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5. CONTAINMENT SYSTEM

5.1 STRUCTURAL DESIGN

5.1.1 GENERAL DESCRIPTION OF CONTAINMENT STRUCTURE

The reactor containment is a fully continuous reinforced concrete structure in the shape of a cylinder with a shallow domed roof and a flat foundation slab. The cylindrical portion is prestressed by a post-tensioning system consisting of horizontal and vertical tendons. The dome has a three-way post-tensioning system. Hoop tendons are placed in 3-120 degree systems using six buttresses as anchorages, with the tendons staggered so that half of the tendons at each buttress terminate at that buttress. The foundation slab is reinforced with conventional reinforcing steel. A welded steel liner is attached to the inside face of the concrete shell to insure a high degree of leaktightness. The base liner is installed on top of the structural slab and will be covered with concrete. The structure will provide biological shielding for both normal and accident situations.

The reactor containment will completely enclose the entire reactor and reactor coolant system and ensure that an acceptable upper limit for leakage of radioactive materials to the environment would not be exceeded even if gross failure of the reactor coolant system were to occur. The approximate dimensions of the reactor containment are: inside diameter, 116 feet; inside height, 206 feet; vertical wall thickness, 3-3/4 feet; dome thickness, 3-1/4 feet; and the foundation slab, 10 feet. The building encloses the pressurized water reactor, steam generators, reactor coolant loops and portions of the auxiliary and engineered safeguards systems. The internal net free volume is 1,900,000 cubic feet.

Full advantage is being taken in the design of this reactor building of the experience gained in the review of similar designs with the AEC for the Florida Power and Light Company's Turkey Point Plant, Consumers Power Company's Palisades Plant, Wisconsin-Michigan Power Company's Point Beach Plant and Duke Power Company's Oconee Nuclear Station, as well as containment designs by others which meet the same functional requirements.

Representative details of the construction that will be used are shown in Figures 5.1-1, 5.1-2, 5.1-3 and Table 5.1-1. 1

5.1.2 BASIS FOR DESIGN LOADS

The reactor containment will be designed for all credible conditions of loading, including normal loads, loads during maximum credible accident, test load, and loads due to adverse environmental conditions. The following loadings will be considered:

a. The loading caused by the pressure and temperature transients of the design base accident.

b. Structure dead load

c. Live loads

d. Earthquake load

e. Wind loads

f. External pressure load

The two critical loading conditions are those caused by the design base accident resulting from failure of the reactor coolant system and those caused by an earthquake.

5.1.2.1 Maximum Credible Accident Load

The minimum design pressure and temperature of the containment will be equal to the peak pressure and temperature occurring as a result of the complete blowdown of the reactor coolant through any rupture of the reactor coolant system up to and including the hypothetical double-ended severance of a 36-inch ID reactor coolant pipe.

The supports for the reactor coolant system will be designed to withstand the blowdown forces associated with the sudden severance of the reactor coolant piping so that the coincidental rupture of the steam system is not considered credible.

Transients resulting from the design base accident and other, lesser, accidents are presented in Section 14 and serve as the basis for a containment design pressure of 59 psig.

The design pressure will not be exceeded during any subsequent long-term pressure transient caused by the combined effects of such heat sources as residual heat and metal-water reactions. These effects will be overcome by the combination of emergency-powered engineered safeguards and structural heat sinks.

5.1.2.2 Structure Dead Load

Dead load will consist of the weight of the concrete wall, dome, base slab, and any internal concrete. Weights used for dead load calculations will be as follows:

a. Concrete	148 lb/ft^3
b. Steel reinforcing	489 lb/ft^3 using nominal cross-sectional areas of reinforcing as defined in ASTM for bar sizes and nominal cross-sectional areas of prestressing
c. Steel lining	489 lb/ft^3, using nominal cross-sectional area of lining

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5.1.2.3 Live Loads

Live loads will include snow and ice loads on the roof of the containment dome. The roof load will be 20 pounds per horizontal square foot.

Equipment loads will be those specified on the drawings supplied by the manufacturers of the various pieces of equipment.

Live loads will be assumed for the design of internal slabs consistent with the intended use of the slabs.

5.1.2.4 Earthquake Loads

Earthquake loading is predicated upon a design earthquake at the site having a horizontal ground acceleration of 0.13g. In addition, a maximum hypothetical earthquake having a ground acceleration of 0.25g 3 will be used to check the design to ensure no loss of function. The seismic design spectrum curves are given in Appendix 5A. A vertical acceleration one-half of the magnitude of the horizontal acceleration will be applied in the load equations simultaneously. A dynamic analysis will be used to arrive at equivalent static loads for design. The acceleration response curves shown in Appendix 5A are based on Figure 1.21 of TID-7024 "Nuclear Reactors and Earthquakes," are corrected to the design ground acceleration, and are plotted on tripartite logarithmic paper.

5.1.2.5 Wind Loads 1

Wind loading for the containment structure is based on Figure 1 (b) of ASCE Paper 3269, "Wind Forces on Structures," using the fastest wind speed for a 100-year recurrence period. ASCE Paper 3629 will also be used to determine shape factors, gust factors, and variation of wind velocity with height. Based upon the site location and inland classification the design wind 1 velocity is 90 MPH at a reference 30 feet above ground level.

5.1.2.6 External Pressure Load

External pressure loading with a differential of approximately two pounds per square inch from outside to inside will be considered.

The external design pressure is equivalent to have a barometric pressure rise to 31 inches of mercury after the containment was sealed at 29 inches of mercury. Therefore, operation of purge valves will not be required due to barometric changes during normal operation.

The external design pressure is also adequate to permit the containment to be cooled to 60 F from an initial maximum operating condition of 120 F. Therefore, operation of purge valves will not be necessary during this condition. Vacuum breakers are not required.

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5.1.3 CONSTRUCTION MATERIALS

Basically four materials will be used for the foundation and the containment structure. These are:

a. Concrete

b. Reinforcing steel

c. Steel prestressing tendons

d. Steel liner plate

Detailed specifications and working drawings for these materials and their installation will be of such scope as to assure that the quality of work will be commensurate with the necessary integrity of the containment structure.

Basic specifications for these materials include the following.

5.1.3.1 Concrete

All concrete work will be in accordance with ACI 318-63 "Building Code Requirements for Reinforced Concrete" and to ACI-301 "Specifications for Structural Concrete for Buildings." Concrete will be a dense, durable mixture of sound coarse aggregate, fine aggregate, cement, and water. Admixtures will be added to improve the quality and workability of the fluid concrete during placement and to retard the set of the concrete. Maximum practical size aggregate, water reducing additives, and a low slump of two to three inches will be used to minimize shrinkage and creep. Aggregates will conform to "Standard Specifications for Concrete Aggregate" ASTM Designation C33. Fine aggregate will consist of sharp, hard, strong, and durable sand, free from adherent coatings, clay loam, alkali, organic material, or other deleterious substances.

Acceptability of aggregates will be based on the ASTM Tests as stated in Section 5.4.3.1.

Cement will be Type II as specified in "Standard Specifications for Portland Cement" ASTM Designation C150 and will be tested to comply with ASTM C-114.

Water for mixing concrete will be clean and free from any deleterious amounts of acid, alkali, salts, oil, sediment, or organic matter.

The water will be potable and will not contain impurities in amounts that will cause a change of more than 25 percent in setting time for the Portland Cement, nor a reduction in the compressive strength of mortar of more than 5 percent as compared with results obtained using distilled water.

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A water-reducing agent will be employed to reduce shrinkage and creep of concrete. Admixtures containing chlorides will not be used. The following types of agent will be tested with the concrete materials selected for the containment structure.

a. Pozzolith No. 8

b. Pozzolith 100 R

c. Plastiment

d. Placewell LS

The agent selected will be the one providing the smallest shrinkage as determined by ASTM C-494, "Specifications for Chemical Admixtures for Concrete."

Concrete mixes will be designed in accordance with ACI 613 using materials qualified and accepted for this work. Only mixes meeting the design requirements specified for containment structure concrete will be used.

Trial mixes will be tested in accordance with applicable ASTM Codes as indicated below:

Test	ASTM
Making and Curing Cylinder in Laboratory	C-192
Air Content	C-231
Slump	C-143
Bleeding	C-232
Compressive Strength Tests	C-39

Eight cylinders will be cast from each design mix for two tests on each of the following days: 3, 7, 28, and 90. The concrete will have a design compressive strength of 5000 psi at 28 days for the containment wall and dome and 4000 psi at 28 days for the containment base slab.

Test cylinders will be cast from the mix proportions selected for construction and the following concrete properties will be determined:

a. Uniaxial creep

b. Modulus of elasticity and Poisson's ratio

c. Autogenous shrinkage

d. Thermal diffusivity

e. Thermal coefficient of expansion

f. Compressive strength

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Concrete samples will be taken from the mix according to ASTM C-172, "Sampling Fresh Concrete." From these samples, cylinders for compression testing will be made. They will be stripped within 24 hours after casting and marked and stored in the curing room. These cylinders will be made in accordance with ASTM C-31, "Tentative Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Field."

Slump, air content, and temperature measurements will be taken when cylinders are cast. Slump tests will be performed in accordance with ASTM C-143, "Standard Method of Test for Slump of Portland Cement Concrete." Air content tests will be performed in accordance with ASTM C-231, "Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method." Compressive strength tests will be made in accordance with ASTM C-39, "Method of Test for Compressive Strength of Molded Concrete Cylinders."

Evaluation of compression tests will be in accordance with ACI 214-65.

A full-time inspector, who has had experience in concrete work, will continuously check the concrete batching and placing operations.

5.1.3.2 Reinforcing Steel

Reinforcing steel in the base slab of the containment structure and around penetrations in the cylinder will be deformed billet steel bars conforming to ASTM Designation A432-65. This steel has a minimum yield strength of 60,000 psi, a minimum tensile strength of 90,000 psi, and a minimum elongation of 7 percent in an 8 inch specimen. Deformed billet steel bars conforming to ASTM A15 or A408 - Intermediate Grade will be used in the cylinder wall and the domed roof to control shrinkage and tensile cracks. This steel has a minimum yield strength of 40,000 psi and a minimum tensile strength of 70,000 psi. The A15 steel has a minimum elongation of 12 percent in 8 inch specimen, while A408 has a minimum elongation of 10 percent in an 8 inch specimen.

Mill test results will be obtained from the reinforcing steel supplier for each heat of steel to show proof that the reinforcing steel has the specified composition, strength, and ductility. Splices in reinforcing bar sizes No. 11 and smaller will be lapped in accordance with ACI 318-63, and for bars larger than No. 11, Cadweld splices will be used.

Welding of reinforcing steel, if required, will be performed by qualified welders in accordance with AWS D12.1, "Recommended Practice for Welding Reinforcing Steel, Metal Inserts, and Connections in Reinforced Concrete Construction," but tack welding will not be permitted.

5.1.3.3 Steel Prestressing Tendons

There are a number of post tensioning systems suited to containment vessels available in this country. The ultimate capacity of the wire or strand systems presently considered suitable for this containment vary from 494 kips to 1080 kips. Listed below are pertinent features of some of these post tensioning systems:

[redacted]

Manufacturer	Freyssinet	BBRV	Stress Steel (SEEE)
Designation	Wire strand	Wires	Wire strand
Ultimate Capacity	494 Kips	1080 Kips	792 Kips
Design Capacity	296 Kips	636 Kips	468 Kips
End Anchorage	Open end, male and female cone	Buttonhead	Swaged, threaded collar and nut

All three of the above systems have been used in foreign prestressed concrete reactor vessels as well as domestic conventional structures. The design will permit the use of any system that meets the specified requirements.

The 12-0.5" Freyssinet system was used in the French containment vessel at Brennilis. A larger Freyssinet system of 12-0.6" seven-wire strands is being used for the prestressed reactor vessel at Wylfa, England. 90 wire BBRV tendons are presently being used for the light structures at the Turkey Point, Palisades, Point Beach and the Oconee plants. BBRV has the following US Licensees:

a. American Stress Wire Corp.

b. Prescon Corp.

c. Joseph T. Ryerson & Sons, Inc.

d. Western Concrete Structures

Stress Steel is the US licensee for the SEEE 19-0.5" strand system. The 0.5" strands are the same as used in the Freyssinet systems. The SEEE strand was used as the prestressing for the French EDF-3 and EDF-4 reactor vessels. SEEE has recently developed a 28-0.5" strand tendon based on the same principles as the 19-0.5" strand tendon. The steel strand will conform to "Specifications for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete," ASTM A-416 with a minimum ultimate strength of 250,000 psi or seven-wire 270 K strands with minimum ultimate strength of 270,000 psi. The minimum yield strength for all strands will not be less than 85 percent of the specified minimum breaking strength.

The BBRV system is presented as the basis for licensing of the Rancho Seco plant. If in the final design, a change in system is desired, SMUD will apply for an amendment. The prestressing wire used in the tendons will conform to "Specifications for Uncoated Stress-Relieved Wire for Prestressed Concrete," ASTM A-421. Anchorages will develop 100 percent of guaranteed minimum ultimate strength of tendons. The tendons will be housed in ungalvanized, spiral-wrapped, semi-rigid, corrugated sheath and will be greased but not grouted. The prestressing wire will be protected against atmospheric corrosion during its shipment and installation, and during the life of the structure. Prior to shipment the wire will 4

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be coated with a thin film of petrolatum containing rust inhibitors, such as Dearborn Chemical Company 490 R. The interior surface of the sheathing is also coated with the same material during manufacture to protect against rusting during shipment, storage, and prior to filling with a grease-like material. The sheathing filler material used for permanent corrosion protection is a modified, thixiotropic, refined petroleum oil base product such as Dearborn Chemical Company NO-Ox-Id CM Casing Filler. It has a proven history of serving as a casing filler for cased pipelines under railroads and highways. The material will be introduced into the sheathing after stressing by pumping at ambient temperature.

The tendon anchorages will develop the minimum guaranteed ultimate tensile strength of the prestressing steel without permanent deformation and without excessive slip. The unit compressive stress developed by the bearing plate under the anchorage will be in conformance with ACI Code 318-63.

Dynamic earthquake loading acceptance standards of the tendons and anchorages are based on 500 cycles of rapid loading from a stress level of 0.70 f's to a stress level of 0.75 f's and back again in cycles of 0.1 second.

The number of cycles where the peaks exceed one half of the maximum value falls in the range between 20 and 30 cycles. A highly conservative factor was applied to the number of observed cycles to provide a margin of safety comparable to the reliance placed on the anchorage system in developing the tendon.

Earthquake, wind, and accident loadings will not generate more than 100 cycles of maximum stress variations during the life of the plant. In addition, the stress level due to these loadings will be between 0.60 f's to 0.64 f's, which is on the safe side. Of this range of 0.04 f's only 10 percent is actually due to seismic loading.

Anchorage performance requirements are now established by the Seismic Committee of the Prestressed Concrete Institute and published in their journal of June, 1966. These requirements are as follows and will be met by the tendon system:

"All anchors of unbonded tendons should develop at least 100 percent of the guaranteed ultimate strength of the tendon. The anchorage gripping shall function in such a way that no harmful notching effect would occur on the tendon. Any such anchorage system used in earthquake areas must be capable of maintaining the prestressing force under sustained and fluctuating load and under the effect of shock. Anchors should also possess adequate reserve strength to withstand any overstress to which they may be subjected during the most severe probable earthquake. Particular attention should be directed to accurate positioning and alignment of end anchorages."

[redacted]

The bearing plate is included as a part of the prestressing system and at its interface with the concrete there is one of the greater interactions with the structures. The average contact pressure between bearing plate and concrete is limited to those permissible by ACI 318-63. The maximum contact pressure exceeds the average at locations nearest where the end anchor contacts the bearing plate. This results from a bending of the bearing plate. It is possible that the bending stress near the end anchor will reach yield since concrete differential creep will increase the bending of the plate from its initially loaded condition, and the largest bending stress in the bearing plate results from a yield moment for the plate. Although a difficult analytical problem, because of the inelastic nature of the materials and difficulty in defining boundary conditions, long experience and testing has shown that concrete reinforcing as used under column base plates and prestressing bearing plates, coupled with the bearing and base plate design approach, result in bearing and base plates that have not failed even though exposed to sub-zero temperatures in heavy industrial structures such as outdoor steel mill crane columns, power plant coal crusher structures and trestle columns. Also, communications with the chief engineer of an established prestressing company indicates that they have not experienced bearing plate failures when stressing tendons to $0.8f'_s$, the highest that had been planned to be imposed on the bearing plates, even while stresssing in sub-zero weather. Since the bearing plates are designed and tested to proven standards; are not subjected to large cycling loads or repeated impact loads; and are used in a climate less extreme than those for which the standards have been proven, it appears that they can satisfy the performance requirements.

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In determining the appropriateness of applying NDT requirements, consideration has been given to:

(1.) The proven history, as cited above, for the use of both structural steel and post-tensioning systems under similar or worse environments to that of this application.

(2.) The A-36 or similar steel used for the bearing plates is in general a better quality steel than the A-7 that has the proven history cited above.

(3.) The fact that neither the AISC Structural Steel Code nor the ACI 318-63 has ever seen fit to incorporate such requirements in those code.

