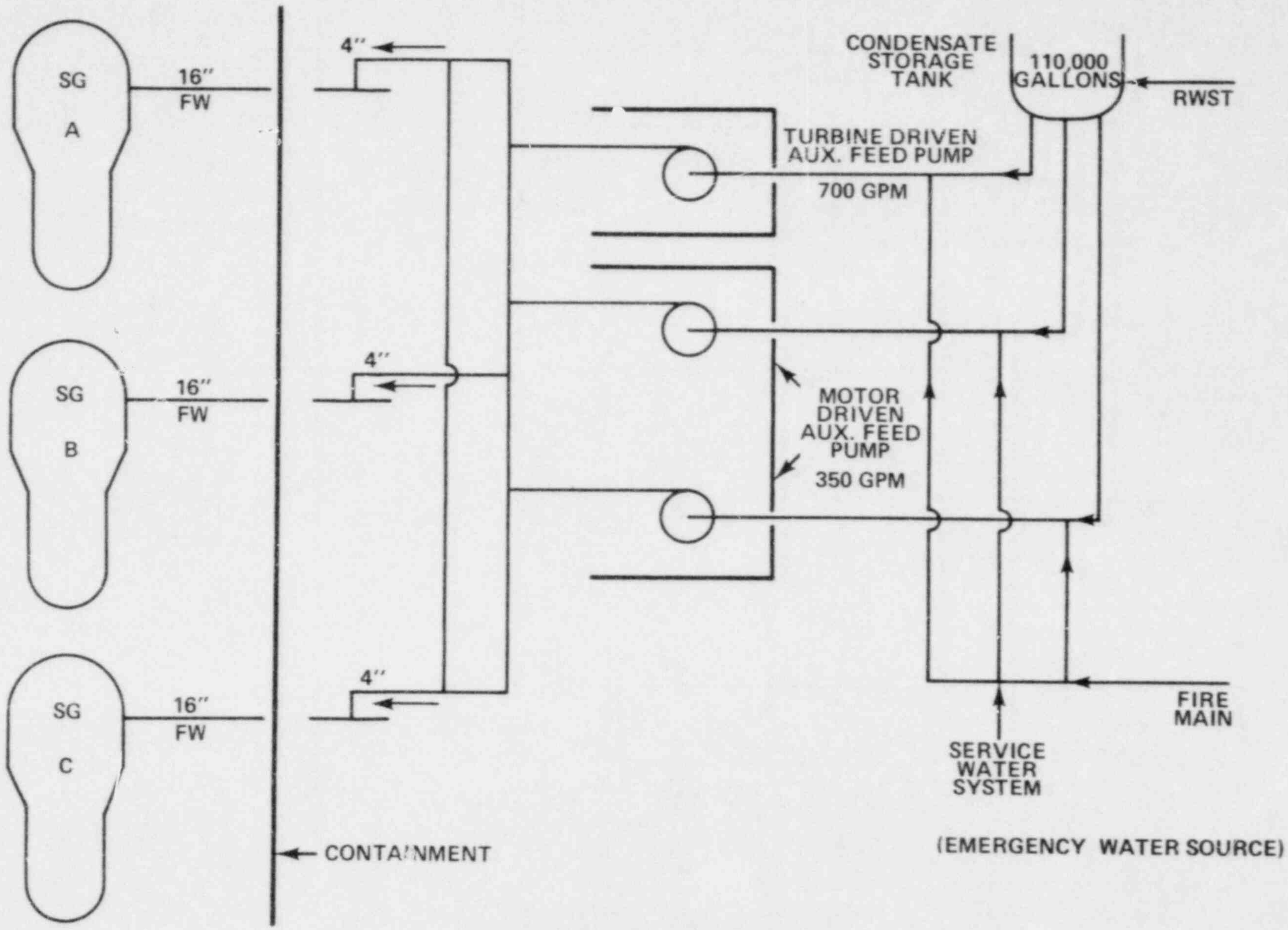
for Safe Shutdown

EQUIPMENT AND SYSTEMS REQUIRED TO REACH SAFE SHUTDOWN FOLLOWING A SEISMIC EVENT

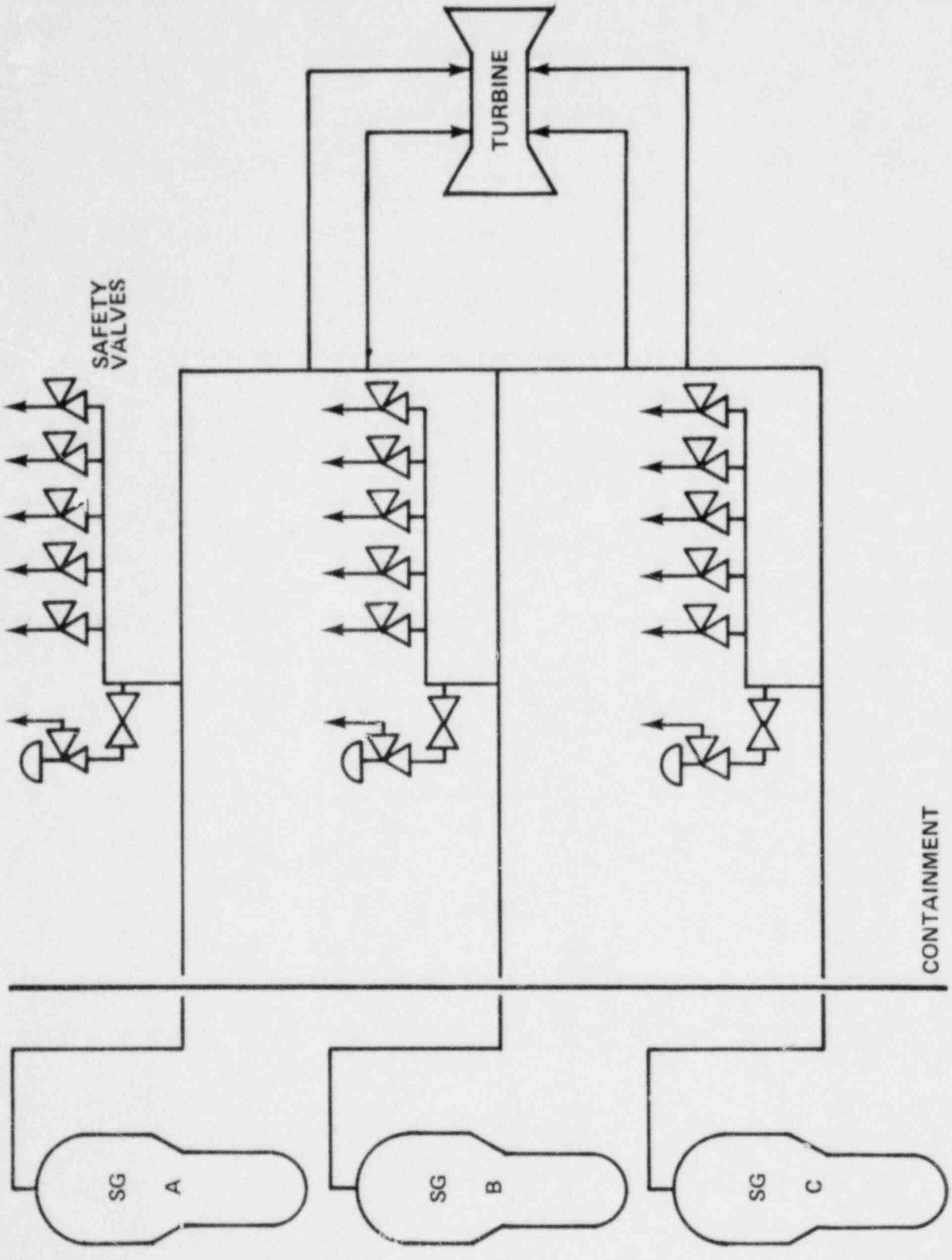
Auxiliary Feedwater System
Portions of Main Steam System
Portions of Component Cooling Water System
Portions of Service Water System
Portions of Chemical and Volume Control System
Instrument Air Supply System

Emergency Diesel Generator
- Switch Gear
- Battery Charger
- Batteries
- Static Inverter