The conclusion that is drawn from the above discussion is that brittle fracture is not a problem for post-tensioning bearing plates.

[redacted]

Certified test results of engineering data for the selected post-tensioning system will be furnished upon selection of a vendor. These results will include tests of ultimate strength, yield strength, wire area reduction, jacking stress, initial prestress, effective prestress, stress-strain relations, and elongation at rupture, and dynamic fatigue characteristics of the anchorages.

In addition, a number of assemblies will be made up with tendons and anchorages as they would be for final installation. These sample tendons will be used in static tests to failure, as appropriate.

5.1.3.4 Steel Liner Plate

The containment structure will be lined with welded steel plate conforming to ASTM-A442, Grade 60, to ensure low leakage. This steel has a minimum yield strength of 30,000 psi and a minimum elongation in an 8 inch specimen of 22 percent.

The design, construction, inspection and testing of the liner plate, which acts as a leak tight membrane and is not a pressure vessel, is not covered by any recognized code or specification. However, the liner plate and structural shapes will be supplied to the requirements of ASTM A-442 "Carbon Steel Plates with Improved Transition Properties" and ASTM A-20, "Specification for General Requirements for Delivery of Rolled Steel Plates of Flange and Firebox Qualities."

All components of the liner which must resist the full design pressure, such as penetrations, are selected to meet the requirements of Paragraph N-1211 of Section III, Nuclear Vessels, of the ASME Code. ASTM A-516 Grade 60 or 70 made to ASTM A-300 is typical of a steel which meets these requirements and will be used as a plate material for penetrations. This material has excellent weldability characteristics and as much ductility as is obtainable in any commercially available pressure vessel quality steel.

In accordance with ASME Code Case 1347, allowable stresses for A-516 Grade 60 and 70 are the same as those permitted for A-201 Grade B and A-212 Grade B, respectively.

The A-442 material was chosen on the basis that it has sufficient strength as well as ductility to resist the expected stresses from design criteria loading and at the same time preserve the required leak tightness of the containment.

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The liner plate is designed to function only as a leak tight membrane. It is not designed to resist the tension stresses from internal applied pressure which may result from any credible accident conditions. The structural integrity of the containment is maintained by the prestressed, post-tensioned concrete. Since the principal applied stress to the liner plate membrane, from shrinkage and creep of the concrete, will be in compression and no significant applied tension stresses are expected from internal pressure loading, there is no need to apply special nil ductility transition temperature criteria to the liner plate material. On the other hand, all material for containment parts which must resist applied internal pressure stresses, such as penetrations, shall be impact tested in accordance with the requirements of Paragraph N-1211 of Section III, Nuclear Vessels, of the ASME Code.

A-442 steel is readily weldable by all of the commercially available arc and gas welding processes.

A fundamental requirement for fabrication and erection of the liner plate is that all welding procedures and welding operators be qualified by tests as specified in Section IX of the ASME Code. This Code requires testing of welded transverse root and face bend samples in order to verify adequate weld metal ductility. Specifically, Section IX of the Code requires that transverse root and face bend samples be capable of being bent cold 180 degrees to an inside radius equal to twice the thickness of the test sample. Satisfactory completion of these bend tests is accepted as adequate evidence of required weld metal and plate material compatibility.

Mill test results will be obtained for the liner plate material. The plate will be visually checked for thickness, possible laminations and pitting.

The surfaces of the liner plate not to be embedded in concrete will be protected by an initial surface cleaning and prime coat of paint applied at the fabrication plant to protect it until installation. A suitable finish paint will be applied to the exposed surface after the plate is installed. |1

5.1.4 CONTAINMENT STRUCTURE DESIGN CRITERIA

Safety of the structure under extraordinary circumstances and performance of the containment structure at various loading stages are the main considerations in establishing the structural design criteria.

[redacted]

The two basic criteria are:

a. The integrity of the liner plate shall be guaranteed under all loading conditions.

b. The structure shall have a low-strain elastic response such that its behavior will be predictable under all design loadings.

The strength of the containment structure at working stress and over-all yielding will be compared to various loading combinations to ensure safety. The containment structure will be examined with respect to strength, the nature and the amount of cracking, the magnitude of deformation, and the extent of corrosion to ensure proper performance. The structure will be designed to meet the performance and strength requirements under the following conditions:

a. Prior to prestressing

b. At transfer of prestress

c. Under sustained prestress

d. At design loads

e. At yield loads

Deviations in allowable stresses for the design loading conditions in the working stress method will be permitted if the yield capacity criteria are fully satisfied. All design will be in accordance with the ACI Code 318-63 unless otherwise stated herein.

No special design bases are required for the design and checking of the base slab. It will act primarily in bending rather than membrane stress. This condition is covered by the ACI Code 318-63. The loads and stresses in the cylinder and dome will be determined as described below.

5.1.4.1 Design Method

The structure will be analyzed using a finite element computer program for individual and various combinations of loading cases of dead load, live load, prestress, temperature and pressure. The computer output will include direct stresses, shear stresses, principal stresses, and displacements of
4 each nodal point.

[redacted]

Stress plots which show the total stresses from appropriate combinations of loading cases will be made and areas of high stress will be identified. The modulus of elasticity will be corrected to account for the nonliner stress-strain relationship at high compression, if necessary. Stresses then will be recomputed if these are sufficient areas which require attention.

The forces and shears will be added over the cross-section and the total moment, axial force, and shear will be determined. From these values, the straight-line elastic stresses will be computed and compared to the allowable values. The ACI 318-63 design methods and allowable stresses will be used for concrete and prestressed and non-prestressed reinforcing steel except as noted in these criteria. 4

5.1.4.2 Loads Prior to Prestressing

Under this condition the structure will be designed as a conventionally reinforced concrete structure. It will be designed for dead load, live loads (including construction loads), and a reduced wind load. Allowable stresses will be according to ACI 318-63 Code.

5.1.4.3 Loads at Transfer of Prestress

The containment structure will be checked for prestress loads and the stresses compared with those allowed by the ACI 318-63 Code with the following exceptions: ACI 318-63, Section 26, allows concrete stress of 0.60 f'_{ci} at initial transfer. In order to limit creep deformations, the membrane compression stress will be limited to 0.30 f'_{ci} whereas in combination with 4 flexural compression the maximum allowable stress will be limited to 0.60 f'_{ci} per the ACI Code.

For local stress concentrations with non linear stress distribution as predicted by the finite element analysis, 0.75 f'_{ci} will be permitted when 4 local reinforcing is included to distribute and control these localized strains. These high local stresses are present in every structure but they are seldom identified because of simplifications made in design analysis. These high stresses are allowed because they occur in a very small percentage of the cross-section, are confined by material at lower stress and would have to be considerably greater than the values allowed before significant local plastic yielding would result. Bonded reinforcing will be added to 4 distribute and control these local strains.

[redacted]

Membrane tension and flexural tension will be permitted provided they do not jeoparidize the integrity of liner plate. Membrane tension will be permitted to occur during the post tensioning sequence but will be limited to 1.0 f'_{ci}. When there is flexural tension, but no membrane tension, the section will be designed in accordance with section 2605 (a) of the ACI Code. The stress in the liner plate due to combined membrane tension and flexural tension, will be limited to 0.5 fy.

Shear criteria will be in accordance with the ACI 318-63 Code, Chapter 26 as modified by the equations shown in paragraph 5.1.4.6, using a load factor of 1.5 for shear loads.

5.1.4.4 Loads Under Sustained Prestress

4 The conditions for design and the allowable stresses for this case will be the same as above except that the allowable tensile stress in non-prestressed reinforcing will be limited to 0.5 fy. ACI 318-63 limits the concrete compression to 0.45 f'_c for sustained prestress load. Values of 0.30 f'_c and 0.60 f'_c will be used as described above, which bracket the ACI allowable value. However, with these same limits for concrete stress at transfer of prestress, the stresses under sustained load will be reduced due to creep.

5.1.4.5 At Design Loads

4 This loading case is the basic "working stress" design. The containment structure will be designed for the following loading cases:

(a) $D+F+L+T_O$

(b) $D+F+L+P+T_A$

Where:

D = Dead Load

L = Appropriate Live Load

F = Appropriate Prestressing Load

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P = Pressure Load (varies with time from design pressure to no pressure)

T_O= Thermal Loads due to Operating Temperature

T_A= Thermal Loads Based on a Temperature Corresponding to a Pressure P (see figure 5-4)

Sufficient prestressing will be provided in the cylindrical and dome portions of the vessel to eliminate membrane tensile stress (tensile stress across the entire wall thickness) under design loads. Flexural tensile cracking will be permitted but will be controlled by bonded reinforcing steel.

Under the design loads the same performance limits stated in 5.1.4.3 will apply with the following exceptions: 4

a. If the net membrane compression is below 100 psi, it will be neglected and a cracked section will be assumed in the computation of flexural bonded reinforcing steel. The allowable tensile stresses in bonded reinforcing will be 0.5 fy.

b. When the maximum flexural stress does not exceed $6\sqrt{f'_c}$ and the extent of the tension zone is no more than 1/3 the depth of the section, bonded reinforcing steel will be provided to carry the entire tension in the tension block. Otherwise, the bonded reinforcing steel will be designed assuming a cracked section. When the bending moment tension is additive to the thermal tension, the allowable tensile stress in the bank reinforcing steel will be 0.5 fy minus the stress in reinforcing due to the thermal gradient as determined in accordance with the method of ACI-505.

c. The problem of shear and diagonal tension in a prestressed concrete structure should be considered in two parts: membrane principal tension and flexural principal tension.

Since sufficient prestressing is used to eliminate membrane tensile stress, membrane principal tension is not critical at design loads. Membrane principal tension due to combined membrane tension and membrane shear is considered under 5.1.4.6.

Flexural principal tension is the tension associated with bending in planes perpendicular to the surface of the shell and shear stress normal to the shell (radial shear stress). The present ACI 318-63 provisions of chapter 26 for shear are adequate for the design purposes with proper modifications as discussed under 5.1.4.6, using a load factor of 1.5 for shear loads. 4

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Crack control in the concrete will be accomplished by adhering to the ACI-ASCE Code Committee standards for the use of reinforcing steel. These criteria are based upon a recommendation of the Prestressed Concrete Institute, and are as follows:

0.25 percent reinforcing shall be provided at the tension face for small members

0.20 percent for medium size members

0.15 percent for large members

4 A minimum of 0.15 percent bonded steel reinforcing will be provided in two perpendicular directions on the exterior faces of the wall and dome for proper crack control.

The liner plate is attached on the inside faces of the wall and dome. Since, in general, there is no tensile stress due to temperature on the inside faces, bonded reinforcing steel is not necessary at the inside faces.

5.1.4.6 Loads Necessary to Cause Structural Yielding

4 The structure will be checked for the factored loads and load combinations given below.

The load factors are the ratio by which loads will be multiplied for design purposes to assure that the load/deformation behavior of the structure is one of elastic, low strain behavior. The load factor approach is being used in this design as a means of making a rational evaluation of the isolated factors which must be considered in assuring an adequate safety margin for the structure. This approach permits the designer to place the greatest conservatism on those loads most subject to variation and which most directly control the overall safety of the structure. It also places minimum emphasis on the fixed gravity loads and maximum emphasis on accident and earthquake or wind loads.

The final design of the containment structure will satisfy the following load combinations and factors:

(a) $YC = 1/\phi \quad (1.05D+1.5P+1.0T_A+1.0F)$

(b) $YC = 1/\phi/ \quad (1.05D+1.25P+1.0T_A+1.25E+1.0F)$

4 (c) $YC = 1/\phi \quad (1.05D+1.25H+1.0R+1.0F+1.25E+1.0T_o)$

(d) $YC = 1/\phi \quad (1.0D+1.0P+1.0T_A+1.0H+1.0E'+1.0F)$

(e) $YC = 1/\phi \quad (1.0D+1.0H+1.0R+1.0E'+1.0F+.0T_o)$

(Wind, W, replaces earthquake, E, where wind stresses control)

Where: YC = required yield capacity strength of the structure as defined below.

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ϕ = capacity reduction factor (defined in Section 5.1.4.7)

D = dead loads of structures and equipment plus any other permanent loading contributing stress, such as hydrostatic or soil. In addition, a portion of live load is added when it includes items such as piping, cable and trays suspended from floors. An allowance is made for future additional permanent loads.

P = design accident pressure load

F = effective prestress loads

R = force or pressure on structure due to rupture of any one pipe

H = force on structure due to thermal expansion of pipes due to design conditions

T_O= thermal loads due to the temperature gradient through wall during operating conditions

T_A= thermal loads due to the temperature gradient through the wall and expansion of the liner. It is based on a temperature corresponding to the factored design accident pressure.

E = design earthquake load

E'= maximum earthquake load

W = wind load

Equation (a) assures that the containment will have the capacity to withstand pressure loadings at least 50 percent greater than those calculated for the postulated loss-of-coolant accident alone.

Equation (b) assures that the containment will have the capacity to withstand loadings at least 25 percent greater than those calculated for the postulated loss-of-coolant accident with a coincident design earthquake or wind.

Equation (c) assures that the containment will have the capacity to withstand earthquake loadings 25 percent greater than those calculated for the design earthquake coincident with rupture of any attached piping. 4

Equation (d) and (e) assure that the containment will have the capacity to withstand either the postulated loss-of-coolant accident or the rupture of any attached piping coincident with the maximum hypothetical earthquake.

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The load combinations, considering load factors given above, will be less than the yield strength of the structure. The yield strength of the structure is defined as the upper limit of elastic behavior of the effective load carrying structural materials. For steels (both prestress and non-prestress) this limit is taken to be the guaranteed minimum yield given in the appropriate ASTM specification. For concrete, it is the ultimate values of shear (as a measure of diagonal tension) and bond per ACI 318-63 and the 28 day ultimate compressive strength for concrete in flexure (f'_c). The ultimate strength assumptions of the ACI Code for concrete beams in flexure will not be allowed; that is, the concrete stress will not be allowed to go beyond yield and redistribute at a strain of 3 to 4 times that which causes yielding.

The maximum strain due to secondary moments, membrane loads and local loads exclusive of thermal loads will be limited to that corresponding to the ultimate stress divided by the modulus of elasticity (f'_c/EC) and a straight line distribution from there to the neutral axis assumed. For the above loads combined with thermal loads the peak strain will be limited to 0.003 inch/inch. For concrete membrane compression, the yield strength will be assumed to be $0.85\ f'_c$ to allow for local irregularities, in accordance with the ACI approach. The reinforcing steel forming part of the load carrying system will be allowed to go to, but not exceed, yield as is allowed for ACI ultimate strength design.

A further definition of yielding is that deformation of the structure which will not cause strains in the steel liner plate to exceed 0.005 in/in. The yielding of non-prestress reinforcing steel will be allowed, either in tension or compression, if the above restrictions are not violated. Yielding of the prestress tendons will not be allowed under any circumstances.

Principal concrete tension due to combined membrane tension and membrane shear, excluding flexural tension due to bending moments or thermal gradients, will be limited to $3\sqrt{f'_c}$. Principal concrete tension due to combined membrane tension, membrane shear, and flexural tension due to bending moments or thermal gradients will be limited to $6\sqrt{f'_c}$. When the principal concrete tension exceeds the limit of $6\sqrt{f'_c}$, bonded reinforcing steel will be provided in the following manner:

(a) Thermal flexural tension - Bonded reinforcing steel will be provided in accordance with the methods of ACI-505. The minimum area of steel provided will be 0.15 percent in each direction.

(b) Bending moment tension - Sufficient bonded reinforcing steel will be provided to resist the moment on the basis of cracked section theory using the yield stresses stated above with the following exception: When the bending moment

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tension is additive to the thermal tension, the allowable tensile stress in the reinforcing steel will be fy minus the stress in reinforcing due to the thermal gradient as determined in accordance with the methods of ACI-505.

Shear stress limits and shear reinforcing for radial shear will be in accordance with chapter 26 of ACI 318-63 with the following exceptions: 4

a. Formula 26-12 of the code shall be replaced by

$$V_{ci} = K\, b'd\, \sqrt{f'_c} + M_{cr}\left(\frac{V}{M'}\right) + V_i \qquad (1)$$ 3

where

$$K = \left[1.75 - \frac{0.036}{np'} + 4.0\, np'\right]$$

but not less than 0.6 for $p' \geq 0.003$. 4

For $p' < 0.003$, the value of K shall be zero.

$$M_{cr} = \frac{I}{Y}\left[6\sqrt{f'_c} + f_{pe} + f_n + f_i\right]$$

f_{pe} = Compressive stress in concrete due to prestress applied normal to the cross-section after all losses, (including the stress due to any secondary moment) at the extreme fibre of the section at which tension stresses are caused by live loads.

f_n = Stress due to axial applied loads, (f_n shall be negative for tension stress and positive for compression stress). 3

f_i = Stress due to initial loads, at the extreme fibre of a section at which tension stresses are caused by applied loads, (including the stress due to any secondary moment. f_i shall be negative for tension stress and positive for compression stress.)

$$n = \frac{505}{\sqrt{f_c'}}$$

$$p' = \frac{As'}{bd}$$

V = Shear at the section under consideration due to the applied loads.

[redacted]

M' = Moment at a distance d/2 from the section under consideration, measured in the direction of decreasing moment, due to applied loads.

V_i = Shear due to initial loads (positive when initial shear is in the same direction as the shear due to applied loads.)

Lower limit placed by ACI-318-63 on V_{ci} as 1.7 b'd $\sqrt{fc'}$ will not be applied.

b. Formula 26-13 of the code shall be replaced by

3

$$V_{cw} = 3.5 \text{ b'd} \sqrt{fc'} \left(\sqrt{1 + \frac{f_{pc} + f_n}{3.5 \sqrt{f_c'}}} \right) \quad (2)$$

The term f_n is as defined above. All other notations are in accordance with chapter 26, ACI-318-63.

(1) This formula is based on the recent tests and work done by Dr. A. H. Mattock of the University of Washington.

(2) This formula is based on the commentary for Proposed Redraft of section 2610-ACI-318 by Dr. A. H. Mattock, dated December, 1962.

4 When the above mentioned equations show that allowable shear in concrete is zero, radial horizontal shear ties will be provided to resist all the calculated shear.

5.1.4.7 Yield Capacity Reduction Factors

The yield capacity of all load carrying structural elements will be reduced by a yield capacity reduction factor (0) as given below. The justification for these numerical values is given in Appendix 5-E. This factor will provide for "the possibility that small adverse variations in material strengths, workmanship, dimensions, control, and degree of supervision while individually within required tolerance and the limits of good practice, occasionally may combine to result in undercapacity" (refer to footnote on page 66 of ACI 318-63 Code).

Yield Capacity Reduction Factors:

Ø = 0.90 for concrete in flexure

Ø = 0.85 for tension shear bond and anchorage in concrete

Ø = 0.75 for spirally reinforced concrete compression members

Ø = 0.70 for tied compression members

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ϕ = 0.90 for fabricated structural steel

ϕ = 0.90 for reinforcing steel in direct tension

ϕ = 0.90 for welded or mechanical splices of reinforcing steel 4

ϕ = 0.85 for lap splices of reinforcing steel

ϕ = 0.95 for prestressed tendons in direct tension

5.1.4.8 Prestress Losses

In accordance with the ACI Code 318-63, the design will provide for prestress losses caused by the following effects:

a. Seating of anchorage

b. Elastic shortening of concrete

c. Creep of concrete

d. Shrinkage of concrete

e. Relaxation of prestressing steel stress 4

f. Frictional loss due to intended or unintended curvature in the tendons.

All of the above losses can be predicted with a reasonable degree of accuracy.

The environment of the prestress system and concrete is not appreciably different, in this case, from that found in numerous bridge and building applications. Considerable research has been done to evaluate the above items and is available to designers in assigning the allowances. Building code authorities consider it acceptable practice to develop permanent designs based on these allowances.

5.1.4.9 Liner Plate Criteria

The design criteria which will be applied to the containment liner to meet the specified leak rate under accident conditions are as follows:

a. That the liner be protected against damage by missiles. (See 5.1.4.10)

b. That the liner plate strains be limited to allowable values that have been shown to result in leak tight vessels or pressure piping.

c. That the liner plate be prevented from developing significant distortion.

d. That all discontinuities and openings be well anchored to accommodate the forces exerted by the restrained liner plate, and that careful attention be paid to details of corners and connections to minimize the effects of discontinuities.

Pressure vessels, pressure piping, high pressure hydraulic tubing, and similar containers are made by cold forming, drawing, and dishing operations where strains may approach the elongation capacity of the material. (For mild steel at failure, this elongation varies 15 percent to 30 percent.) These forming operations result in high strains both in tension and compression. Vessels and piping components manufactured by these methods have a history of high leak tight integrity proving that subjecting the steel material to high strain does not affect its leak tight integrity.

The best basis for establishing allowable liner plate strains is considered to be that portion of the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Vessels, Article 4. Specifically, the following sections have been adopted as guides in establishing allowable strain limits:

a.	Para. N-412 (m)	Thermal Stress (2)
b.	Para. N-414.5	Peak Stress Intensity Table N-413 Fig. N-414, N-415 (A)
c.	Para. N-412 (n)	
d.	Para. N-415.1	

Implementation of the ASME design criteria requires that the liner material be prevented from experiencing significant distortion due to the thermal load and that the stresses be considered from a fatigue standpoint. (Para. N-412 (m) (2).)

The following fatigue loads will be considered in the design of the liner plate.

a. Thermal cycling due to annual outdoor temperature variations. Daily temperature variations will not penetrate a significant distance into the concrete shell to appreciably change the average temperature of the shell relative to the liner plate. The number of cycles for this loading will be 40 cycles for the plant life of 40 years.

b. Thermal cycling due to containment interior temperature varying during the startup and shutdown of the reactor system. The number of cycles for this loading will be assumed to be 500 cycles.

c. Thermal cycling due to the MCA will be assumed to be one cycle. Thermal load cycles in the piping systems are somewhat isolated from the liner plate penetrations by the concentric sleeves between the pipe and the liner plate. The attachment sleeve will be designed in accordance with ASME Section III fatigue considerations. All penetrations will be reviewed for a conservative number of cycles to be expected during the plant life.

The thermal stresses in the liner plate fall into the categories considered in Article 4, Section III, Nuclear Vessels of the ASME Boiler and Pressure Vessel Code. The allowable stress in Figure N-415 (A) are for alternating stress intensity for carbon steels and temperatures not exceeding 700 F. In addition, the ASME Code further requires that significant distortion of the material be prevented.

In accordance with ASME Code Paragraph 412 (M) 2, the liner plate is retrained against significant distortion by continuous angle anchors and never exceeds the temperature limitation of 700 F and also satisfies the criteria for limiting strains on the basis of fatigue consideration.

Paragraph 412 (N) Figure N-415 (A) of the ASME Code has been developed as a result of research, industry experience, and the proven performance of code vessels. Because of the conservative factors it contains on both stress intensity and stress cycles, and its being a part of a recognized design code, Figure N-415 (A) and its appropriate limitations have been used as a basis for establishing allowable liner plate strains. Since the graph in Figure N-415 (A) does not extend below 10 cycles, 10 cycles is being used for an MCA instead of one cycle.

Establishing an allowable strain based on the one significant thermal cycle of the accident condition would permit an allowable strain (from (N-415A) of approximately 2 percent. The strain in the liner plate at yield will be approximately 0.1 percent. The liner plate will be allowed to go beyond yield strains during the accident condition. Maximum allowable tensile or compressive strain has been conservatively set at 0.5 percent (compared to 2 percent shown above). The maximum predicted strain in the liner plate during accident conditions has been found to be 0.25 percent compression.

At the design accident pressure condition, there will be no tensile stress anywhere in the liner plate membrane. This is true both at the time of initial pressure release and under any later pressure temperature condition. The purpose of specifying an NDT temperature requirement is to provide protection against a brittle fracture or cleavage mode of failure. However, this type of failure is precluded by the absence of tensile stresses.

No allowable compressive strain value has been set for the test condition because the value will be less than that experienced under the accident conditions. The maximum predicted compressive strain will be approximately 0.07 percent.

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The maximum allowable tensile strain will be 0.2 percent under test conditions. The predicted value will be very nearly zero.

The stability of the liner plate will be ensured by the stiffening and anchoring of the plate to the prestressed concrete structure.

3 (Deleted)

The maximum compressive strains are caused by accident pressure, thermal loading, prestress, shrinkage and creep. The maximum strains will not exceed .0025 in./in. and the liner plate will always remain in a stable condition.

The conservative design approach of the stiffening system used in the liner plate to prevent significant distortions at accident conditions, and stringent welding and weld inspection requirements will ensure that the leak tightness of the liner plate at accident conditions will not change from that at the test conditions.

In isolated areas the liner plate may have initial inward curvature due to construction. The anchors will be designed to resist the forces and moments induced when a section of the liner plate between anchors has initial inward curvature.

The anchor and welds will be subjected to a shear force (N_2-N_1), force V and moment M. The axial force N_1 is smaller than N_2 since the liner plate will deform inward and the axial load will relax. Calculations have indicated that the relaxation is approximately 10 percent. The values of N_1, M, and V will be obtained by use of a computer program and the finite difference method of plate theory.

The liner plate will be anchored at all discontinuities to eliminate excessive strains at the discontinuities. The forces in the liner plate at the discontinuities will be evaluated by use of the finite element computer program and the anchors will be designed to resist these forces.

At all penetrations the liner plate will be thickened to reduce stress concentrations in accordance with the ASME Boiler and Pressure Vessel Code 1965, Section III, Nuclear Vessels. The thickened portion of the liner plate will then be anchored to the concrete by use of anchor studs completely around the penetrations. For details of the penetrations see Figure 5.1-2. The sleeves, pipe cap, and all welds associated with the penetrations will be designed to resist all loads previously mentioned and also the prestress forces and internal design pressure.

The crane is to be supported by steel anchors, as shown in Figure 5.1-1, embedded into the concrete containment structure walls. The liner plate will be thickened at the location to reduce stress concentrations.

5.1.4.10 Missile Protection Criteria

High pressure reactor coolant system equipment which could be the source of missiles is suitably screened either by the concrete shield wall enclosing the reactor coolant loops, by the concrete operating floor or by special missile shields to block any passage of missiles to the containment walls. Potential missile sources are oriented so that the missile will be intercepted by the shields and structures provided. A structure is provided over the control rod drive mechanism to block any missiles generated from fracture of the mechanisms.

Missile protection will be provided to comply with the following criteria.

a. The containment and liner will be protected from loss of function due to damage by such missiles as might be generated in a loss-of-coolant accident for break sizes up to and including the double-ended severance of a main coolant pipe.

b. The engineered safeguards systems and components required to maintain containment integrity will be protected against loss of function due to damage by the missiles defined below.

During the detailed plant design, the missile protection necessary to meet the above criteria will be developed and implemented using the following methods:

a. Components of the reactor coolant system will be examined to identify and to classify missiles according to size, shape and kinetic energy for purposes of analyzing their effects.

b. Missile velocities will be calculated considering both fluid and mechanical driving forces which can act during missile generation.

c. The reactor coolant system will be surrounded by reinforced concrete and steel structures designed to withstand the forces associated with double-ended rupture of a main coolant pipe and designed to stop the missiles.

d. The structural design of the missile shielding will take into account both static and impact loads and will be based upon the state of the art of missile penetration data.

The types of missiles for which missile protection will be provided are:

a. Valve stems

b. Valve bonnets

c. Instrument thimbles

[redacted]

d. Various types and sizes of nuts and bolts

e. Complete control rod drive mechanisms, or parts thereof

f. Large pieces of pipe, up to 10 inches in diameter

g. Reactor coolant pump flywheel

Protection is not provided for certain types of missiles for which postulated accidents are considered incredible because of the material characteristics, inspections, quality control during fabrication, and conservative design as applied to the particular component. Included in this category are missiles caused by massive, rapid failure of the reactor vessel, steam generator, pressurizer and main coolant pump casings.

5.1.4.11 Main Steam Turbine Missiles

The turbine-generator supplier* has made a study of potential missiles resulting from the failure of turbine-generator rotating elements operating at design (115% of normal operating) speed or, due to failure of components that control admission of steam to the turbine, operating at excessive overspeed. Historical reliability plus continued improvements in design indicate that excessive overspeed is the only envisaged cause of turbine-generator failure. An overspeed condition is very unlikely because of the redundancy and reliability of the turbine control and protection system and of the steam system. Nevertheless, the consequences of a turbine-generator runaway caused by all the steam admission valves stuck fully open upon a full load rejection have been analyzed.

On the low pressure turbine, an analysis was made of the bursting speed of each disc based upon an ultimate tensile strength 20 percent greater than the minimum guaranteed tensile strength. Each alloy steel disc is accurately machined and shrunk on to an alloy steel rotor. After shrinking on all the discs, the blading is installed, and the finished assembly is balanced to close tolerances. The completed rotor is tested at operating temperature and overspeed. Based upon experience and tests, it is concluded that the mode of failure of a disc, should it occur, is a rupture in two or four parts. The maximum speed at which the unit might run with no disc failure is 175 percent of nominal speed. At this speed the first discs will rupture. Immediately following the rupture of the first discs, the steam flow between the blades of the remaining discs would be significantly reduced, the turbine-generator would slow down, and further disc failures would not be anticipated. A disc rupture in the low pressure turbine would result in a missile which would strike and deeply deform the inner cylinder 1 causing some deformation of the inner cylinder 2 and of the outer cylinder but will be contained within the unit. Therefore, no outside missile is anticipated to be generated from the low pressure turbine.

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*Westinghouse Electric Corporation

[redacted]

On the high pressure turbine the maximum theoretical speed at which the unit may run, based on the admission steam thermodynamic properties and blade geometry, is 205 percent of normal speed. As shown here before, the maximum speed at which the unit may run, based upon the stress analysis of the low pressure unit, is 175 percent of nominal speed. The minimum bursting speed of the spindle, based on the minimum guaranteed mechanical properties of the spindle material, is 270 percent of nominal speed. Therefore, it is concluded that no missiles should be generated by the high pressure turbine due to a unit runaway.

A more complete description of the results of the analysis of potential turbine missiles is contained in a report titled Consideration of the Consequences of a Turbine Generator Failure in Which Missiles are Generated, included as Appendix 5-D.

5.1.5 STRUCTURAL DESIGN ANALYSIS

The containment structure will be analyzed by a finite element computer program for individual loading cases of dead load, live load, temperature, and pressure as described in 5.1.4.1.

The ACI-318-63 code design methods and allowable stresses will be used for concrete and prestressed and non-prestressed reinforcing steel except as noted herein.

5.1.5.1. Critical Design Areas

Based on a recent design study of prestressed concrete containment structures, it has been substantiated that the main areas for design analysis are:

a. The restraints at the top and bottom of the cylinder

b. The restraints at the edge of the spherical sector dome

c. The stresses around the large penetrations

d. The behavior of the base slab relative to an elastic foundation

e. The stresses due to transient temperature gradients in the liner plate and concrete

f. Stresses within the ring girder

g. Penetrations and concentrated loads

h. Seismic or wind loads

[redacted]

[redacted]

5.1.5.2 Analytical Techniques

The containment structure analysis will be performed by the finite element method developed by E. L. Wilson, under sponsorship of National Science Foundation Research Grant G18986. This program has been further developed to apply to axisymmetric structures. Such a method of analysis is normally used only for thick-walled structures where conventional shell analysis yields inaccurate results. Good correlation has been demonstrated between the finite element analysis method and the test results for thick wall model vessels.

The design analysis for items a - f is done using the finite computer program because all of the conditions are axisymmetric. Items g and h are non-axisymmetric and are handled by techniques described in 5.1.5.5, 5.1.5.6 and 5.1.5.7. Effect of the non-axisymmetric loads will be combined with those obtained from the finite element technique.

The finite element technique is a general method of structural analysis in which the continuous structure is replaced by a system of elements (members) connected at a finite number of nodal points (joints). Conventional analysis of frames and trusses can be considered to be examples of the finite element method.

In the application of the method to an axisymmetric solid (e.g.,) a concrete containment structure, the continuous structure is replaced by a system of rings of triangular cross-section which are interconnected along circumferential joints. Based on energy principles, work equilibrium equations are formed in which the radial and axial displacements at the circumferential joints are unknowns of the system. A solution of this set of equations is inherent in the solution of the finite element system.

The finite element grid of the structure base slab will be extended down into the foundation material to take into consideration the elastic nature of the foundation material and its effect upon the behavior of the base slab.

The use of a finite element analysis will permit an accurate determination of the stress pattern at any location on the structure. The analysis method has been demonstrated on the following types of structures:

a. Arch dams (including a portion of the foundation)

b. Thick-walled prestressed concrete vessels

c. Spacecraft heat shields

d. Rocket nozzles

The computer program used in the analysis will handle the following inputs:

a. Seven different materials

b. Non-linear stress-strain curves for each material [redacted]

c. Any shape transient temperature curves

d. Any shape axisymmetric loading

The program outputs will be:

a. The direct stress and shear stress for each element

b. The principal stresses and their directions for each element

c. The deflections for each nodal point

An auxiliary computer program will plot stress curves based on the above analysis program outputs.

Additional information regarding this technique, the computer program employed, and a comparison of the results with other analytical methods is contained in Appendix 5-G.

5.1.5.3 Thermal Loads

The thermal loads are a result of the temperature differential within the structure. The design temperature gradients for this structure are shown on Figure 5.1-4. The finite element analysis was prepared so that when temperatures are given at every nodal point, stresses are calculated at the center of each element. This way the liner plate was handled as an integral part of the structure, having different material properties, and not as a mechanism which would act as an outside source to produce loading on the concrete portion of the structure.

The liner plate is designed to have plastic deformation as a result of prestressing and high thermal stresses.

The finite element method includes this analysis too, by successive approximations, changing the modulus of elasticity of those elements which are subject to stresses higher than the proportional limit.