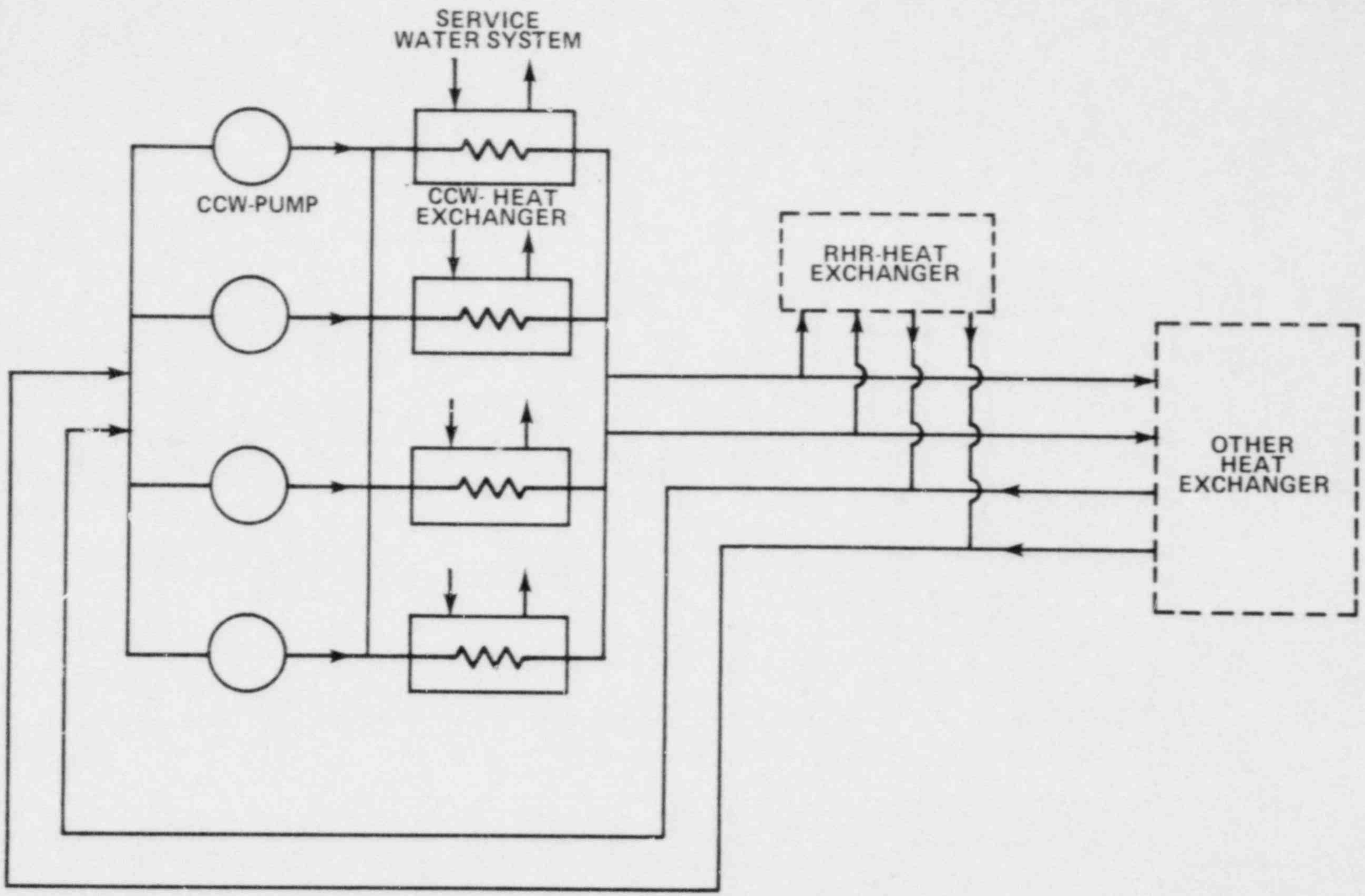
AUXILIARY FEEDWATER SYSTEM



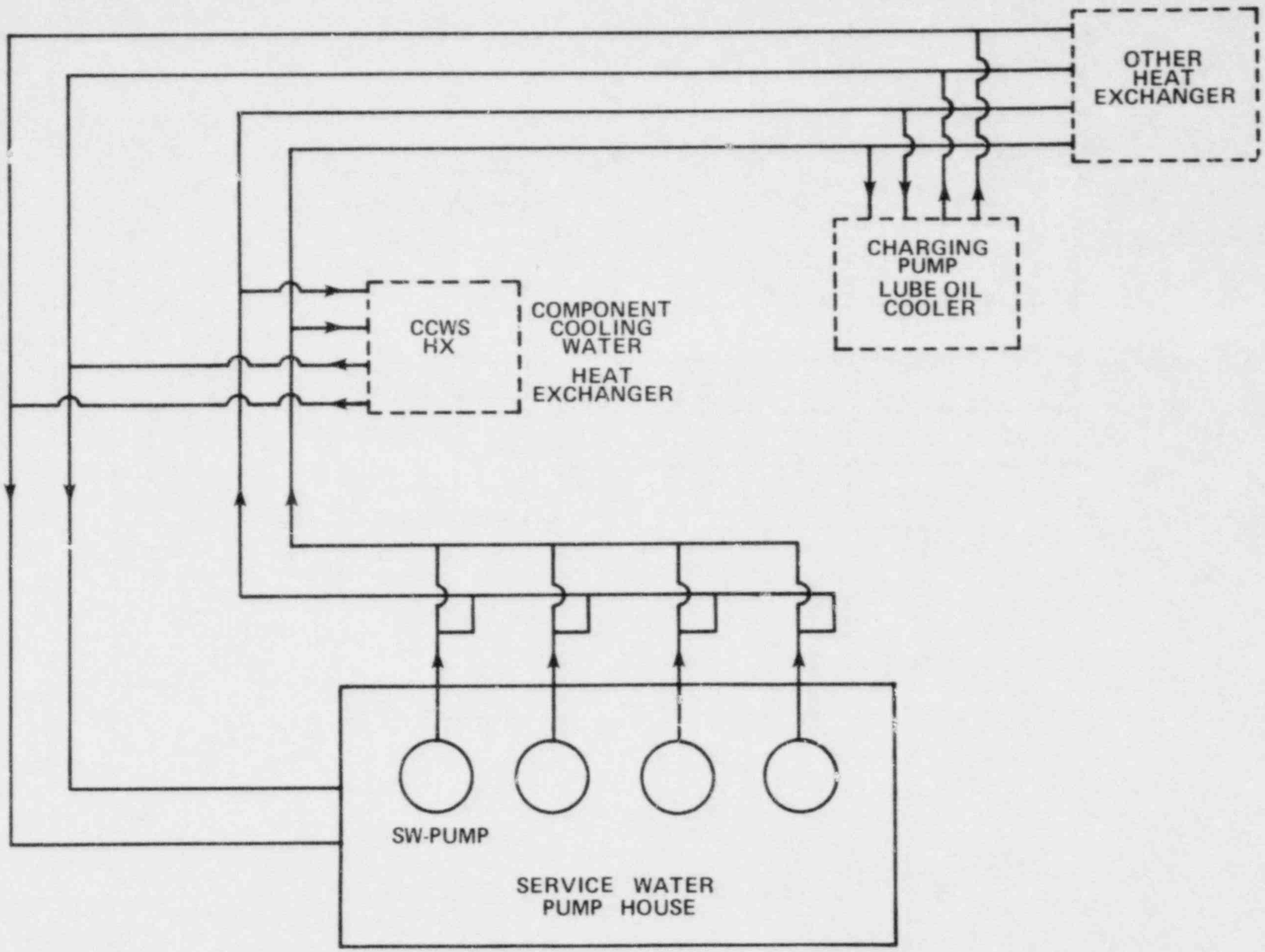
MAIN STEAM SYSTEM



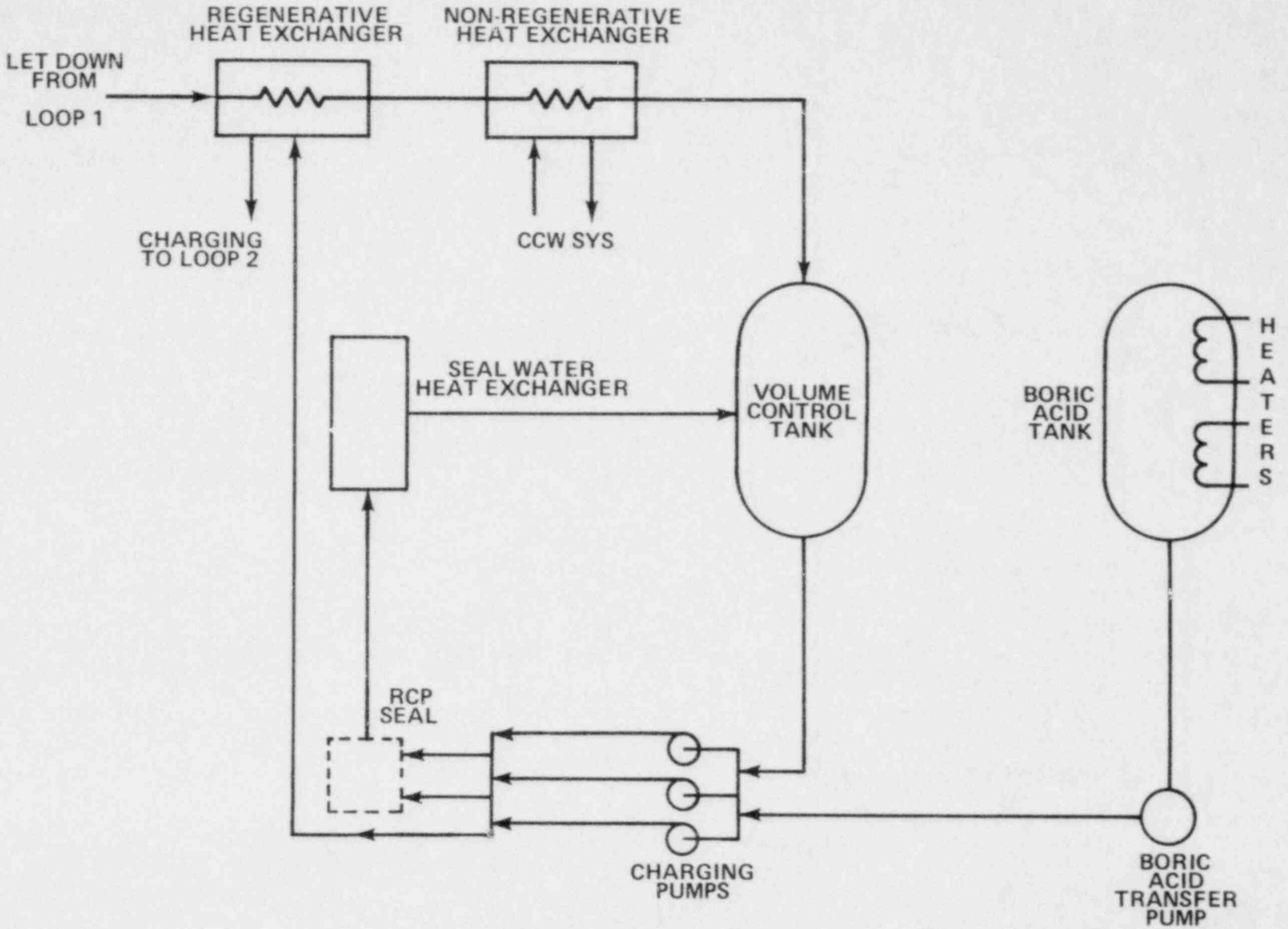
COMPONENT COOLING WATER SYSTEM



SERVICE WATER SYSTEM



CHEMICAL AND VOLUME CONTROL SYSTEM



SEISMIC DESIGN MARGIN

EQUIPMENT	MAXIMUM CALCULATED STRESS KSI	ALLOWABLE STRESS (0.9 Sy*) KSI	DESIGN MARGIN = ALLOWABLE STRESS / CALCULATED STRESS
AUXILIARY FEEDWATER TURBINE-DRIVEN PUMP			
ANCHOR BOLT** (4 ANCHOR BOLTS AND 3 SHEAR PINS)	29.1	32.4	1.11
BATTERY RACKS			
ANCHOR BOLT (42 ANCHOR BOLTS)	27.0	32.4	1.20
			DESIGN MARGIN = ALLOWABLE CAPACITY / MAXIMUM REACTION
CONTROL & RELAY ROOM A/C COIL ASSEMBLY SUPPORT	MANUFACTURER'S LOAD CAPACITY TEST DATA USED WITH A SAFETY FACTOR OF 4 OR MORE		
DRILLED-IN ANCHOR BOLT SLEEVE (4 ANCHOR BOLTS)			1.05
20 KVA STATIC INVERTER			
DRILLED-IN ANCHOR BOLT SLEEVE (6 ANCHOR BOLTS)			1.08