The output of the computer analysis shows the effect of the thermal loads on liner plate and concrete. The liner plate and the inside of the concrete are subject to compressive stress and the outside of the concrete section is subject to tension. These tension stresses balance the compressive stresses so that, except close to any discontinuity, there is no resultant membrane force. That is, all the compressive forces in the liner plate are carried by the prestressed concrete and reinforcement near the outside surface of the structure.

The compressive stresses in the liner plate exceed the proportional limit in the case of the design basis accident. An increased temperature would keep the liner plate in plastic condition, but only a negligible additional stress could develop, and thermal stresses would stay unchanged.

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5.1.5.4 Tendon Failure Analysis

There will be approximately 180 vertical tendons and 600 hoop tendons. The hoop tendons will be placed in three 120° sections around the cylinder using six buttresses as anchorages. Therefore, failure of a hoop tendon or a series of adjoining tendons or spaced hoop tendons is limited between 120° segments of the containment vessel.

It is well known that all prestressed tendons are subject to the most critical stress during initial tensioning. There will be a loss of prestress on the order of 15 percent due to elastic and plastic losses, which will reduce the stress level. Even at the factored yield loads, the stress in the tendons will not be as high as during initial tensioning. Each of the tendons has been pre-tested at the time of initial jacking and the stress in the tendons under accident loading is only 80 percent of this jacking stress. This means that the possibility of tendon failure under design accident loading is quite remote.

Although it is felt that there is ample reserve capacity in the tendon and structure, the complex nature of the structural behavior makes it difficult to predict the effect of a hypothetical series of tendon failures until the final design is complete.

It is estimated that if two or three of the tendons fail during accident conditions, and if they are side by side or close together, it will not affect the integrity of the structure or the liner because the thick concrete walls will be sufficient to transmit the force from the adjoining tendons without resulting in any serious local stresses.

5.1.5.5 Stresses Near Equipment Openings

Analytical solutions for the determination of state of stress in the vicinity of equipment openings are obtained from reference to the following articles.

a. "State of Stress in a Circular Cylindrical Shell with a Circular Hole," by A. C. Eringen, A. K. Naghdi, and C. C. Thiel - Welding Research Council Bulletin No. 102, January, 1965.

b. Samuel Levy, A. E. McPherson and F. C. Smith, "Reinforcement of a Small Circular Hole in a Plane Sheet Under Tension," Journal of Applied Mechanics, June, 1948.

The analysis of the containment structure as a whole is first carried out without considering the openings in it. This analysis has been done by using the finite element program.

The containment structure with the opening in it is then analyzed in the following steps.

a. Formulation of differential equations for the shell in complex variable form with the center of the hole as the origin (See reference a above)

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b. Solution of the differential equations (See reference a above)

c. Evaluation of parameters in the solution (See reference a above)

d. Formulation of the boundary conditions based on the stresses obtained from the vessel analysis above without the hole

e. Calculation of membrane forces, moments, and shears around and at the edge of the opening

f. The wall thickness around the opening will then be increased and reinforced to carry the higher forces, moment, and shears. The affect of the thickening on the stress concentration factors will be considered using reference b above.

g. Evaluation of some of the effects of prestressing that are not handled in reference a above

h. Finally, the design will be checked to ensure that the strength of the reinforcement provided replaces the strength removed by the opening. This check is to maintain a good degree of compatibility between the general vessel shell and the area around the opening.

Details of the reinforcing and deflected strand pattern around the equipment hatch opening are shown on Figure 5.1-3.

The pattern of membrane stresses at design accident loading is not expected to be significantly different from the pattern of membrane stresses during the proof test, since the membrane stresses due to pressure are far more significant than those due to dead load or seismic load.

The deflection of the tendons does not significantly affect the stress concentrations. This is a plane stress analysis, and did not include the effect of the curvature of the shell; however, it gives an assurance of the correctness of the assumed membrane stress pattern caused by the prestressing around the opening.

The seismic load creates vertical membrane stress in the structure based on a cantilevered circular beam subjected to base accelerations. The membrane stresses at the opening are modified by appropriate stress concentration factors.

The temperature variation through the concrete wall creates a stress condition like one caused by a moment, constant in all directions on the continuous cylindrical or spherical surface. However, at any discontinuity, such as an opening, stress concentrations occur.

[redacted]

[redacted]

Using the center of the opening as the reference point to relate the directions of moments, the radial moment is zero at the edge of the opening, there being no resistance against radial rotation. The hoop moment is highly increased, the outside fiber being forced to take the shape of a larger circle, while the inside fiber takes the shape of a smaller circle.

Away from the edge of the opening both moments gradually reach the constant value on the undisturbed portion of the cylinder.

In the case of 1.0P (prestress fully neutralized) + 1.0T (accident temperature) the cracked concrete with highly strained tension reinforcement constitutes a shell with stiffness decreased but still constant in all directions. In order to control the increased hoop moment around the opening, the hoop reinforcement should produce strength about twice that of the radial one.

In the case of accident temperature combined with low internal pressure, very small or no tension develops on the outside, so the thermal strains will be built up without the relieving effect of the cracks. However, as has already been stated elsewhere, the liner plate will reach its yield stress, and so will the concrete at the inside corner of the penetration, thereby relieving once again the very high stresses, but still carrying the high moment in the state of redistributed stresses.

For the analysis of the thermal stresses around the opening the same method was used as for the other loadings.

At the edge of the opening a uniformly distributed moment equal but opposite to the moment existing on the rest of the shell was applied, and evaluated using the methods of the preceding reference and the effects were superimposed on the stresses calculated by the computer using the finite element method for axisymmetric solids.

5.1.5.6 Seismic Analysis

The loads on the containment structure caused by earthquake will be determined as a result of a dynamic analysis of the structure. The dynamic analysis will be made on an idealized structure of lumped masses and weightless elastic columns acting as spring restraints. The analysis will be performed in two stages; the determination of the natural frequencies of the structure and its mode shapes, and the modal response of these modes to the earthquake by the spectrum response method. Appendix 5-A contains more details on the seismic design basis for this plant.

The natural frequencies and mode shapes are computed from the equations of motion of the lumped masses established in a stiffness of displacement method and are solved by iteration techniques by a fully tested digital computer program. The form of the equations is:

$$(K) \quad (\Delta) \quad = \quad \omega^2 \quad (M) \quad (\Delta)$$

(K) = Matrix of stiffness coefficients including the combined effects of shear and flexure

(M) = Matrix of concentrated masses

(Δ) = Matrix of mode shape

ω = Angular frequency of vibration

The results of this computation are the several values of ω_n and mode shapes $(\Delta)_n$ for n = 1, 2, 3 --- m where m is the number of degrees of freedom (i.e., lumped masses) assumed in the idealized structure.

The response of each mode of vibration to the design earthquake is then computed by the response spectrum technique, as follows:

a. The base shear contribution of the nth mode

$$V_n = W_n \; S_{an} \; (W_n \gamma)$$

Where:

W_n = Effective weight of the structure in the nth mode computed from:

$$Wn = \frac{(\Sigma_x \; \Delta_{xn} \;\; W_x)^2}{\Sigma_x \; (\Delta_{xn})^2 \; W_x}$$ where the

subscript x refers to levels throughout the height of the structure.

ω_n = Angular frequency of the nth mode

$S_{an} \; (\omega_n, \gamma)$ = Spectral acceleration of a single degree of freedom system with a damping coefficient of γ, obtained from the response spectrum.

b. The horizontal load distribution for the nth mode is then computed as:

$$F_x = V_n \left(\frac{\Delta_{xn} \; W_x}{\Sigma_x \, \Delta_{xn} \;\; W_x} \right)$$

The several mode contributions are then combined to give the final response of the structure to the design earthquake.

c. Additional Considerations:

The number of modes to be considered in the analysis will be determined at the time of final design to adequately represent the structure being analyzed. Since the spectral response technique yields the maximum value of response for each mode, and these maxima do not occur at the same time, the response of the modes of vibration will be combined on a root-mean-square basis to obtain the most probable value of maximum response.

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The mathemetical model to be used in the earthquake analysis of the containment structure will be established with due consideration given to the rotational and translational stiffness of the surrounding soil.

The following values of damping and ground acceleration will be used in the analysis together with the natural periods to obtain spectral accelerations:

3

Type of Motion	Design Earthquake % Damping	Maximum Hypothetical Earthquake % Damping
Structural	2%	5%
Translation	30%	30%
Rocking	5%	9%

5.1.5.7 Wind Analysis

The loads caused by the incident design wind on the containment structure are a function of the kinetic energy per unit volume of the moving air mass. The product of one-half of the air density and the square of the resultant design velocity results in the dynamic pressure of the design wind.

The dynamic pressure (PSF) for standard air at 0.07651 pcf corresponding to 15°C at 760 mm of mercury in terms of the velocity at the appropriate height zone is given by:

$$q = 0.002558\ V^2$$

Similarly, the design pressure to be mutliplied by the projected elevation
1 area to obtain the total force on the structure includes the effect of the
shape coefficient (C_d) and is given by:

$$p = q \times C_d = 0.002558 V^2 C_d$$

The shape coefficient includes the effect of drag, lift, shape, aspect ratio, and surface smoothness. The containment structure has an aspect ratio (h/d) of 1.48 and surface smoothness (t/d) of 1.57 percent. The shape coefficient is found to be:

$$C_d = 0.70$$

Where

h = Containment height above ground
t = Projection of buttresses
d = Maximum outside diameter of the containment structure

[redacted]

The final design pressure including the variation of design wind velocity with height are as follows:

Height Above Ground (H)	Fastest Wind (V)	Design Pressure ($p = 0.002558V^2C_d$)
0-50 ft.	90 MPH	14.5 PSF
50-150 ft.	105 MPH	19.8 PSF
150-400 ft.	125 MPH	28.0 PSF

The variation of design pressure in the horizontal direction follows the ASCE recommendations of Table 4(f). Maximum positive and negative pressures in terms of the incident pressure at the appropriate height level are 1.0 p and -1.7 p respectively.

A gust factor of 1.1 will be taken in accordance with the report recommendations.

The final wind pressures will be applied to the structure as equivalent static loads.

[redacted]

[redacted]

TABLE 5.1-1

CONCRETE PROTECTION FOR REINFORCEMENT AND PRESTRESSING TENDONS

LOCATION	TYPE OF STEEL	COVERAGE TO BE USED	ACI 318-63	
			INTERIOR	EXTERIOR
Dome	Reinforcing	18 & 14S 2-1/4 IN. Others 2-1/4 IN.	2-1/4 & 1-3/4 IN. 1-1/2 IN.	2-1/4 & 2 IN. 2 IN.
	Prestressing	6 IN.	1-1/2 IN.	2 IN.
Cylinder	Reinforcing	18 & 14S 2-1/4 IN. Others 2-1/4 IN.	2-1/4 & 1-3/4 IN. 1-1/2 IN.	2-1/4 & 2 IN. 2 IN.
	Prestressing	6 IN.	1-1/2 IN.	2 IN.
Base Mat	Bottom Reinforcing & Unformed Surfaces	18 & 14S 3 IN. Others 3 IN.		3 IN. 3 IN.
	Top Reinforcing	18 & 14S-2-1/4 IN. Others -2-1/4 IN.	2-1/4 & 1/3-4 IN. 1-1/2 IN.	2-1/4 & 2 IN. 2 IN.

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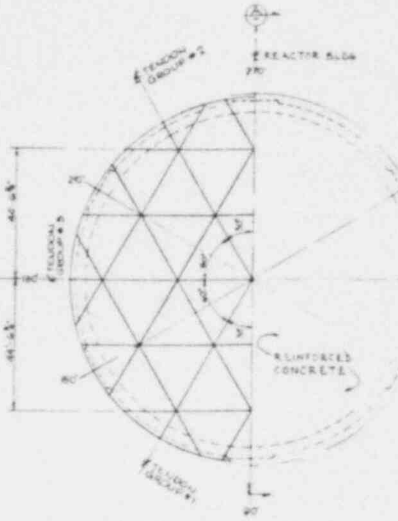
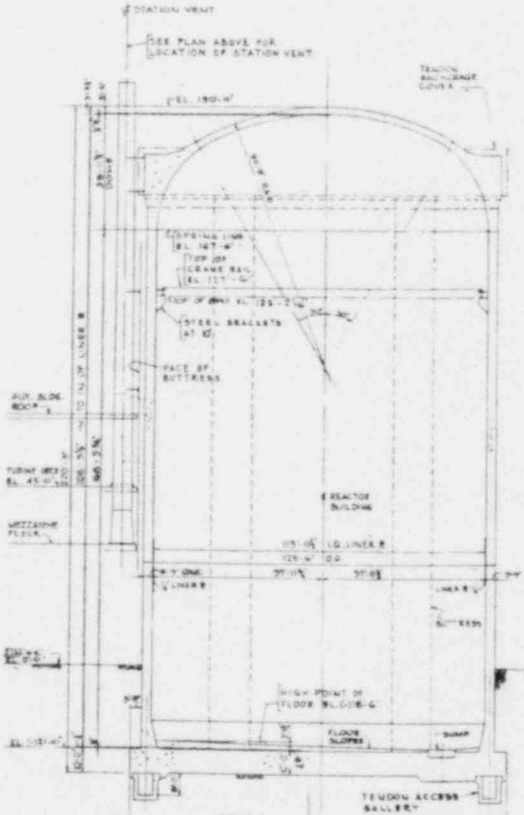


ROOF PLAN FLOOR PLAN



SEC. (A)

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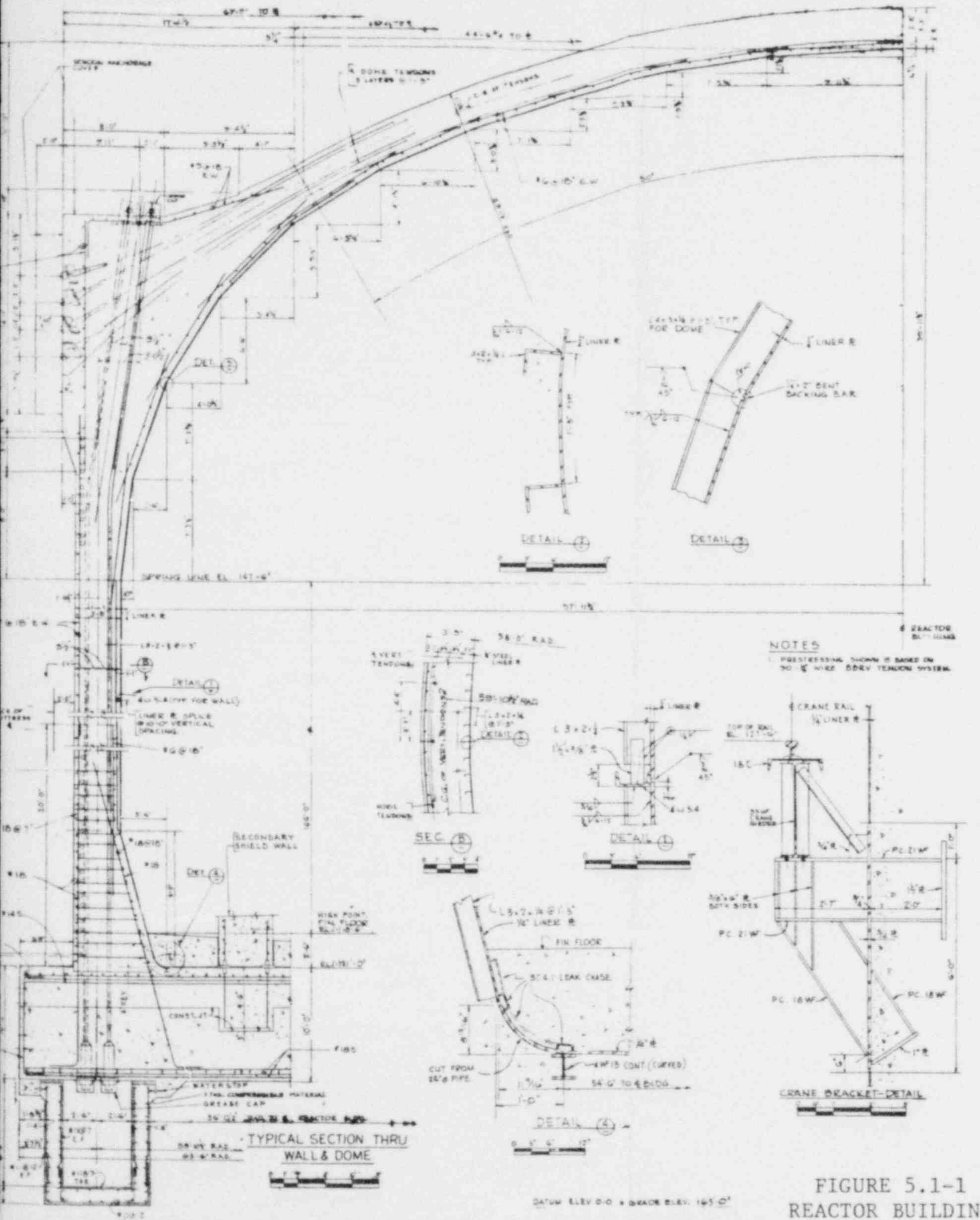