*Sy = YIELD STRESS

**SEE TABLE 1 IN THE REPORT TEXT.

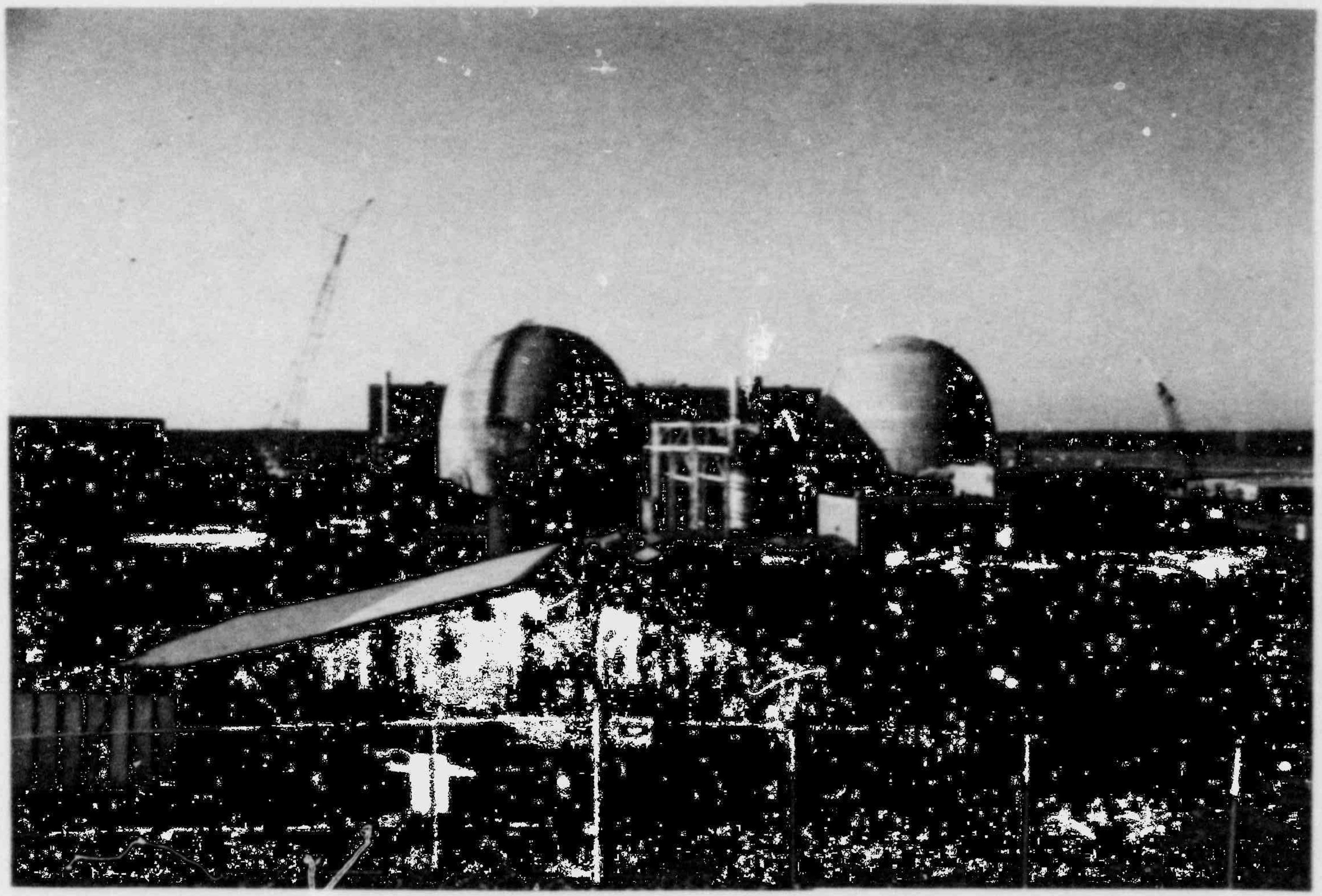


Figure 1. North Anna Nuclear Power Station Units 1 and 2.

2. Turbine-driven auxiliary feedwater pump housed in a separate room.

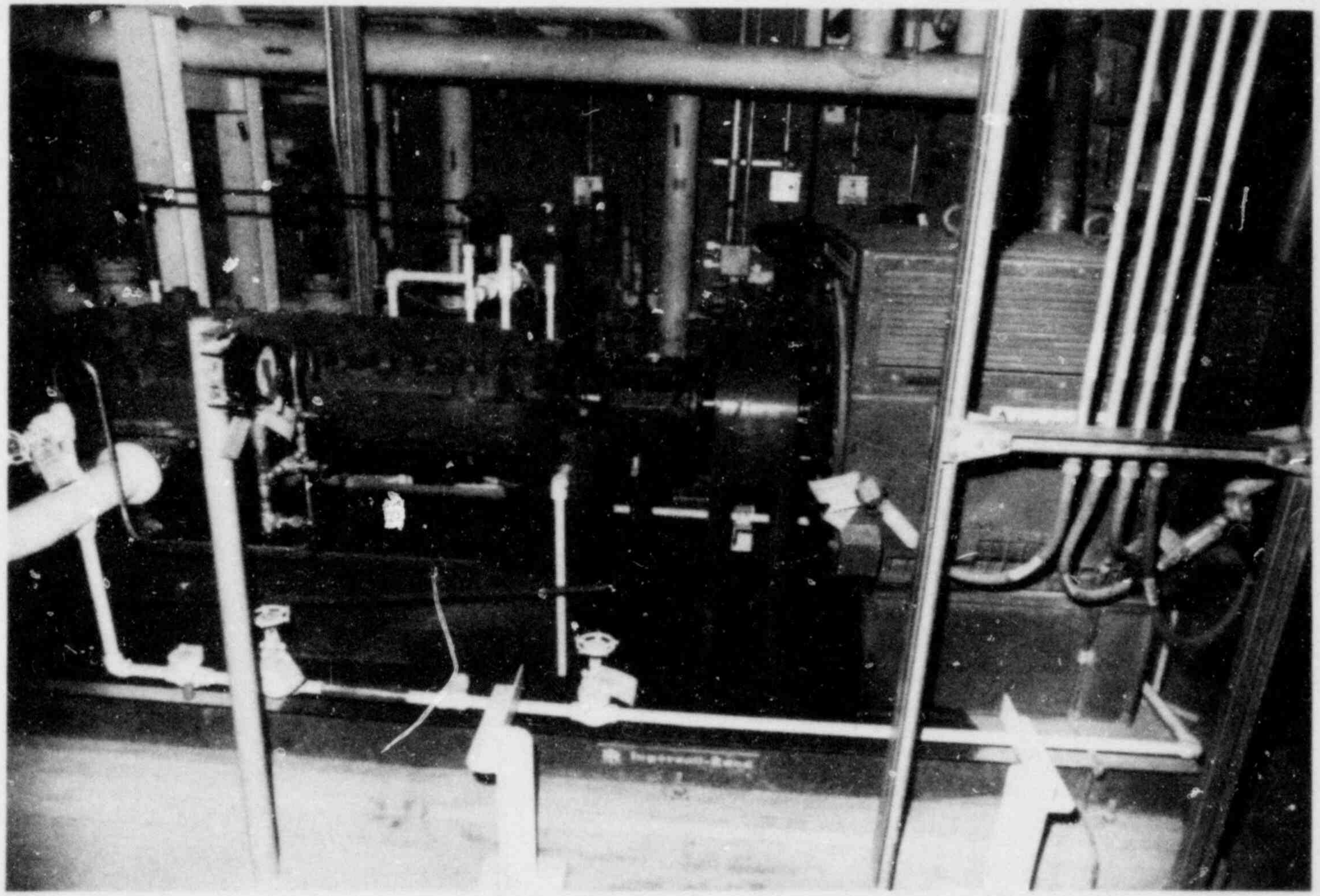


Figure 3. Two motor-driven auxiliary feedwater pumps housed in a separate room.

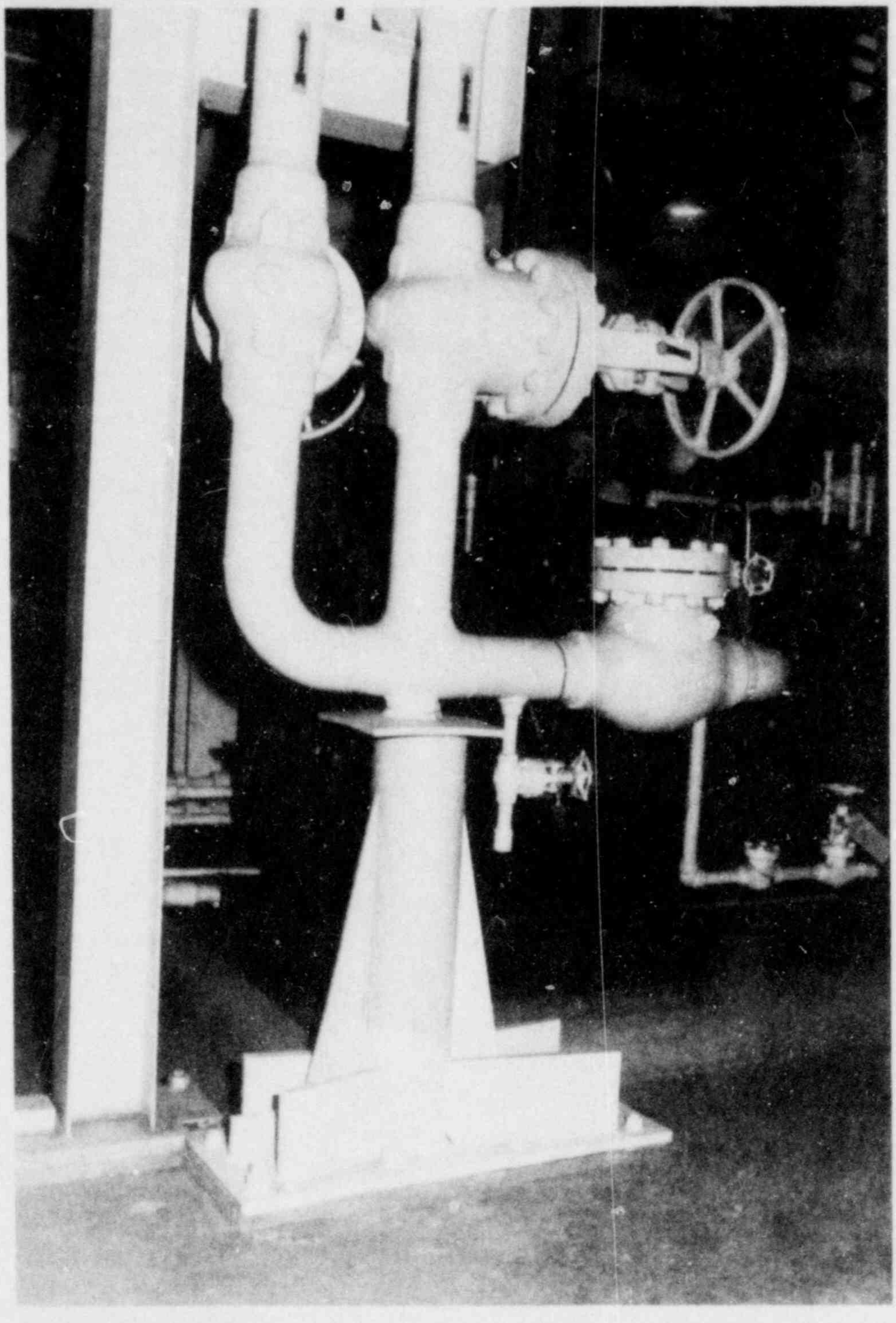


Figure 4. Auxiliary feedwater discharge piping towards steam generator.

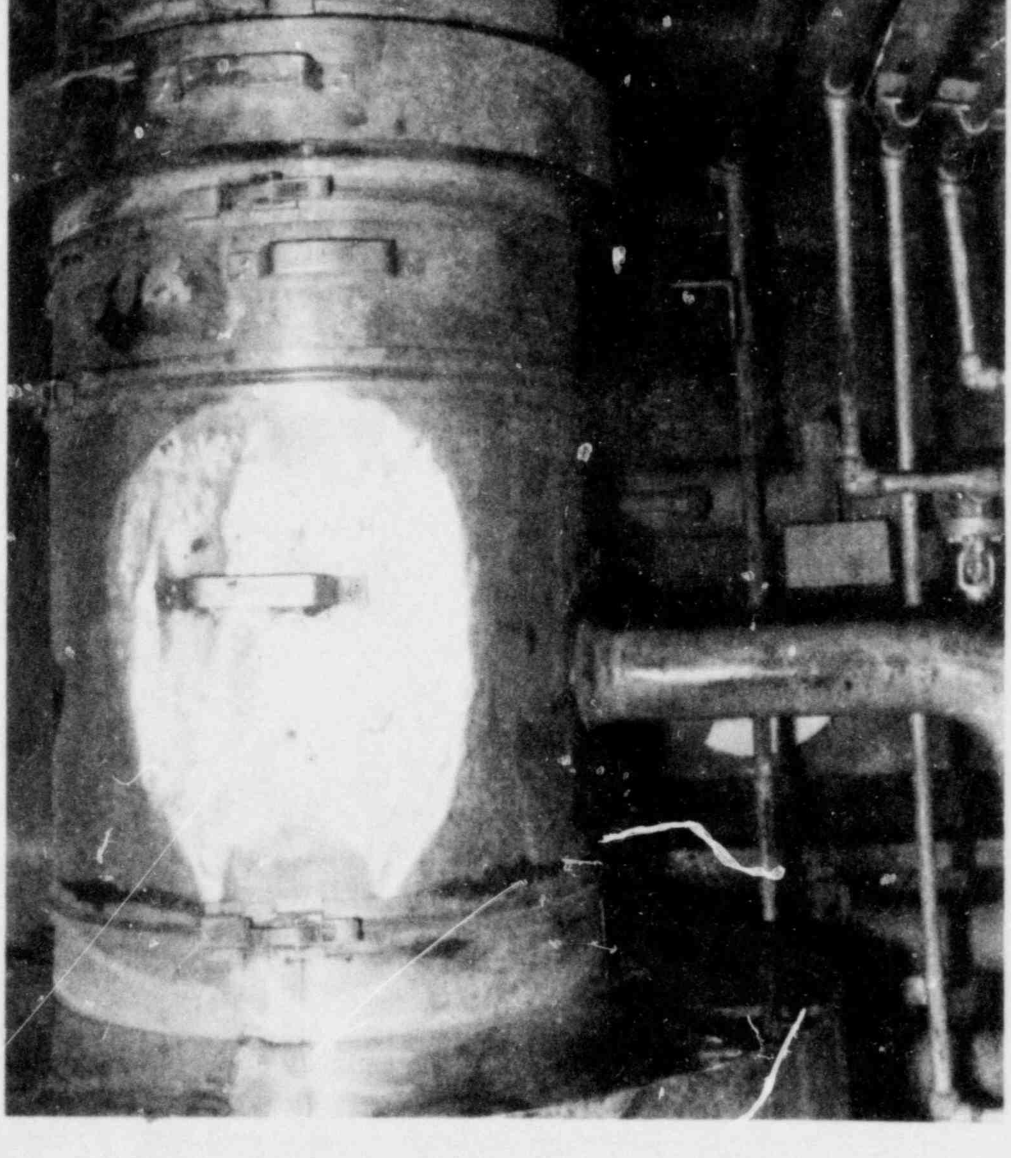


Figure 5. Auxiliary feedwater discharge piping entering feedwater piping in containment penetration area.

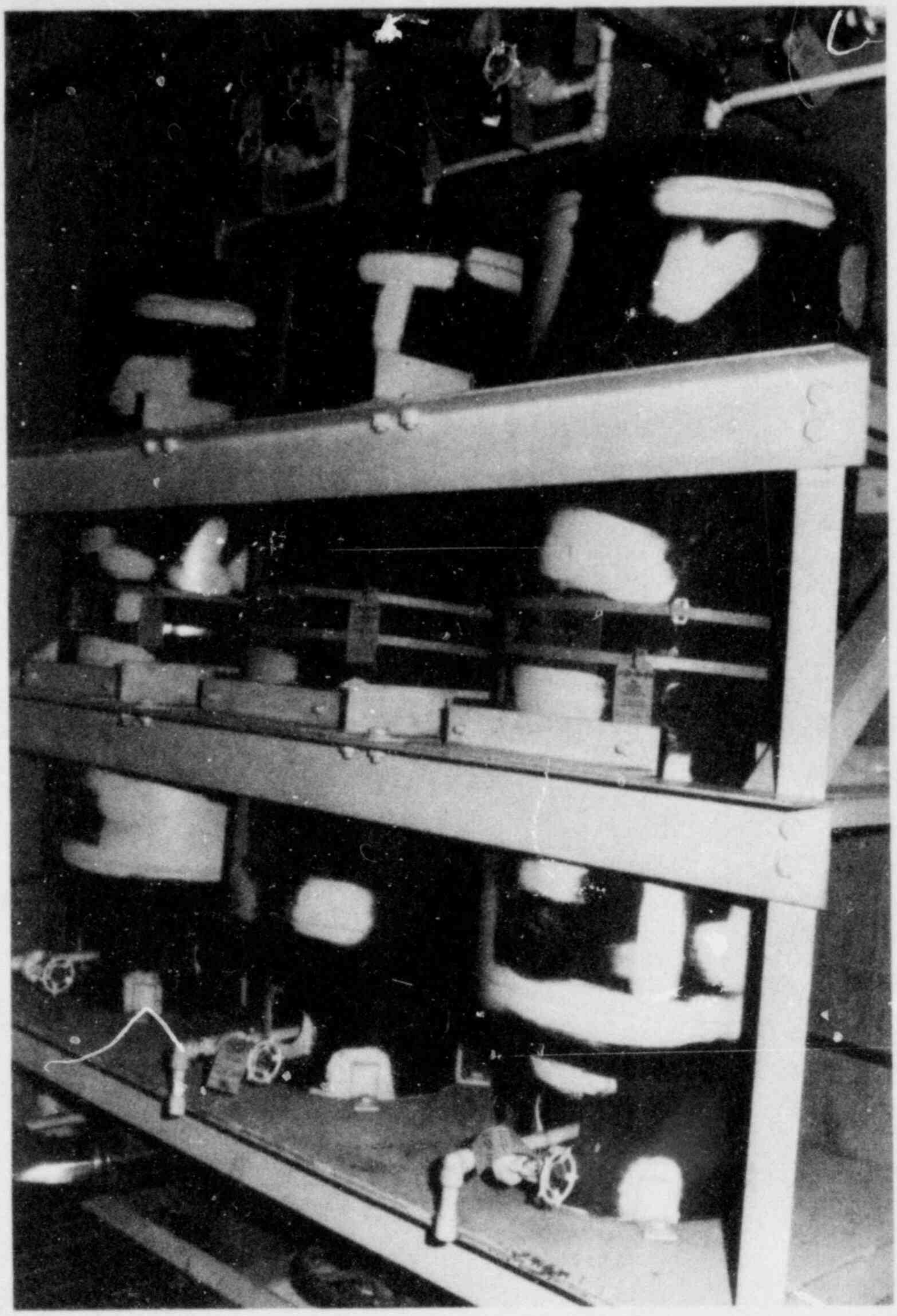


Figure 6. Air bottles with seismic restraints for instrumentation and control components for auxiliary feedwater system as redundant air supply.