FIGURE 5.1-1
REACTOR BUILDING
TYPICAL DETAILS

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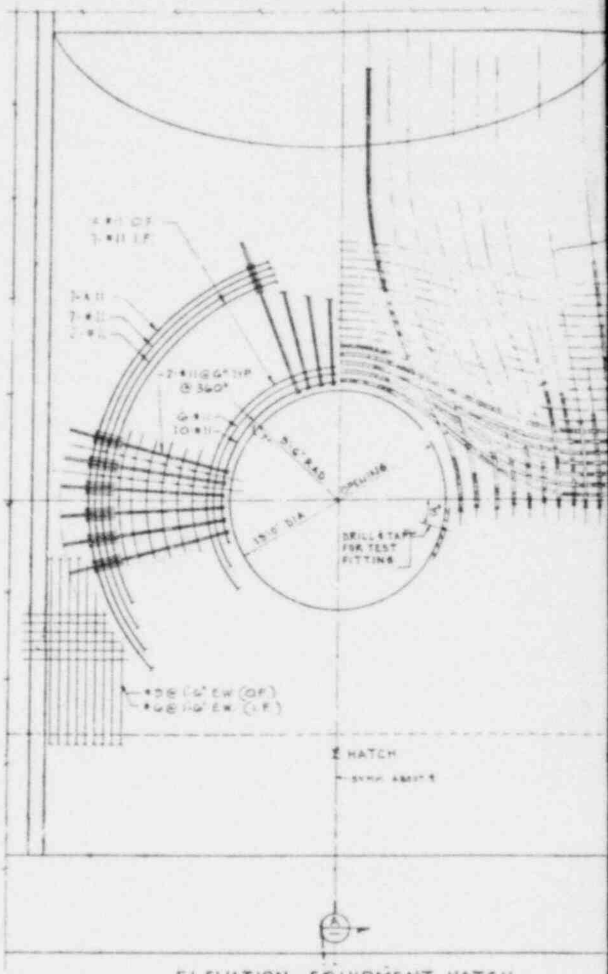
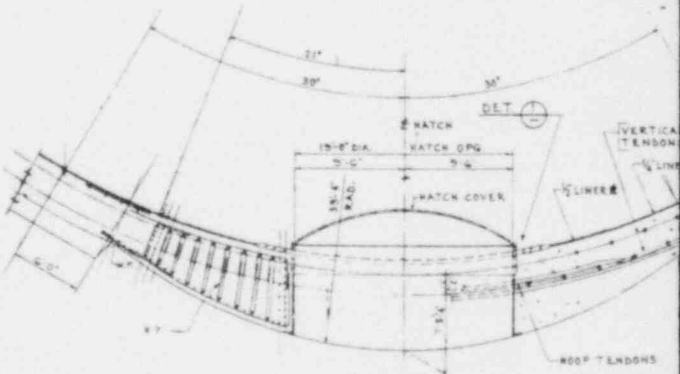
Amendment 3



ELEVATION - EQUIPMENT HATCH

4 2 0 4 8 12



SEC. B

4 2 0 4 8 12

[redacted]

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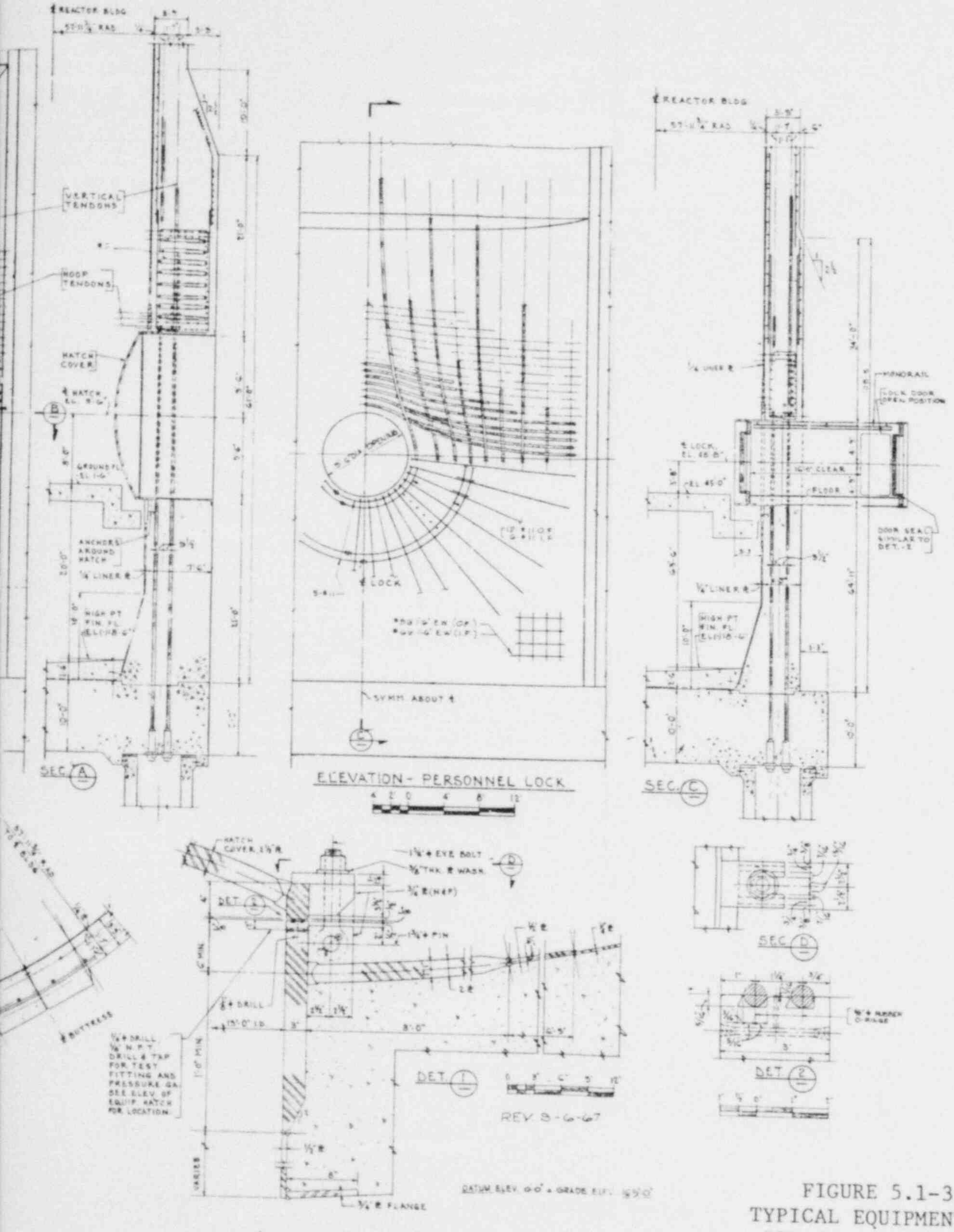

FIGURE 5.1-3
TYPICAL EQUIPMENT AND
PERSONNEL OPENINGS

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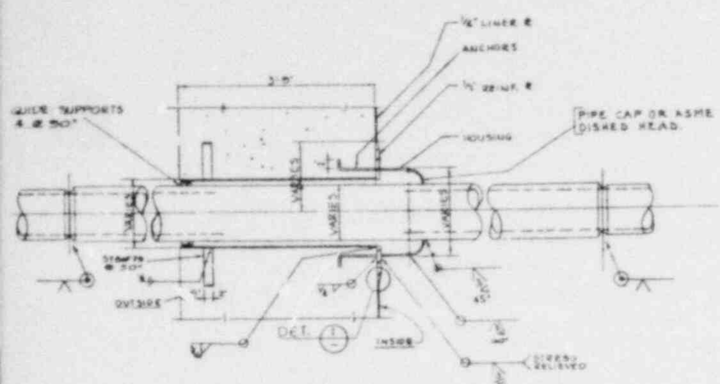
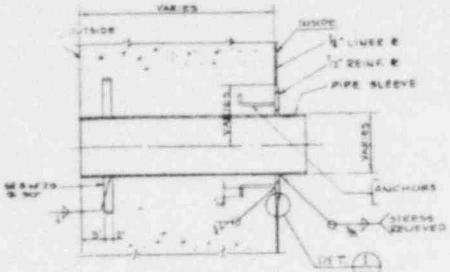
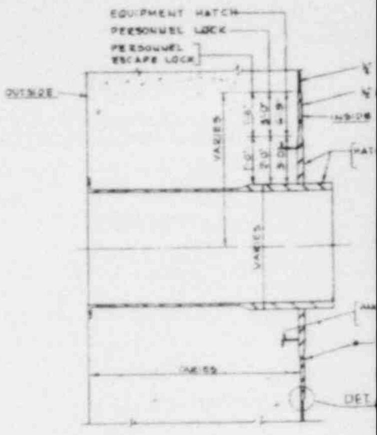


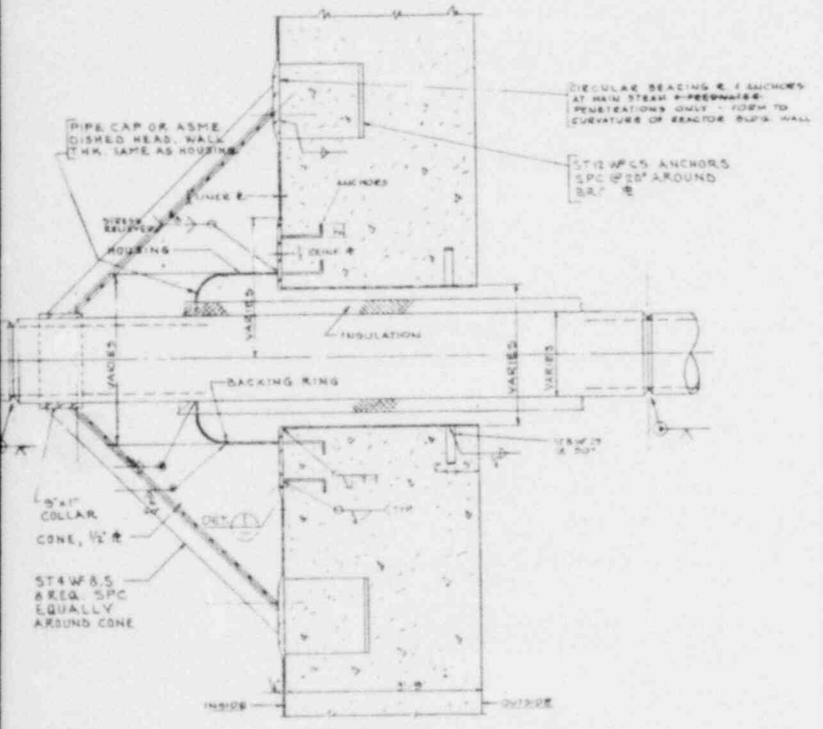
TYPE - I
TYP. COLD PIPE PENETRATION
LESS THAN 150° F.
NO SCALE



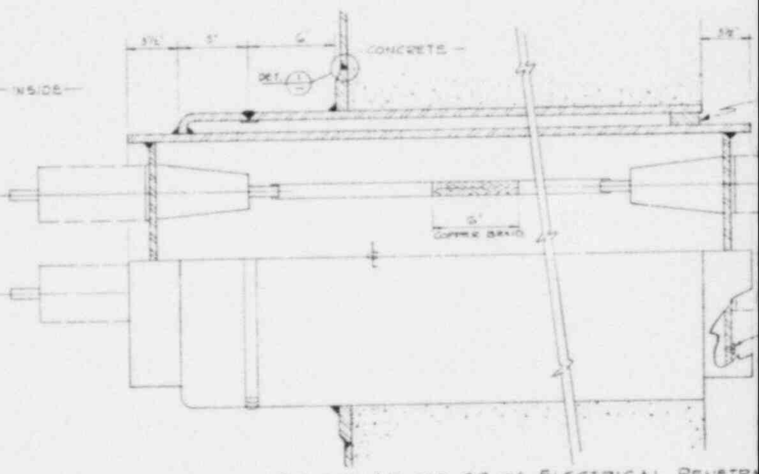
TYPE - III
TYP. ELECTRICAL PENETRATION
NO SCALE



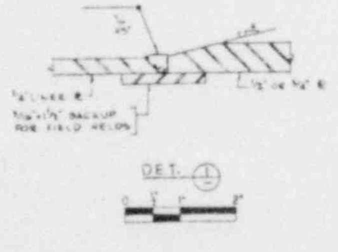
TYPE - IV
HATCH PENETRATION
NO SCALE



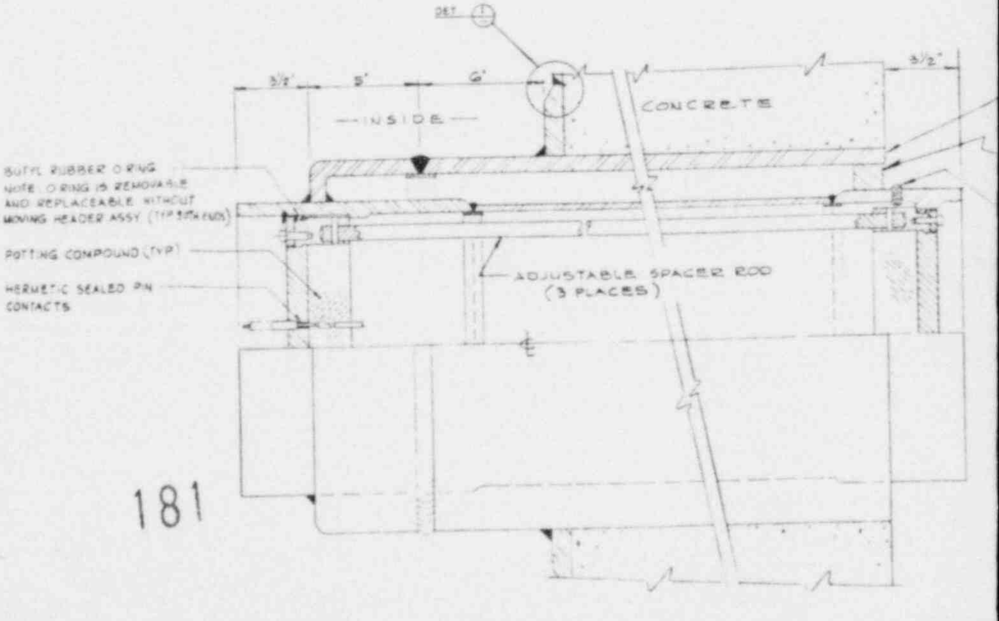
TYPE - II
TYP. HOT PIPE PENETRATION
GREATER THAN 150° F.
NO SCALE



TYPICAL 4.16 AND 6.9 KV. ELECTRICAL PENETRA
NOT TO SCALE



DET. 1



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[redacted] TYPICAL LOW VOLTAGE POWER, CONTROL & INSTRUMENTATION PENETRATION
NO SCALE

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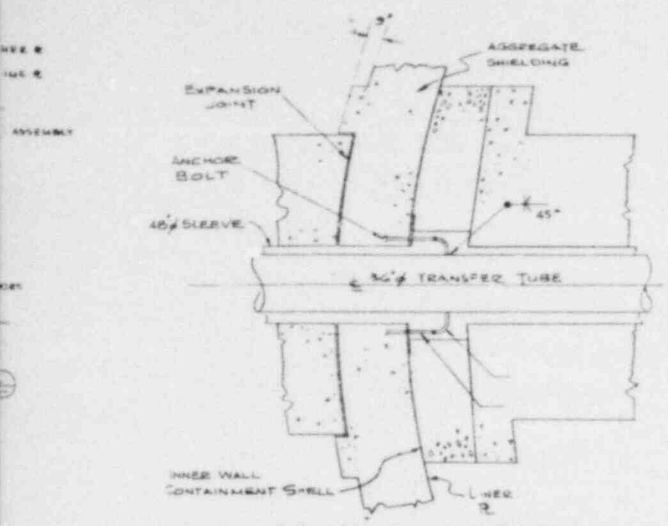
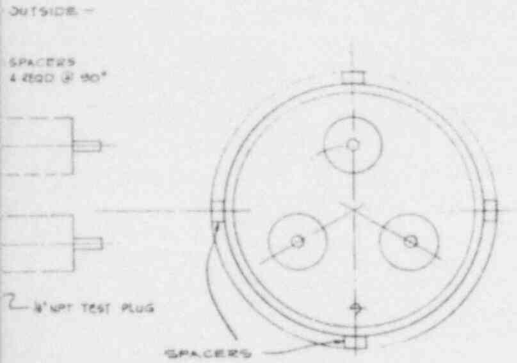


FUEL TRANSFER TUBE PENETRATION



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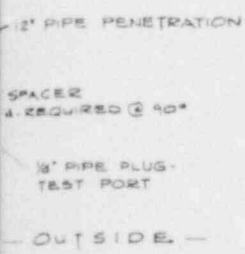

FIGURE 5.1-2
TYPICAL ELECTRICAL AND
PIPING PENETRATIONS

SMUD
SACRAMENTO MUNICIPAL UTILITY DISTRICT

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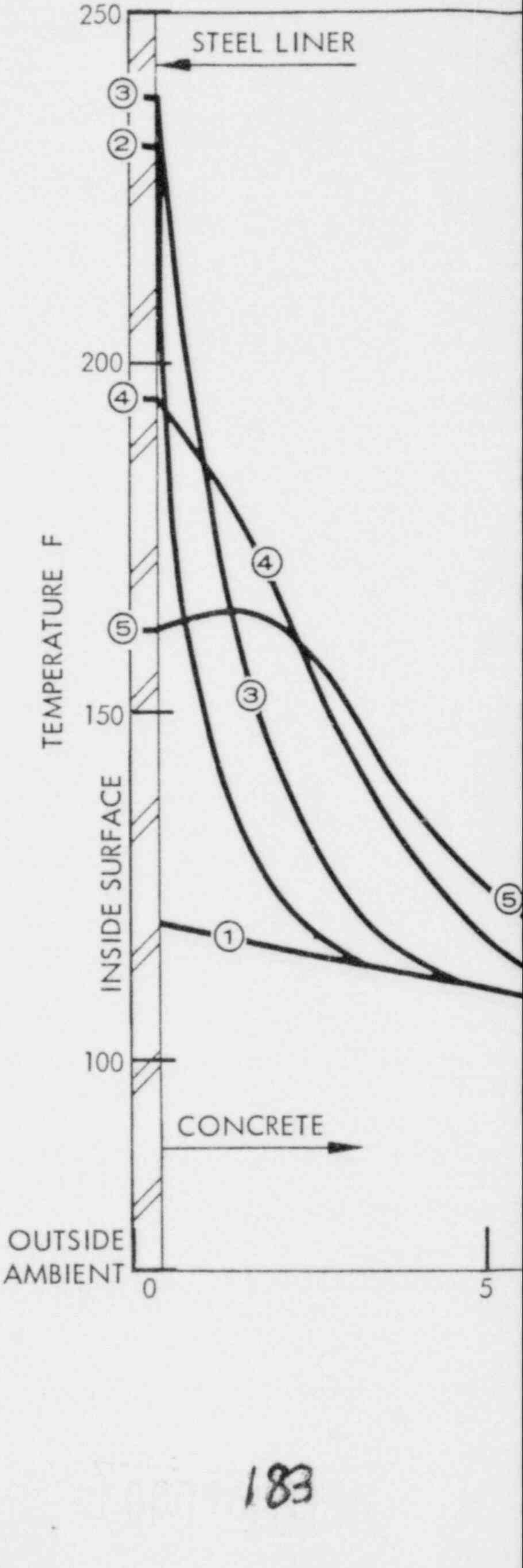

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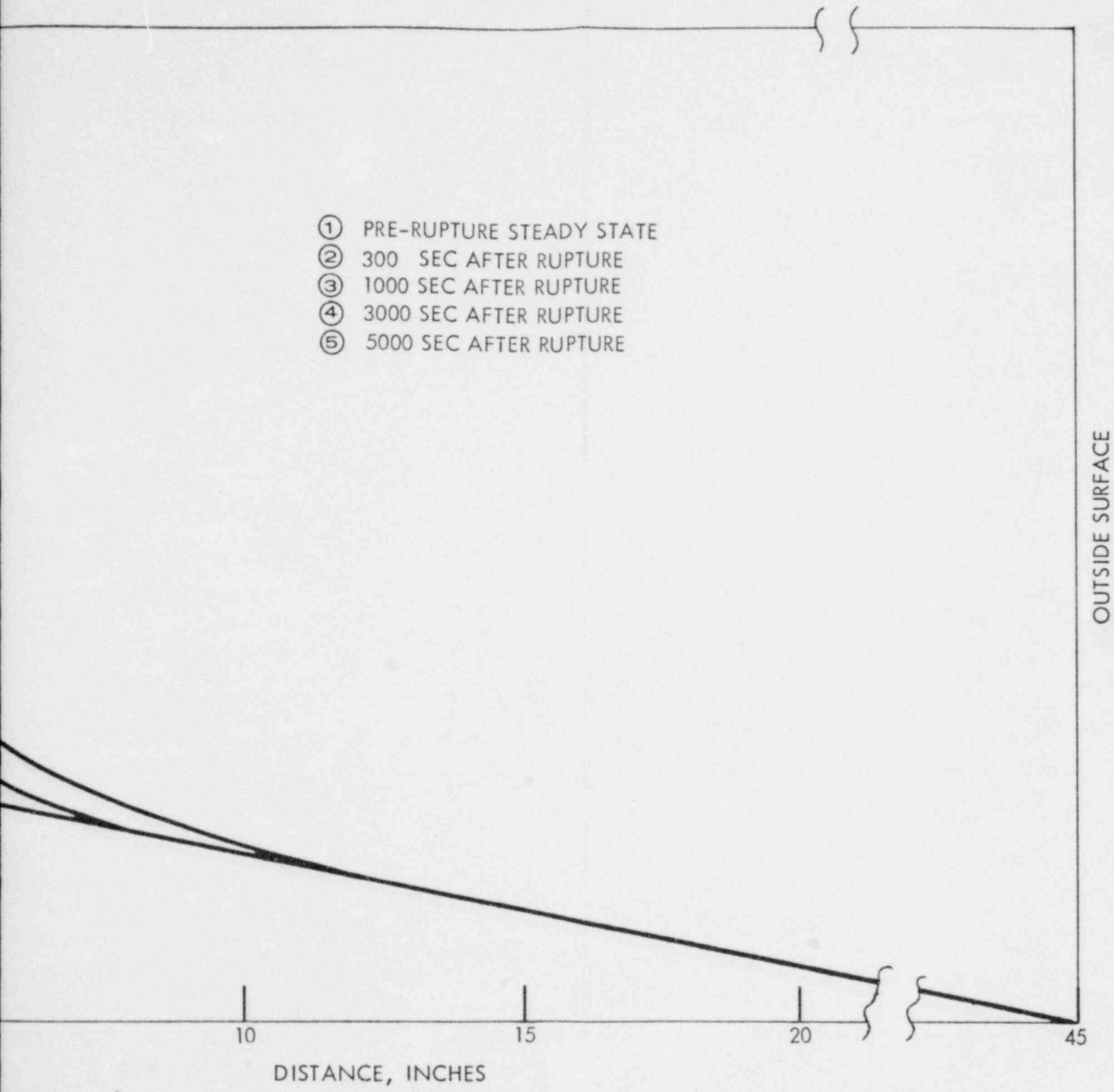

FIGURE 5.1-4
THERMAL GRADIENT ACROSS
CONTAINMENT WALL

5.2 DESIGN, CONSTRUCTION, AND TESTING OF PENETRATIONS

5.2.1 TYPES OF PENETRATIONS

All penetrations will be pressure resistant, leak-tight, welded assemblies designed, fabricated and tested in accordance with the ASME Nuclear Vessel Code, Section III.

5.2.1.1 Electrical Penetrations

Cannister type penetrations are used for all electrical conductors passing through the containment. The penetration cannister is a hollow cylinder closed on both ends with an insulated bushing assembly or a connector assembly. The cannister assembly is secured in place by welding to the containment penetration sleeve (at one end only) thereby leaving an air space between the cannister and sleeve for cooling and testing the weld. Figure 5.1-2 shows typical electrical penetrations. In general there are two types used:

a. Type 1 - High voltage power, 4160 and 6900 volts, 3 phase

b. Type 2 - Low voltage power, control and instrumentation

The high voltage penetrations comprise three phase shop built assemblies, essentially a cannister with 2-sets of leak tight bushings welded in place with provisions for leak testing.

The low voltage power, control and instrumentation penetrations comprise multi-circuit shop built assemblies, essentially a cannister with conductor pins sealed in headers at each end. The assemblies are provided with leak test connections.

5.2.1.2 Piping Penetrations

Single barrier piping penetrations are provided for all piping passing through the containment. The closure of the pipe to the liner plate is accomplished with a pipe reducer welded to the pipe and to the liner plate reinforcement. In the case of piping carrying hot fluid, the pipe will be insulated and cooling may be required to reduce the concrete temperature. Figure 5.1-2 shows typical hot and cold pipe penetrations.

The anchorage of penetration closure connecting pipes to the containment wall will be designed as Class 1 structures to resist all forces and moments caused by a postulated pipe rupture. The design conditions will include the maximum pipe reactions, and pipe rupture forces.

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The following design criteria for typical piping penetrations is used to ensure the integrity of the liner penetration junction at the piping.

a. The penetration assembly consisting of pipe reducer and pipe sleeve section and the assembly welds and welds to the liner plate will be full penetration welds. The assembly is anchored into the wall concrete and designed to accommodate all forces and moments due to pipe rupture and thermal expansion.

b. The design criteria will be that the pipe penetration will be the strongest point in the system when a pipe break is postulated. Pipe stops, increased pipe thickness or other means will be used to attain this. Part of this criteria will also be that the operation of closure valves will not be impaired by any postulated pipe break.

5.2.1.3 Equipment and Personnel Access Hatches

An equipment hatch nineteen feet in diameter is provided as shown on Figure 5.1-3 which is fabricated from welded steel and furnished with a double gasketed flange and bolted dished door. Equipment up to and including the size of the reactor vessel head can be transferred into and out of containment through this hatch. There is also a six foot diameter new fuel loading hatch.

Two personnel locks are provided. One of these is for emergency access only. Each personnel lock is a double door, welded steel assembly. A quick-acting type, equalizing valve connects the personnel lock with the interior and exterior of the containment vessel for the purposes of equalizing pressure in the two systems when entering or leaving the containment.

The two doors in each personnel lock are interlocked to prevent both being opened simultaneously and to ensure that one door is completely closed before the opposite door can be opened. Remote indicating lights and annunciators situated in the control room indicate the door operational status. Provision is made to permit by-passing the door interlocking system to allow doors to be left open during plant cold shutdown. Each door lock hinge is designed to be capable of independent, three-dimensional adjustment to assist proper seating. An emergency lighting and communication system operating from an external emergency supply is provided in the lock interior.

5.2.1.4 Special Penetrations

a. Fuel Transfer Penetration

A fuel transfer penetration is provided for fuel movement between the refueling transfer canal in the reactor containment and the spent fuel storage pool. The penetration consists of a 36-inch stainless steel pipe installed inside a 48-inch pipe. The inner pipe acts as the transfer tube and is fitted

[redacted]

with a double-gasketed blind flange in the refueling canal and a standard gate valve in the spent fuel pit. This arrangement prevents leakage through the transfer tube in the event of an accident. The outer pipe is welded to the containment liner. Bellows expansion joints are provided on the pipes to compensate for any differential movement between the two pipes or other structures.

b. Containment Supply and Exhaust Purge Ducts

The ventilation system purge duct is equipped with two tight-seating valves to be used for isolation purposes. The valves are manually opened for containment purging as described in 9.7.

5.2.2 DESIGN OF PENETRATIONS

5.2.2.1 Design Criteria

Penetrations will conform to the applicable sections of ASA N6.2-1965, "Safety Standard for the Design, Fabrication and Maintenance of Steel Containment Structures for Stationary Nuclear Power Reactors." All personnel locks and any portion of the equipment access door extending beyond the concrete shell will conform in all respects to the requirements of ASME Section III Nuclear Vessels Code.

Each line which penetrates the containment and contains high pressure or high temperature fluids (steam, feedwater, and steam generator blowdown) will pass through a structural steel guide mounted on the containment wall. This guide will act as a positive stop to prevent whipping associated with fracture of a line containing high internal energy and thereby prevent damage to the penetration and breeching of the containment.

Further protection of each line, necessary to preclude pipe rupture between penetration and first valve, is accomplished by shortening the exposed length of pipe and installing the first valve as close as possible to the containment internal or external wall, dependent upon valve operating and maintenance clearances. Criteria which apply to the provision of automatic and manual isolation valves in the penetration lines are contained in 5.6.

5.2.2.2 Code of High-Temperature Penetrations

The main high temperature piping consists of two penetrations for feedwater and two penetrations for main steam which have a maximum operating temperature range between 450 F and 566 F. Thermal insulation is provided on the outside diameter of each line and separate coolant circulation, with instrumentation suitable for flow monitoring, in the air gap between insulation and penetration liner sleeve. The combination of insulation and coolant circulation is designed to restrict maximum temperature rise in the concrete to 150 F. 3

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For the condition of loss of penetration coolant circulation, the maximum steady state temperature in the concrete will be 300 F at the penetration surface and decrease to 120 F at a maximum depth of 48 inches in the containment wall. Actual peak temperatures in the penetrations resulting from accident conditions are expected to subside within six hours. A maximum temperature of 390 F may be tolerated for 120 days* without appreciable deterioration of the concrete.

The basis for limiting strains in the penetration steel will be the ASME Boiler and Pressure Vessel Code for Nuclear Vessels, Section III, Article 4, 1965, and therefore, the penetration structural and leak tightness integrity will be maintained. Local heating of the concrete immediately around the penetration will develop compressive stress in the concrete adjacent to the penetration and a negligible amount of tensile stress over a large area. The mild steel reinforcing added around penetrations will distribute local compressive stresses for overall structural integrity.

5.2.2.3 Penetration Materials

The materials for penetrations including the personnel and equipment access hatches together with the mechanical and electrical penetrations will be carbon steel and will conform with the requirements of the ASME Nuclear Vessel Code. As required by the Nuclear Vessel Code, the penetration materials shall meet the necessary Charpy V-notch impact values at a temperature 30 F below the lowest service temperature.

a. Piping Penetration Materials

Materials specifications are listed below.

Piping Penetration Material	Specification
Penetration Sleeve	ASTM - A333
Penetration Reinforcing Rings	ASTM - A516
Penetration Sleeve Reinforcing	ASTM - A516
Bar Anchoring Rings and Plates	ASTM - A516
Rolled Shapes	ASTM - A36

b. Electrical Penetration Materials

The penetration sleeves to accommodate the electrical penetration assembly canisters will be carbon steel pipe, except where otherwise noted.

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* Davis, Harold S., "Thermal Considerations in Design of Concrete Shields," ASCE Proceedings, September, 1958.

c. Access Penetration Materials

The equipment and personnel access hatch materials will be as follows.

Access Penetration Material	Material Specification
Equipment Hatch Insert	All ASTM A516 made to ASTM A300
Equipment Hatch Flanges	
Equipment Hatch Head	
Personnel Hatch	

5.2.3 INSTALLATION OF PENETRATIONS

The qualification of welding procedures and welders will be in accordance with Section IX, "Welding Qualifications" of the ASME Boiler and Pressure Vessel Code. The repair of defective welds will be in accordance with Paragraph N-528 of Section III, "Nuclear Vessels" of the above Code.

5.2.4 TESTABILITY OF PENETRATION WELDS

Some lines which penetrate the containment are not open to the containment atmosphere. Where these lines are located outside the missile barrier, they are considered to be closed systems, not subject to rupture following a loss-of-coolant-accident. The main steam lines, the feedwater lines, and the service water lines which provide cooling water to the coolers in the ventilation air handling units fall within this category.

Any leakage through these closed lines will be detected as part of the preoperational integrated leak test of the containment.

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5.3 CONTAINMENT ACCESSIBILITY CRITERIA

The normal mode of operation will be to have the containment completely closed. Access is permitted into the reactor building for inspection and maintenance of miscellaneous rotating equipment during rated power operation and for periodic calibration of the incore monitoring system.

To permit entry the containment vessel will be purged as required to reduce the concentration of radioactive gases and airborne particulates to tolerable levels. To assure removal of particulate matter and radioactive gasses, the purged air will be passed through a high efficiency filter and a charcoal filter before being released to the atmosphere through the purge vent in addition to the continuous clean-up in the containment by the cooler high efficiency and charcoal filters.

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5.4 CONSTRUCTION PRACTICES AND QUALITY ASSURANCE

5.4.1 ORGANIZATION OF QUALITY ASSURANCE PROGRAM

Quality of both materials and construction of the containment structure will be assured by a continuous program of quality control and inspection by Bechtel Corporation, the Engineer-Construction Manager, and by the Applicant.

Qualified field supervisory personnel and inspectors will be assigned to the project to carry out the work in accordance with the specifications and drawings. Project design personnel will make frequent visits to the job site to coordinate the construction with the design. Inspectors will be experienced and thoroughly familiar with the type of work to be inspected, particularly in the field of prestressed concrete. The inspector will be given complete access to the work and will perform such examinations as are necessary to satisfy himself that the standards set forth in the applicable codes and specifications have been met.

Where material does not satisfy the standards, he will have the authority to stop work until the necessary alterations are made.

5.4.2 APPLICABLE CONSTRUCTION CODES

The following codes of practice will be used to establish standards of construction procedure.

a. ACI 301 - Specification for Structural Concrete for Buildings (proposed)

b. ACI 318 - Building Code Requirements for Reinforced Concrete

c. ACI 347 - Recommended Practice for Concrete Formwork 1

d. ACI 605 - Recommended Practice for Hot Weather Concreting

e. ACI 613 - Recommended Practice for Selecting Proportions for Concrete

f. ACI 614 - Recommended Practice for Measuring, Mixing and Placing Concrete

g. ACI 315 - Manual of Standard Practice for Detailing Reinforced Concrete Structures

h. Part UW - Requirements for Unfired Pressure Vessels Fabricated by Welding of Section VIII of the ASME Boiler and Pressure Vessel Code

In addition to the foregoing initial user tests, a daily inspection control program will be carried on during construction to ascertain consistency in potentially variable characteristics such as gradation and organic content.

d. Water

Water to be used in concrete mixing will be sampled and analyzed by a qualified testing laboratory to assure conformance with specifications.