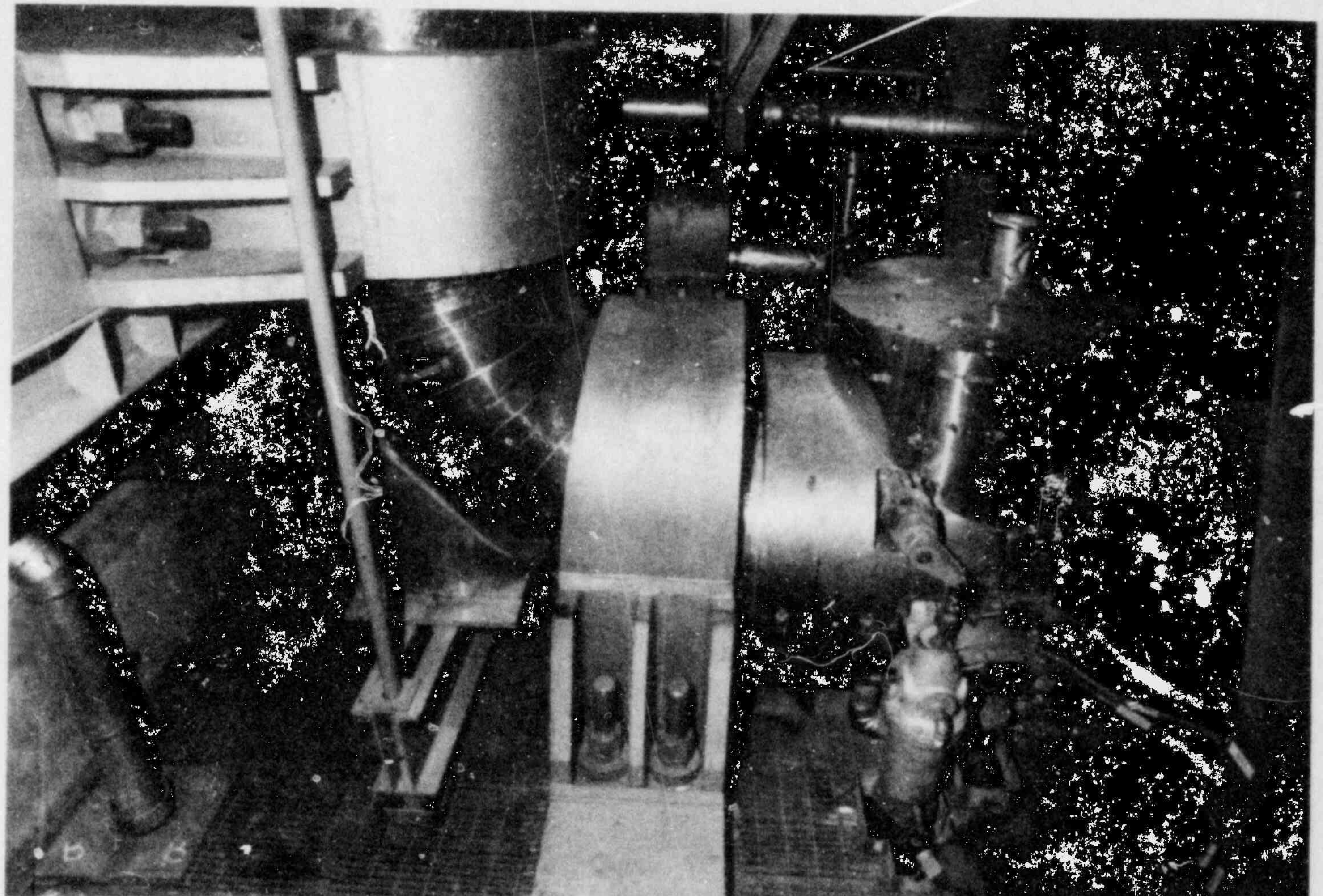


Figure 7. Main steam isolation valve with pipe whip restraints.

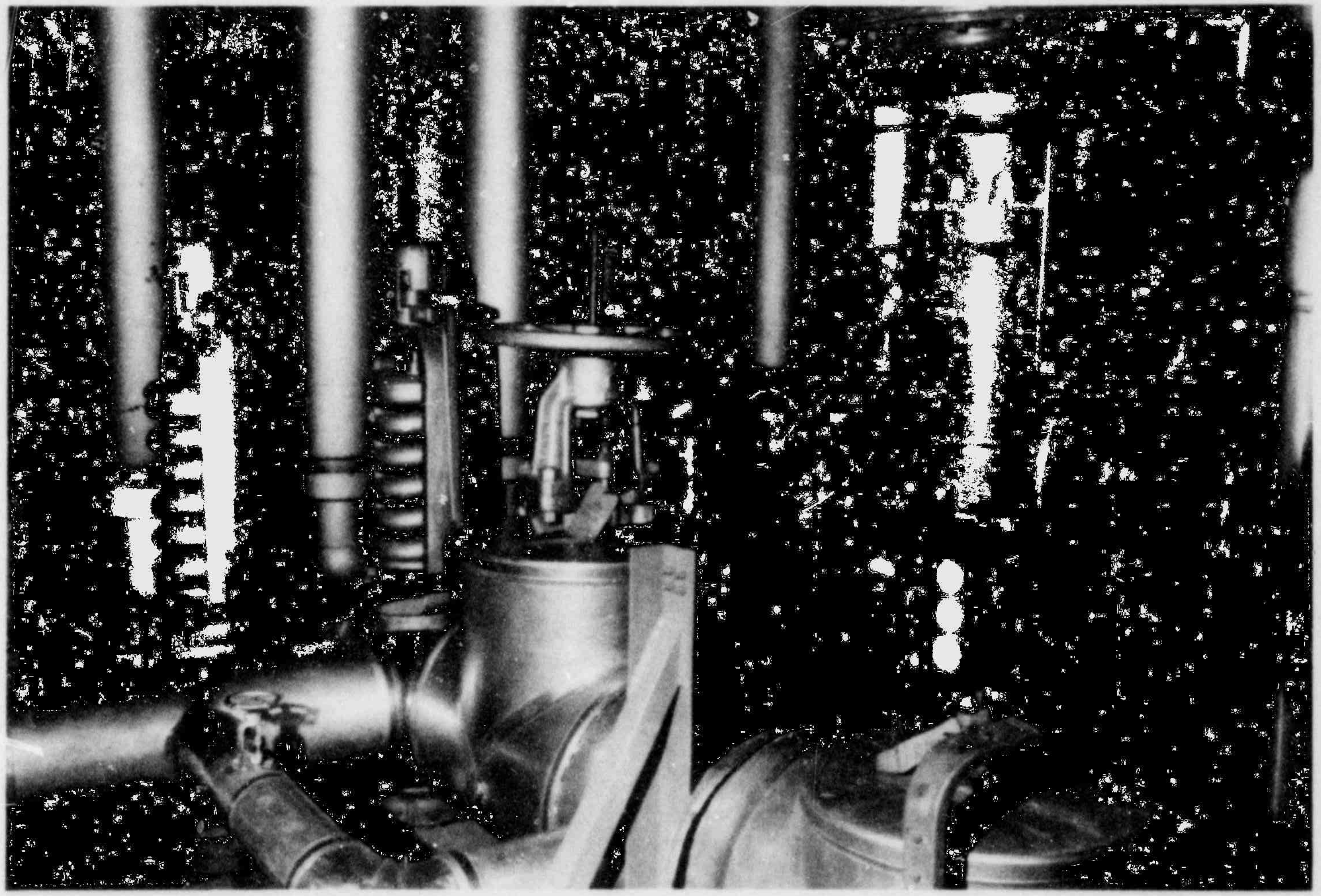


Figure 8. Main steam safety valves and power-operated relief valve.