5.4.3.2 Concrete

a. Design Mix

Design mixes and the associated tests will be provided by a qualified concrete testing laboratory. The design of mixes will be in accordance with ACI 613 to obtain material proportions for the specified concrete.

During construction the field inspection personnel will make any minor modifications that may be necessitated by variations in aggregate gradation or moisture content.

b. Compressive Strength

Concrete strength, slump, and temperature inspections will be performed. The purpose of the tests and inspection is to ascertain conformance to specifications. The basis for the proposed inspection procedure is ACI Manual of Concrete Inspection with upgraded modifications to meet the more stringent requirements of this application.

5.4.3.3 Reinforcing Steel

a. Material

All reinforcing steel will be user-tested in accordance with ASTM specifications. Tests will include one tension and one bend test per heat or per mill shipment, whichever is less, for each diameter bar. Test samples will be obtained at the fabrication plant. High strength bars will be clearly identified prior to shipment to prevent any possibility of mix-up with lower strength reinforcing bars.

b. Mechanical Splices

The "Cadweld" inspection program is detailed in Appendix 5-C. Ordinary welded splices will not be used for main bars in the containment structure, as stated in 5.1.3.2. 4|

i. AISC - Steel Manual, Code of Standard Practice

j. PCI - Inspection Manual

k. AWS - Code for Welding in Building Construction (D 1.0-66)

l. AWS - Recommended Practices for Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction (D 12.1-61)

In every instance the construction procedure for the containment will equal or exceed the recommendations set forth in the foregoing publications. The extent to which each detailed process will exceed standard requirements cannot be described without incorporating all applicable job specifications and anticipating hypothetical construction problems and conditions. In general, however, wherever the applicable codes specify minimum and ideal criteria, the ideal will be incorporated into the specifications.

5.4.3 CONSTRUCTION MATERIALS INSPECTION AND INSTALLATION

Materials to be used in the containment structure include concrete materials, reinforcing steel, prestressing system materials, and steel liner plate. The user inspection and testing of each material will be as follows:

5.4.3.1 Concrete Materials

a. Cement

In addition to the tests required by the cement manufacturers, the following user tests will be performed:

(1) ASTM C 114 - Chemical Analysis

(2) ASTM C 115 - Fineness of Portland Cement

(3) ASTM C 151 - Autoclave Expansion

(4) ASTM C 191 - Time of Set

(5) ASTM C 109 - Compressive Strength

(6) ASTM C 190 - Tensile Strength

The purpose of the above tests is to ascertain conformance with ASTM Specification C 150. In addition, tests ASTM C 191 and ASTM C 109 will be repeated periodically during construction to check storage environmental effects on cement characteristics. The tests will supplement visual inspection of material storage procedures.

b. Water Reducing Agents

A concrete testing laboratory will perform the necessary strength and shrinkage tests on various water reducing agents to establish the particular additive with the most desirable characteristics for this application.

c. Aggregates

User tests of concrete aggregate include the following:

Test		Basis For	Results to be Achieved
ASTM No.	Name		
C 131	Los Angeles Abrasion	ASTM Spec C-33	To conform with specification
C 142	Clay Lumps	ASTM Spec C-33	To conform with specification
C 117	Material Finer than #200 Sieve	ASTM Spec C-33	To conform with specification
C 87	Mortar Making Properties	ASTM Spec C-33	To conform with specification
C 40	Organic Impurities	ASTM Spec C-33	To conform with specification
C 289	Potential Reactivity (Chemical)	ASTM Spec C-33	To conform with specification
C 136	Sieve Analysis	ASTM Spec C-33	To conform with specification
C 88	Soundness	ASTM Spec C-33	To conform with specification
C 127	Specific Gravity and Absorption	ASTM Spec C-33	Mix Design Calculations
C 128	Specific Gravity and Absorption	ASTM Spec C-33	Mix Design Calculations
C 295	Petrographic	ASTM Spec C-33	To conform with specification

b. Installation

All prestressing installation work shall be continuously inspected by a qualified inspector. All measuring equipment used for installation will be calibrated and certified by an approved independent testing laboratory. During stressing operations, records will be kept by the engineer for use in comparing force measurements with elongation for all tendons. The resultant cross-reference will provide a final check on measurement accuracy. Measurement accuracy and rejection allowances will be in accordance with ACI-318, Chapter 26.

c. Grease

Grease will be sampled after delivery and submitted to a qualified testing laboratory for chemical analysis to establish conformance with specifications.

5.4.3.5 Containment Liner

a. Steel Plate

Steel plate will be tested at the mill in full conformance to the applicable ASTM specifications. Certified mill test reports will be supplied for review and approval by the engineer.

There will be no impact testing done on the liner plate material. The purpose of impact testing is to provide protection against brittle failure. The possibility of a brittle fracture of the liner plate is precluded because at the design accident pressure condition there will not be any tensile stress anywhere in the liner plate whether there is instantaneous release of pressure or there is some time lag in temperature load application. Therefore, the NDT temperature of the liner plate loses significance.

b. Fabrication and Installation

Welding inspection will conform to the quality control inspection procedure described in detail by Appendix 5-H.

1 Dimensional tolerances will be checked by an installation inspector to prevent unanticipated installation deformations. The radial tolerance will limit variation of the design radius to ± 1-1/2 in. In addition, no more than 3/4 in. deviation in radius will be allowed on a single plate section using a 15 ft template. The maximum inward deflection of the liner plate between the stiffeners (spaced at 15 in.) will be 1/8 in. relative to a 15 in. straight edge.

c. Fabrication

Visual inspection of fabricated reinforcement will be performed to ascertain dimensional conformance with specifications and drawings.

d. Placement

Visual inspection of in-place reinforcement will be performed by the placing inspector to assure dimensional and location conformance with drawings and specifications.

5.4.3.4 Prestress System

a. Wires

Sampling and testing of the tendon material used in construction will conform to ASTM Standard A-421 or ASTM A-416. The following procedure will be used:

(1) Buttonhead rupture tests from each reel of wire will be made.

(2) Each size of wire from each mill heat and all strands from each manufactured reel to be shipped to the site shall be assigned an individual lot number and tagged in such a manner that each such lot can be accurately identified at the job site. Anchorage assemblies shall likewise be identified. All unidentified prestressing steel or anchorage assemblies received at the job site will be subject to rejection.

(3) Random samples as specified in the ASTM Standards stated above will be taken from each lot of prestressing steel to be used in the work. With each sample of prestressing steel wire or strand that is tested, there shall be submitted a certificate stating the manufacturer's minimum guaranteed ultimate tensile strength of the sample to be tested. Stress-strain curves will be plotted and the yield and tensile strength verified. For the prefabricated tendons, one completely fabricated prestressing test specimen 5 feet in length including anchorage assemblage, will be tested for each size of tendon contained in an individual manufacturing run. The anchorages will develop the minimum guaranteed ultimate strength of the tendon and the minimum elongation of the tendon material as required by the applicable ASTM specification.

Field inspection will ensure that there are no visible mechanical or metallurgical notches or pits in the tendon material.

e. The construction opening will be closed.

f. The remaining tendons will be installed including buttonheads.

3 g. The remaining lower hoop tendons will be stressed following the pattern used on the upper hoop tendons.

h. The vertical tendons will be tensioned.

i. All remaining tendons will be stressed.

The procedure for prestressing will be carefully worked out with the post-tensioning vendor.

All procedures will be subject to the approval of the Engineer.

The Engineer will provide to the vendor prestressing forces for each tendon, the anticipated concrete elastic, shrinkage, and creep prestress losses, and the maximum prestress forces for each stage of prestressing. The vendor will incorporate all this information along with any steel relaxation, friction, and anchorage losses to establish the initial jacking force for each sequential operation.

Force and stress measurements will be made by measuring the elongation of the prestressing steel and comparing it with the force indicated by the jack-dynamometer or pressure gage. The gage will indicate the pressure in the jack within plus or minus two percent. Force-jack pressure gage or dynamometer combinations will be calibrated against known precise standards just before application of prestressing forces begins and all calibrations will be so certified prior to use. Pressure gages and jacks so calibrated will always be used together.

During stressing, records will be kept of elongations as well as pressures obtained. Lift-off stress reading will be taken at the end of each stressing operation to check the actual stress in the tendon. Jack-dynamometer or gage combinations will be checked against elongation of the tendons and the cause of any discrepancy exceeding plus or minus five percent of that predicted by calculations (using average load elongation curves) will be corrected, and if caused by differences in load-elongation from averages will be so documented. Calibration of the jack-dynamometer or pressure gage combinations will be maintained accurately within above limits.

5.4.4.3 Liner Plate Sequence

The construction sequence of the containment liner plate is as follows:

1 a. Inserts for the erection of the floor and the first wall section will accompany the placing of the base slab. The installation and testing of the floor liner plate can be done at anytime prior to the placing of the liner plate protective slab.

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5.4.4 SPECIFIC CONSTRUCTION TOPICS

5.4.4.1 Bonding of Concrete Between Lifts

Horizontal construction joints will be prepared for receiving the next lift by wet sandblasting, by cutting with an air-water jet, or by bush hammering. Surface set retardant compounds will not be used.

When wet sandblasting is to be employed, it will be continued until all laitance, coating, stains, debris, and other foreign materials are removed. The surface of the concrete will be washed thoroughly to remove all loose material.

When air-water cutting is to be used, it will be performed after initial set has taken place but before the concrete has taken its final set. The surface will be cut with a high pressure air-water jet to remove all laitance and to expose clean, sound aggregate, but not so as to undercut the edges of the larger particles of aggregate. After cutting, the surface will be washed and rinsed as long as there is any trace of cloudiness of the wash water. Where necessary to remove accumulated laitance, coatings, stains, debris, and other foreign material, wet sandblasting will be used before placing the next lift, to supplement air-water cutting.

Horizontal surfaces will be wetted and covered with one-quarter inch to one-half inch of mortar of the same cement-sand ratio as used in the concrete, immediately before the concrete is placed.

Vertical joints will also be sandblasted or bush hammered, cleaned, and wetted before placing concrete.

5.4.4.2 Prestressing Sequence

The detailed stressing sequence will be based on the following general requirements to minimize unbalanced loads and differential stresses in the structure.

a. All hoop tendons will be tensioned at three alternate buttresses within a strip extending from 20 feet above the construction opening to one 30 feet below the bottom of the ring girder.

b. Every second hoop tendon at the same three buttresses will be tensioned from the bottom of the ring girder to the previously stressed tendons. 3

c. A shift of 60° will be made to the other three buttresses and all hoop tendons will be tensioned within a strip extending from 30 feet above the construction opening to one 50 feet below the bottom of the ring girder.

d. The dome tendons will be fully tensioned using a balanced approach.

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b. The first wall liner plate will be prefabricated, welded, tested, and then installed after erection of the buttresses in segments of approximately 60 degrees (center to center of buttresses) in lifts of 10 ft. This is followed by the welding and testing of the remaining horizontal and vertical seams. The installation of wall tendon tubes and reinforcing steel is followed by the pouring of the walls in alternating 60 degree segments.

c. The procedure is repeated for the remaining lifts of the wall in similar fashion. Liner plate erection is permitted to reach two courses (approximately 10 ft. each) above the concrete pours provided adequate bracing is included. 1

d. Upon completion of the wall the erection trusses for the dome are installed. The erection of the dome liner plate is completed including all welding and testing. This is followed by a 7 in. concrete pour upon the entire dome area to support the remaining dome concrete.

The above procedure is a general outline. The exact sequence of construction will be determined by the contractor and approved by the engineer to ensure the quality of work.

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syrup, liquid detergent, and glycerin. The solution shall be prepared not more than 24 hours preceding the test and its bubble formation properties shall be checked with a sample leak every half hour during the test.

c. Radiography

Radiography will be used as an aid to quality control. The primary purpose of the liner plate and the welds therein is to provide leak tightness integrity to the post-tensioned concrete containment vessel. Structural integrity of the containment is provided by the post-tensioned concrete and not by the liner plate.

Radiography is not recognized as an effective method for examining welds to assure leak tightness. Therefore, the only benefit which can be expected from radiography in connection with obtaining leak tight welds is an aid to quality control. Random radiography of each welder's work will provide structural verification that the welding is or is not under control and being done in accordance with the previously established and qualified procedures. Additionally, employing random radiography to inspect each welder's work has been proved by past experience to have a positive psychological effect on improving overall welding workmanship.

The criterion for radiographic techniques shall be in accordance with Paragraph UW-51 of Section VIII of the ASME Code. At least one spot radiograph shall be taken in the first 10 feet of welding completed in the flat, vertical, horizontal, and overhead positions by each welder. Thereafter, approximately 2 percent of the welding will be spot examined on a random basis, in such manner that an approximately equal number of spot radiographs will be taken from the work of each welder.

d. Dye Penetrant

Dye penetrant inspection will also be used as an aid to quality control. The field welding inspectors will use dye penetrant inspection to closely examine welds judged to be of questionable quality on the basis of the initial visual inspection. Also, dye penetrant inspection will be used to confirm the complete removal of all defects from areas which have been prepared for repair welding. Dye penetrant inspection of liner plate welds will be in accordance with Appendix VIII, "Methods for Liquid Penetrant Examination," of Section VIII of the ASME Boiler and Pressure Vessel Code.

5.5 CONTAINMENT SYSTEM INSPECTION, TESTING, AND SURVEILLANCE

5.5.1 TESTS TO ENSURE LINER INTEGRITY

a. Construction Tests: These take place during the erection of the containment building liner.

b. Pre-operational Tests: These are performed after the erection of the structure is complete but before reactor operation.

5.5.1.1 Tests on Liner During Construction

Inspection procedures to be employed during construction for the liner seam welds, liner fastening, and around penetrations will consist of visual inspection, vacuum box soap bubble testing, radiography, and dye penetrant testing.

a. Visual Inspection of Welds

All of the welding will be visually examined by a technician responsible for welding quality control. The criteria for workmanship and visual quality of welds will be as follows.

(1) Each weld will be uniform in width and size throughout its full length. Each layer of welding shall be smooth and free of slag, cracks, pinholes, and undercut, and shall be completely fused to the adjacent weld beads and base metal. In addition, the cover pass shall be free of coarse ripples, irregular surface, nonuniform bead pattern, high crown, and deep ridges or valleys between beads. Peening of welds will not be permitted.

(2) Butt welds shall be of multipass construction, slightly convex, of uniform height, and have full penetration.

(3) Fillet welds shall be of the specified size, with full throat and legs of uniform length.

b. Soap Bubble Tests

All of the welding which will be covered by concrete or otherwise inaccessible after construction will be vacuum box soap bubble tested. In this test a vacuum box containing a window is placed over the area to be tested and is evacuated to produce at least 5 psi pressure differential. Before the vacuum box is placed over the test area, a soap solution is applied to the weld and any leaks will be indicated by bubbles observed through the window in the box. The soap solution consists of equal parts of corn

5.5.3 IN-SERVICE TENDON SURVEILLANCE PROGRAM

The in-service surveillance program for the containment structure consists of evaluating the tendon system performance and the corrosion protection system performance. Further, the containment structure is a passive type system where mechanical operational failures are non-existent, thus only requiring that the system remain in status-quo and available to perform its function in the unlikely event that it will be required. It is the intent of the surveillance programs to provide sufficient in-service historical evidence necessary to maintain confidence that the integrity of the containment structure is being preserved.

To accomplish the surveillance program, the following quantity of tendons will be made available for inspection and lift-off readings.

Horizontal - Three 120° tendons comprising one complete hoop system.

Vertical - Three tendons spaced approximately 120° apart.

Dome - Three tendons spaced approximately 120° apart.

The surveillance program for structural integrity and corrosion protection will consist of the following operations being performed during each inspection.

3 a. Lift-off readings will be taken for all nine tendons.

b. One tendon of each directional group will be relaxed and three wires or one strand removed as samples for inspection.

c. After the inspection the tendons will be retensioned to the stress level measured at the lift-off reading, and then checked by a final lift-off reading.

d. Should the inspection reveal any significant corrosion (pitting, or loss of area), further inspection of the other two sets will be made to determine the extent of the corrosion and its significance to the load carrying capacity of the structure. Samples of corroded wire or strand will be tested to failure to evaluate the effects of any corrosion.

Inspection requirements for containment, as well as those for other systems, will be a part of the technical specifications for the plant and therefore, will be included in the operating license application. Changes in these inspection requirements or their elimination at any time during plant life will be subject to AEC regulations governing technical specifications and will require review and approval by the AEC after justification by the applicant.

Conservative testing requirements will be established at the operating license stage and nothing in the design of the containment will preclude the testing of tendons or pneumatic testing of the containment during its life.