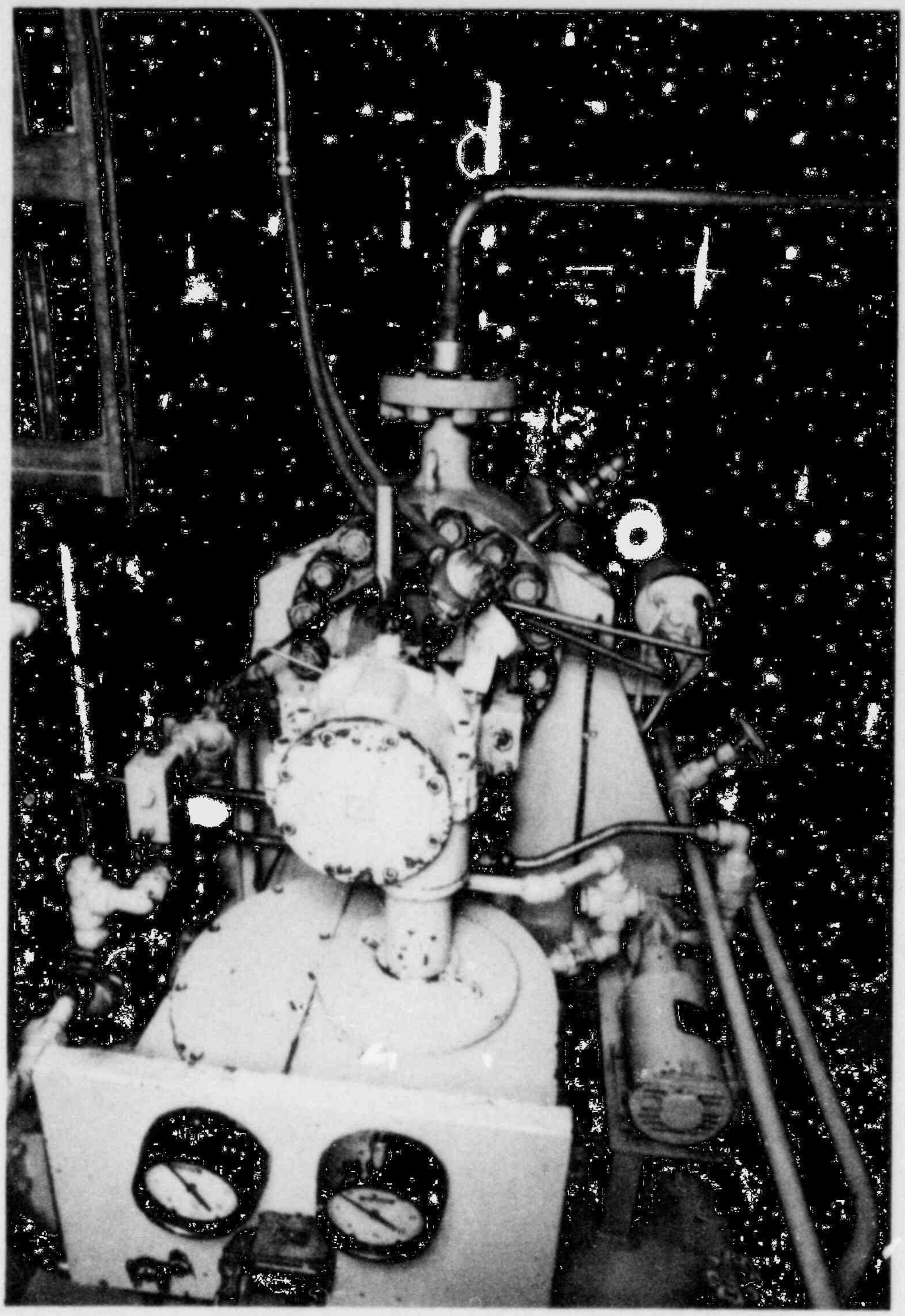


Figure 9. Charging pump for chemical and volume control system.

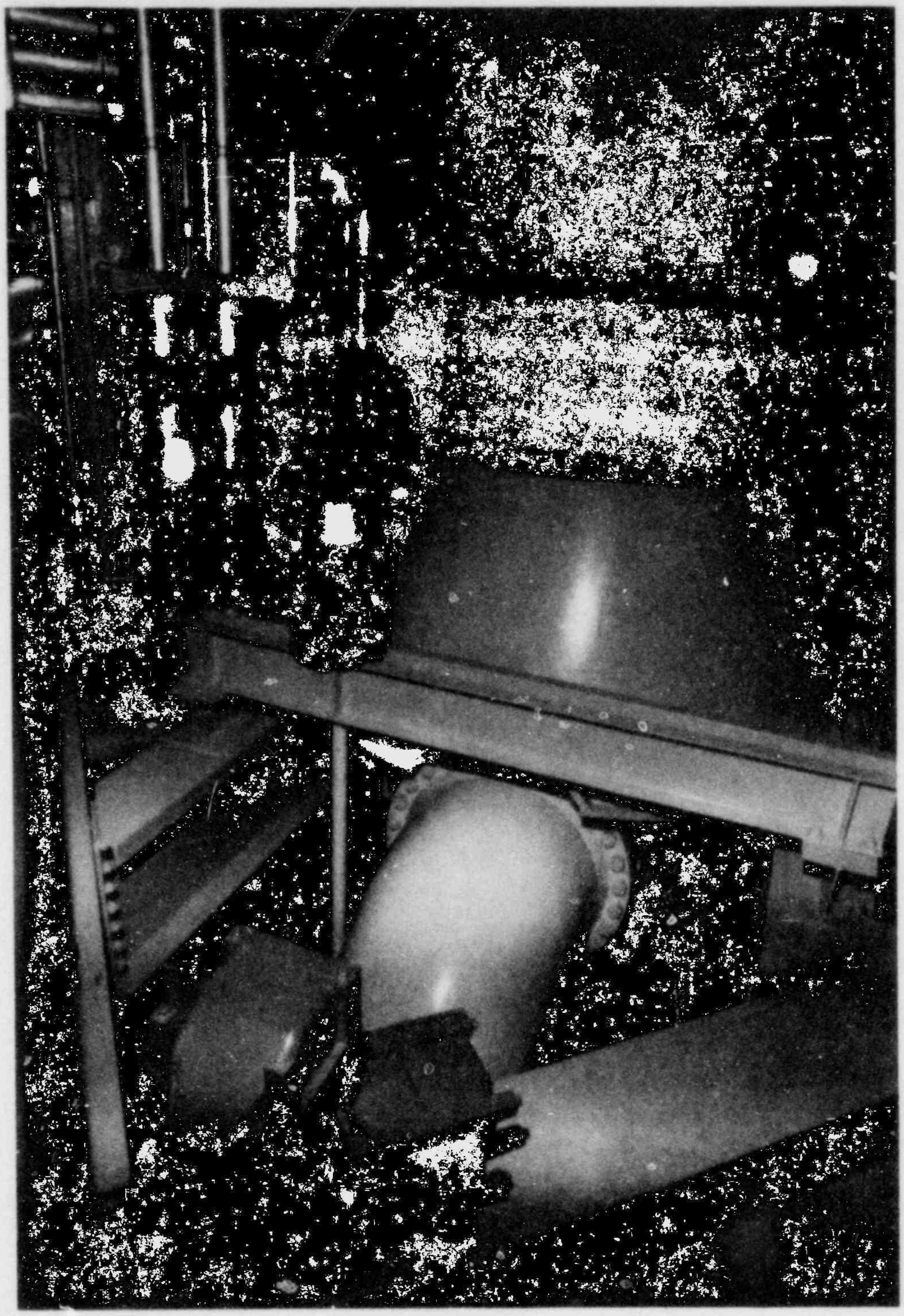


Figure 10. Component cooling water heat exchanger with three direction seismic shock recorder (blue).

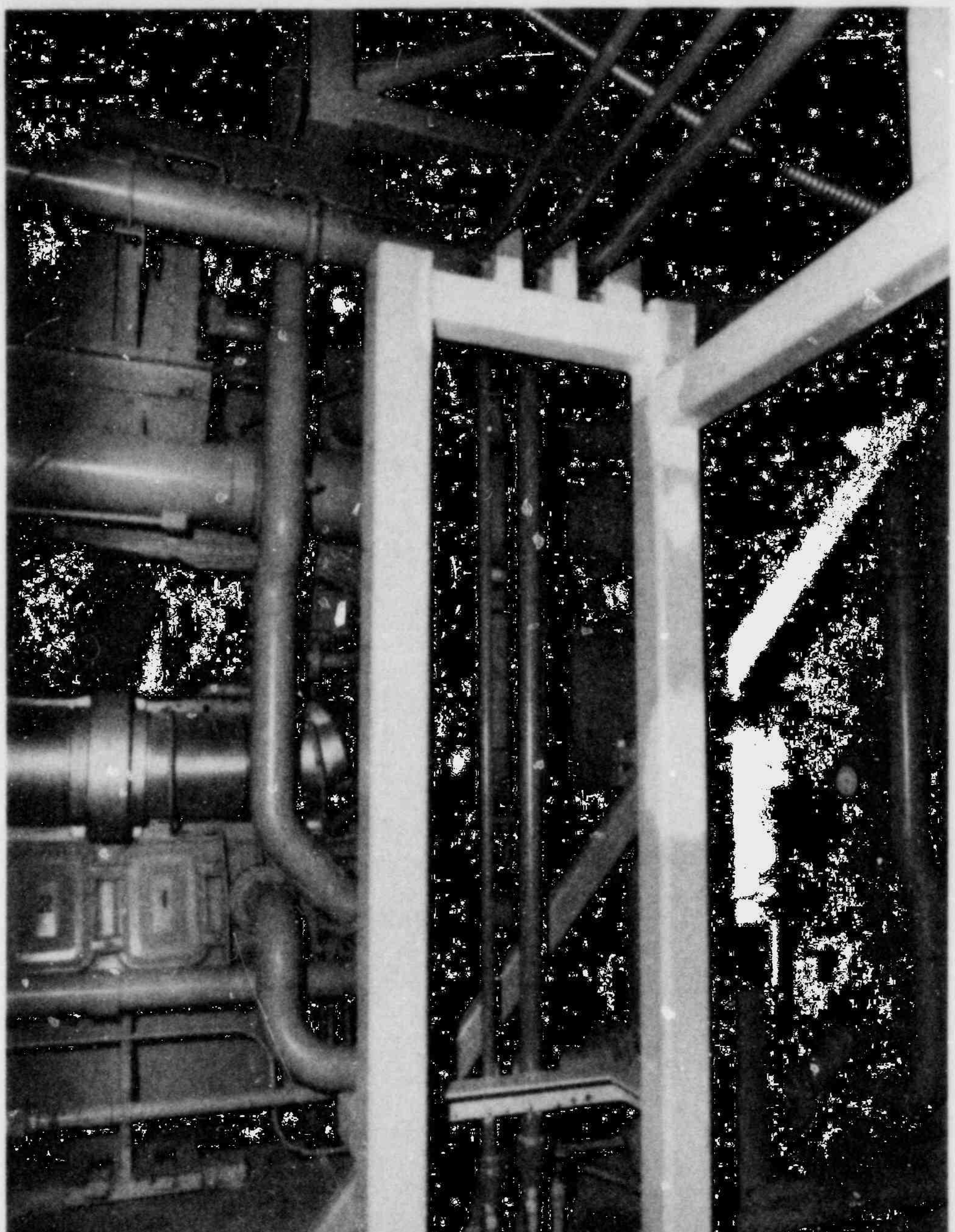


Figure 11. Diesel engine fuel lines (yellow) with seismic support.

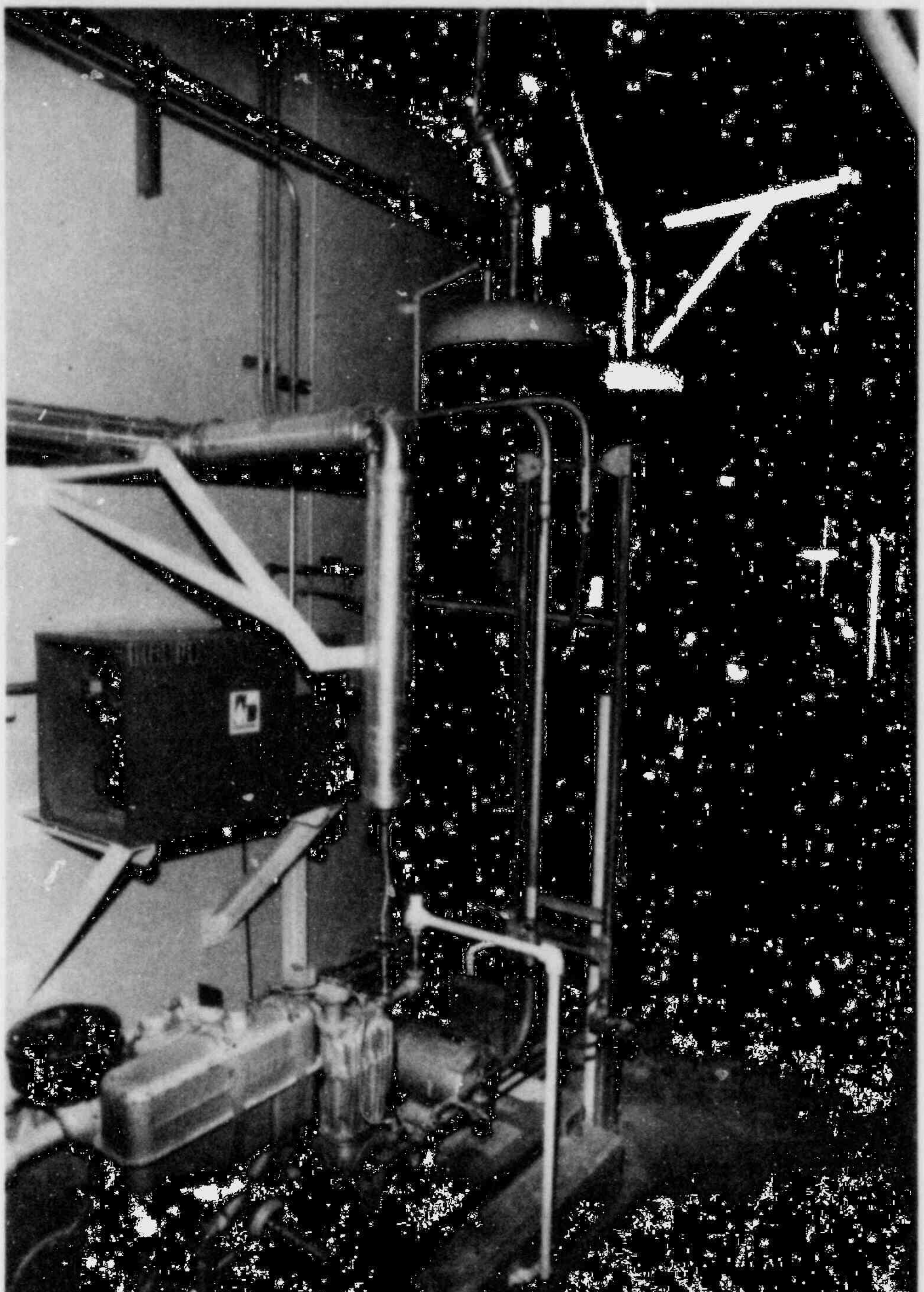


Figure 12. Diesel engine compressed air system.

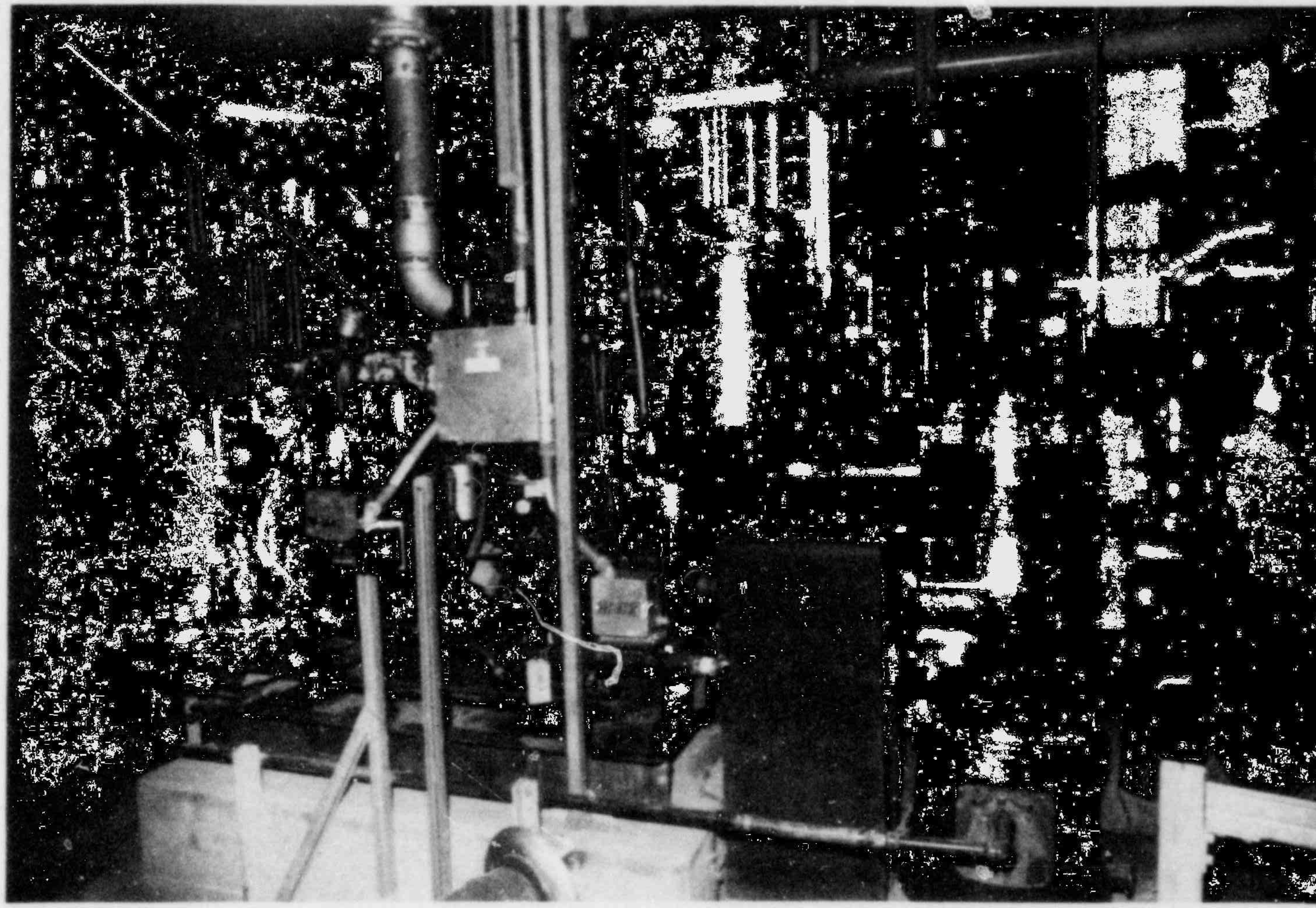


Figure 13. Fire pump in service water building.

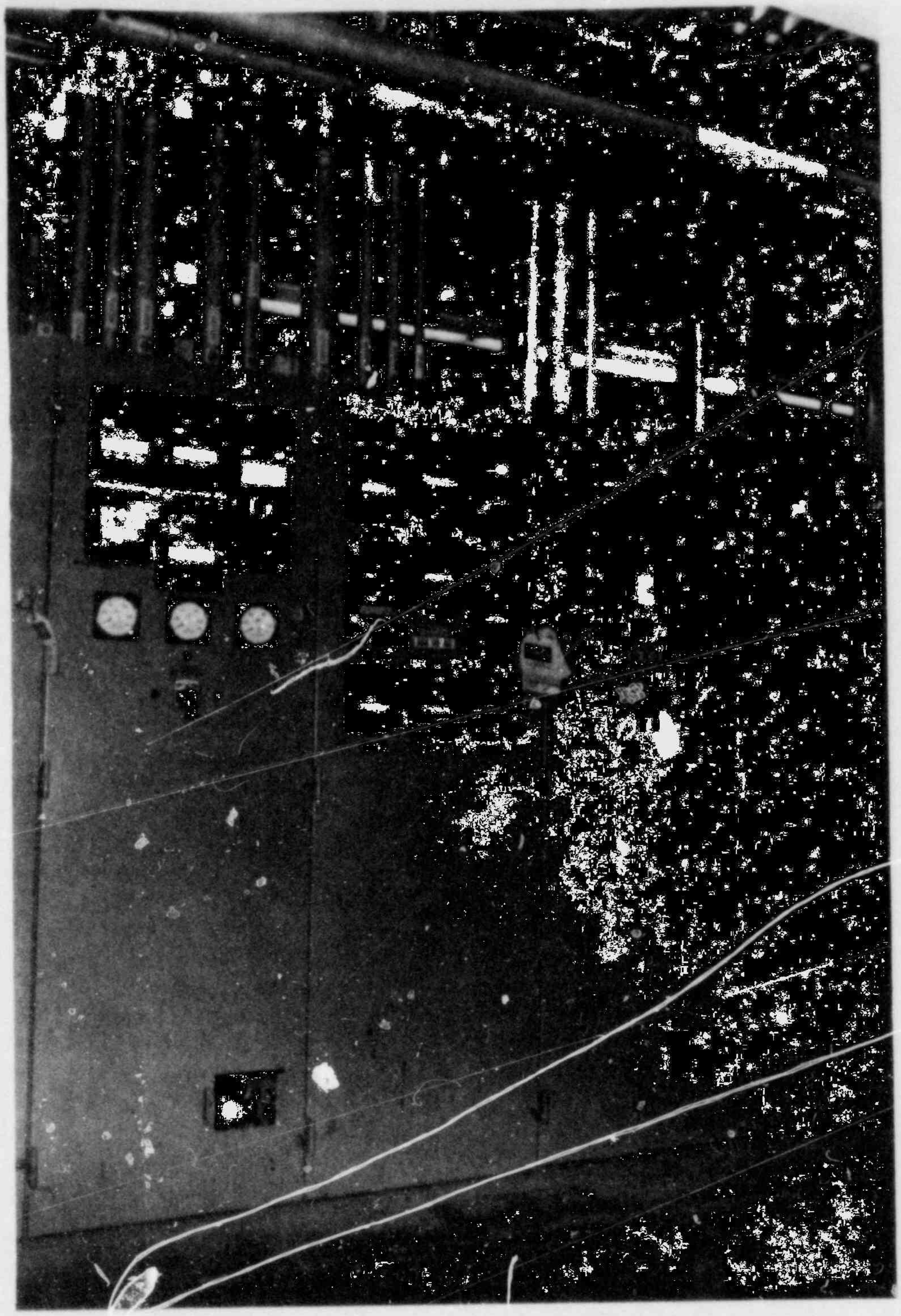


Figure 14. Emergency switchgear.

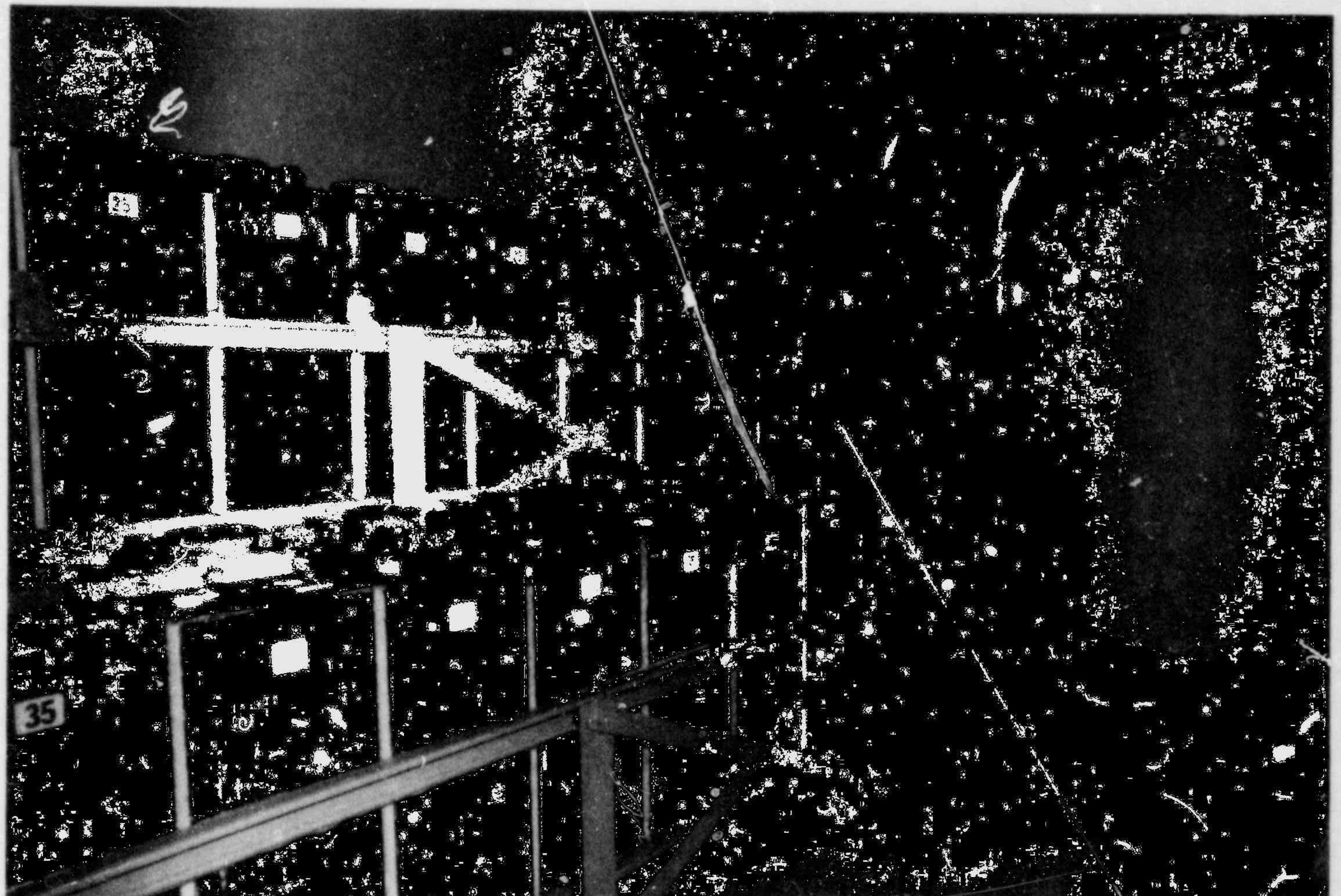


Figure 15. Batteries with racks in a battery room.

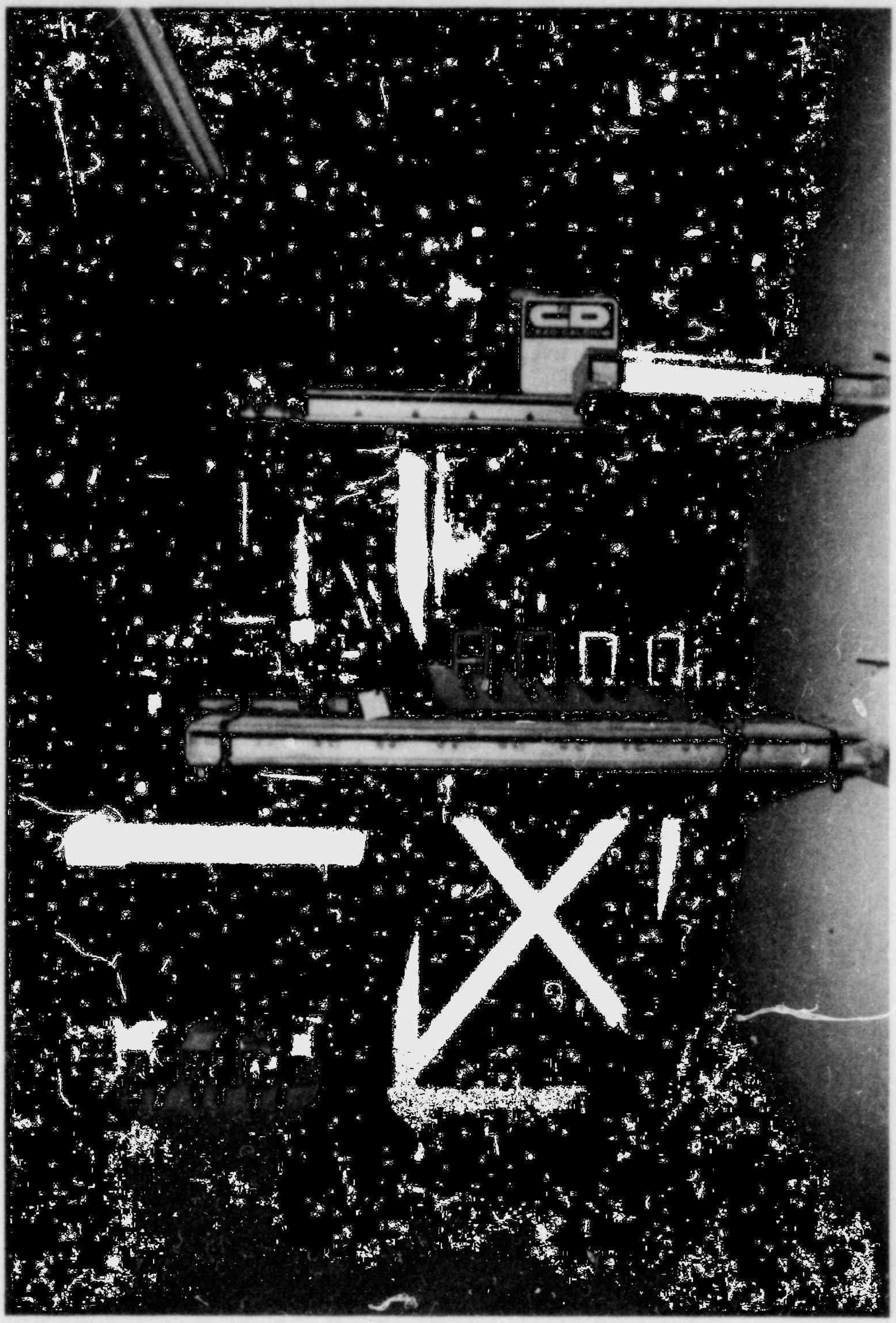


Figure 16. Side view of batteries with seismic restraints.

NRC FORM 335 (7-77) U.S. NUCLEAR REGULATORY COMMISSION **BIB IOGRAPHIC DATA SHEET**	1. REPORT NUMBER (Assigned by DDC) NUREG-0792
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	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) Kulin D. Desai	5. DATE REPORT COMPLETED — MONTH: May; YEAR: 1981
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	11. CONTRACT NO.
13. TYPE OF REPORT: Technical Report	PERIOD COVERED (Inclusive dates)
15. SUPPLEMENTARY NOTES	14. (Leave blank)

16. ABSTRACT (200 words or less)

The Advisory Committee on Reactor Safeguards recommended that the NRC staff review in detail the capability and available seismic design margin of fluid systems and equipment used in North Anna, Units 1 and 2 to achieve safe shutdown following an SSE event.

The staff conducted a series of plant visits and meetings with the licensee to view and discuss the seismic design methodology used for systems, equipment and their supports.

The report is a description and evaluation of the seismic design criteria, design conservatisms and seismic design margin for North Anna, Units 1 and 2.

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SEISMIC DESIGN MARGIN EVALUATION OF SYSTEMS AND EQUIPMENT REQUIRED
FOR SAFE SHUTDOWN OF NORTH ANNA, UNITS 1 AND 2, FOLLOWING AN SSE EVENT

JUNE 1981