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e. Initial Leak Test for Base Slab Liner Plate Welds

The welds for each section of base slab liner plate will be vacuum box soap bubble tested immediately upon installation. After successfully passing this leakage test, they will be covered with test channels and the particular welds associated with that section of liner plates will be pressure tested using a Freon-Air mixture or soap bubble test at design pressure for a period of at least two hours with no drop in pressure. Any repairs will be carried out utilizing the same high standards and control exercised in the initial construction.

5.5.1.2 Pre-operational Integrated Leak Test

The design leak rate will not be more than 0.1 percent by volume of the contained atmosphere in 24 hours at 59 psig. It has been demonstrated that, with good quality control during erection, this is a reasonable requirement.

The basis of the leak rate test is the reference volume method. Every effort is made to demonstrate the leak tightness of the reference volume system. The entire reference volume system is pressurized to a minimum of 100 psi gage with air containing 20 weight percent Freon. All reference volume joints are bagged with plastic and the system held at this pressure for 48 hours. The reference volume system, especially the joints, is checked with a halogen leak detector to demonstrate integrity.

In addition to the usual calculation of leak rate as a function of pressure differential, air is returned to the reactor containment at the conclusion of the test through a precision gas meter until the differential pressure is returned to its original condition. This provides a check on the calculated leak rate. Reactor containment ambient temperature and humidity are also measured during the course of the test to provide further backup information.

The initial leak rate test consists of establishing a leak rate at design pressure. Because the containment is a thick-walled concrete structure, short-term temperature or meteorological variations should not have any appreciable effect on the containment ambient temperature and pressure. It should, therefore, be possible to establish meaningful leak rates in a shorter term test than might be required on a bare steel vessel. The containment will be held at each test pressure for a minimum of 24 hours.

5.5.2 STRENGTH TEST

A pressure test will be made on the completed building using air at 1.15 times the design pressure. This pressure will be maintained on the building for a period of one hour. During this test, measurements and observations will be made to verify the adequacy of the structure design.

It is expected that experience gained in surveillance testing of the containment structure as well as from other sources during the life of the plant will show that testing frequency can be relaxed subject to AEC review and approval. 3

b. Type II

Each line connecting directly to the reactor building atmosphere has two isolation valves. At least one valve is external, and the other may be internal or external to the reactor building. These valves may be either a check valve and a remotely operated valve or two remotely operated valves of different types, depending upon the direction of normal flow. Isolation valves will be located as close to the reactor building wall consistent with required clearances.

c. Type III

Each line not directly connected to the reactor coolant system or not open to the reactor building atmosphere has one valve, either a check valve or a remotely-operated valve. This valve is located external to the reactor building.

d. Type IV

Lines which penetrate the reactor building and are connected directly to the atmosphere, but which are never opened during reactor operation, have single valves with provisions for locking in a closed position. Depending on service, a lock, interlock, or an operating procedure ensures that these valves are closed whenever containment is required.

There are additional subdividions in each of these major groups. The individual system flow diagrams show the manner in which each reactor building isolation valve arrangement fits into its respective system. For convenience, each different valve arrangement is shown in Table 5.6-1 and Figure 5.6-1 of this section. The symbols on this figure are identified on Figure 9.0-1. The table lists the mode of actuation, the type of valve, its normal position and its position under reactor building isolation conditions. The specific system penetrations to which each of these arrangements is applied is also presented. It may be noted that only motor-operated or check valves are used inside the reactor building to eliminate the need for additional pneumatic lines and associated isolation valves for the actuating air associated with air-operated valves. Each valve will be tested periodically during normal operation or during shutdown conditions to ensure its operability when needed. Diaphragm valves where used for external isolation are held open by air pressure and closed by a compressed spring, except engineered safeguards systems.

The accident analysis for failure or malfunction of each valve is presented with the respective system evaluation of which that valve is a part, e.g. chemical addition and sampling system, etc.

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5.6 ISOLATION SYSTEM

5.6.1 DESIGN BASES

The general design basis governing isolation valve requirements is:

> Leakage through all fluid penetrations not serving accident-consequence-limiting systems is to be minimized by a double barrier so that no single, credible failure or malfunction of an active component can result in loss-of-isolation or intolerable leakage. The installed double barriers take the form of closed piping systems, both inside and outside the Reactor Building, and various types of isolation valves. The power conversion steam and feed water systems are provided with the turbine stop-valves or similar process valves that serve to effectively isolate these systems.

Reactor building isolation occurs on a signal of approximately 4 psig in the reactor building. Valves which isolate penetrations that are directly open to the reactor building such as the reactor building purge valves and sump drain valves, will also be closed on a high radiation signal.

The isolation system closes all fluid penetrations, not required for operation of the engineered safeguards system, to prevent the leakage of radioactive materials to the environment. Fluid penetrations serving engineered safeguards systems also meet this design basis.

All remotely-operated reactor building isolation valves are provided with position limit indicating lights in the control room.

5.6.2 SYSTEM DESIGN

The fluid penetrations which require isolation after an accident may be classed as follows:

a. Type I

Each line connecting directly to the reactor coolant system has two reactor building isolation valves. One valve is external, and the other valve is internal to the reactor building. These valves may be either a check valve and a remotely operated valve, or two remotely operated valves of different types, depending upon the direction of normal flow. Isolation valves will be located in the reinforced zone of the pipe as close as possible to the reactor building wall, consistent with clearances required for valve operation.

TABLE 5

REACTOR BUILDING ISOLATI

Penetration No.	Service	System	Flow Direction	Valve Arrangement	Location In Ref. To RB	Valv Type
1	Pressurizer Sample Lines	CA	Out	1	Inside Outside	Gate Gate Gate
2	Steam Generator Secondary Water Sample Lines	CA	Out	1	Inside Outside	Gate Gate Gate
3	Component Cooling Water Inlet Line	CC	In	4	Outside Inside	Gat Che
4	Component Cooling Water Outlet Line	CC	Out	14	Outside Inside	Gat Gat
5, 6 7, 8	Reactor Building Emergency Cooling Units Cooling Water Inlet	NS	In	2	Outside	Gat
9, 10 11, 12	Reactor Building Emergency Cooling Units Cooling Water Outlet	NS	Out	3	Outside	Gat
13, 14	Reactor Building Normal and Emergency Sump Drains	WD	Out	5	Outside	Gat Gat
15	Let Down Line to Purification Demineralizers	MU	Out	1	Inside Outside	Ga Ga Ga
16	Reactor Coolant Pump Seal Water Supply	MU	In	6	Inside Outside	St Gl Ga Gl

*All valves with electric motor operators are also equipped wit
**Postaccident Reactor Coolant System pressure causes valve to c

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ON VALVE ARRANGEMENTS

e	Line Size	Method of Actuation	Signal	Normal Valve Position	Position With Power Failure	Position Indication	Post Accident Position	
	3/8"	Emo*	ES	Closed	As Is	Yes	Closed	
	3/8"	Emo*	ES	Closed	As Is	Yes	Closed	2
	3/8"	Air	ES	Closed	Closed	Yes	Closed	
	3/4"	Emo	Remote Manual	Closed	As Is	Yes	Closed	
	3/4"	Emo	Remote Manual	Closed	As Is	Yes	Closed	
	3/4"	Air	ES	Closed	Closed	Yes	Closed	
	14"	Emo	ES	Open	As Is	Yes	Closed	2
k	14"	--	--	Open	Closed	No	Closed	
e	14"	Emo	ES	Open	As Is	Yes	Closed	2
e	14"	Air	ES	Open	Closed	Yes	Closed	
e	8"	Emo	ES	Closed	As Is	Yes	Open	2
e	8"	Emo	ES	Closed	As Is	Yes	Open	2
e	3"	Emo	ES	Closed	Closed	Yes	Closed	
e	3"	Air	ES	Closed	Closed	Yes	Closed	
te	2-1/2"	Emo	ES	Open	As Is	Yes	Closed	
te	2-1/2"	Emo	ES	Closed	As Is	Yes	Closed	2
te	2-1/2"	Air	ES	Open	Closed	Yes	Closed	
op Check(4)	1	--	--	Open	Closed	No	Closed	
obe	4"	Air	dP	Throttled	Closed	No	Closed**	
te (2)	4"	Manual	--	Open	Open	No	Open	
obe	4"	Manual	--	Closed	Closed	No	Closed	

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Table 5.6-1 Continue

Penetration No.	Service	System	Flow Direction	Valve Arrangement	Location In Ref. To RB	Valv Type
17	Reactor Control Rod Drive Seal Water Supply	MU	In	8	Inside	Chec
					Outside	Glob
						Gate
						Glob
18	Reactor Coolant Pump Seal and Control Rod Drive Seal Water Return	MU	Out	1	Inside	Gate
						Gate
					Outside	Gate
19	Normal Makeup To Reactor Coolant System	MU	In	8	Inside	Chec
					Outside	Glob
						Gate
						Glob
20, 21, 22, 23	High Pressure Injection Line	MU	In	9	Inside	Chec
					Outside	Gat
24	Fuel Transfer Tube	SF	In/Out	11	Inside	Spec
						Clo
					Outside	Gat
25, 26	Reactor Building Spray Inlet Lines	RBS	In	7	Inside	Chec
					Outside	Gat
27, 28	Decay Heat Removal Inlet Line	DH	In	9	Inside	Chec
					Outside	Gat
29	Decay Heat Removal Pump Suction Line and Fuel Transfer Canal Drain Line	DH	Out	12	Inside	Gat
						Gat
						Gat
					Outside	Gat
30, 31	Reactor Building Emergency Sump Recirculation Line	DH	Out	3	Outside	Gat
32	Reactor Coolant System Vent Header	WD	Out	14	Outside	Gat
					Inside	Gat

**Postaccident Reactor Coolant System pressure causes valve to cl

***Opened by operator on low-level alarm for borated water storage

e	Line Size	Method of Actuation	Signal	Normal Valve Position	Position With Power Failure	Position Indication	Post Accident Position	
k	1-1/2"	--	--	Open	Closed	No	Closed	
e	1-1/2"	Air	dP	Throttled	Closed	No	Closed**	2
(2)	1-1/2"	Manual	--	Open	Open	No	Open	
e	1-1/2"	Manual	--	Closed	Closed	No	Closed	
	1-1/2"	Emo	ES	Open	As Is	Yes	Closed	
	4"	Emo	ES	Open	As Is	Yes	Closed	
	4"	Air	ES	Open	Closed	Yes	Closed	
k	2-1/2"	--	--	Open	Closed	No	Open	
e	2-1/2"	Air	Pressurizer Level	Throttled	As Is	No	Open	
(2)	2-1/2"	Manual	--	Open	Open	No	Open	
e	2-1/2"	Manual	--	Closed	Closed	No	Closed	
k	2-1/2"	--	--	Closed	Closed	No	Open	
	2-1/2"	Emo	ES	Closed	Closed	Yes	Open	
ial ure	30"	--	--	Closed	Closed	No	Closed	
	30"	Manual	--	Closed	Closed	No	Closed	
k	10"	--	--	Closed	Closed	No	Open	2
	10"	Air	ES	Closed	Closed	Yes	Open	
k	10"	--	--	Closed	Closed	No	Open	
	10"	Emo	ES	Closed	Closed	Yes	Open	
	12"	Emo	Remote Manual	Closed	Closed	Yes	Closed	
	12"	Emo	Remote Manual	Closed	Closed	Yes	Closed	
	10"	Manual	--	Closed	Closed	No	Closed	
	12"	Air	ES	Closed	Closed	Yes	Closed	
	18"	Emo	Remote Manual	Closed	Closed	Yes	Open***	
	2"	Air	ES	Open	Closed	Yes	Closed	
	2"	Emo	ES	Open	As Is	Yes	Closed	

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Table 5.6-1 Continued

Penetration No.	Service	System	Flow Direction	Valve Arrangement	Location In Ref. To RB	Va Ty
33	Reactor Coolant System Drain Header	WD	Out	14	Inside Outside	Ga Ga
34	Reactor Building Purge Inlet Line	RBV	In	15	Inside Outside	Bu Bu
35	Reactor Building Purge Outlet Line	RBV	Out	16	Inside Outside	Bu Bu Bu
36, 37, 38, 39	Feedwater Lines		In	10	Outside	Ch Ga Gl Ch Ga Ga Ga Gl
40, 41	Main Steam Lines		Out	17	Outside	Ga Ga Re V. St Th
42	Demineralized Water Supply Line	DW	In	7	Inside Outside	Ch Ga
43	Service Air Supply Line	SA	In	7	Inside Outside	Ch Ga
44, 45	Core Flooding Tank Fill & Nitrogen Supply Line	CA	In	18	Inside Outside	Ch Ch
46	Pressurizer Relief Tank Nitrogen Supply	CA	In	13	Inside Outside	Ch Gl Ga
47	Core Flooding Tank Sample Line	CA	Out	1	Inside Outside	Ga Ga
48	Pressurizer Gas Sample Line	CA	Out	14	Inside Outside	Ga Ga
49, 50	Steam Generator Drain Lines	WD	Out	14	Inside Outside	Ga Ga

[redacted]

lve pe	Line Size	Method of Actuation	Signal	Normal Valve Position	Position With Power Failure	Position Indication	Post Accident Position	
te	3"	Emo	ES	Open	As Is	Yes	Closed	
te	3"	Air	ES	Open	Closed	Yes	Closed	
tterfly	70"	Emo	ES	Closed	Closed	Yes	Closed	
tterfly	70"	Air	ES	Closed	Closed	Yes	Closed	
tterfly	70"	Emo	ES	Closed	Closed	Yes	Closed	
tterfly	70"	Air	ES	Closed	Closed	Yes	Closed	
tterfly	10"	Air	ES	Closed	Closed	Yes	Closed	
eck	18"	--	--	Open	Closed	No	Closed	
te	18"	Emo	ICS	Open	Closed	Yes	Closed	
obe	18"	Air	ICS	Open	Closed	Yes	Closed	
eck	6"	--	--	Closed	Open	No	Closed	
te	6"	Emo	ICS	Closed	Open	Yes	Closed	
te	6"	Emo	ICS	Closed	Closed	Yes	Closed	
obe	6"	Air	ICS	Open	Open	Yes	Closed	
te (2)	10"	Air	ES	Open	Open	Yes	Closed	
te (3)	12"	Air	ICS	Closed	As Req'd	Yes	As Req'd	
lief alves (8)	6"	Self Act.	High Press.	Closed	As Req'd	No	As Req'd	2
p Check(2)	34"	Elec/Hydr	Reactor Trip	Open	Closed	Yes	Closed	
rottle(2)	34"	Elec/Hydr	Reactor Trip	Open	Closed	Yes	Closed	
eck	2"	--	--	Closed	Closed	No	Closed	
te	2"	Air	Remote Manual	Closed	Closed	No	Closed	
eck	2"	--	--	Closed	Closed	No	Closed	
te	2"	Air	Remote Manual	Closed	Closed	No	Closed	
eck	1"	--	--	Closed	Closed	No	Closed	
eck	1"	--	--	Closed	Closed	No	Closed	
eck	3/4"	--	--	Closed	Closed	No	Closed	
obe	3/4"	Manual	--	Open	Open	No	Open	
te	3/4"	Solenoid	Remote	Closed	Closed	Yes	Closed	
te (2)	1-1/2"	Emo	Remote Manual	Closed	As Is	Yes	Closed	
te	1-1/2"	Air	ES	Closed	Closed	Yes	Closed	
te	3/4"	Emo	ES	Closed	As Is	Yes	Closed	
te	3/4"	Air	ES	Closed	Closed	Yes	Closed	
te	4"	Emo	ES	Closed	Closed	Yes	Closed	
te	4"	Air	ES	Closed	Closed	Yes	Closed	

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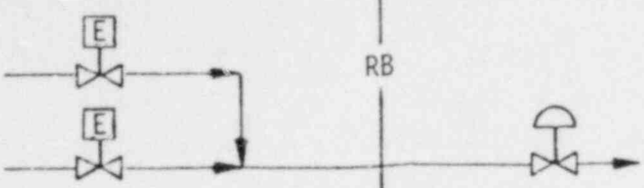
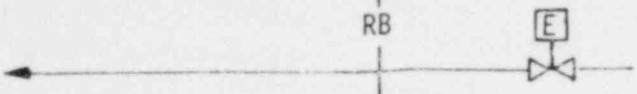
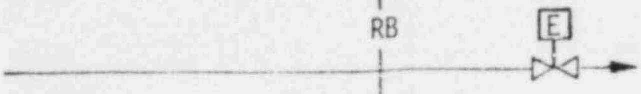
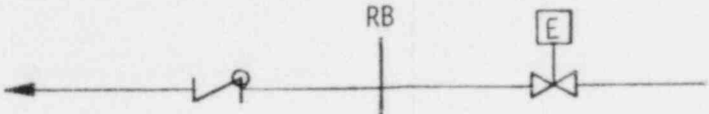
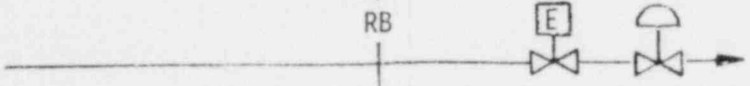
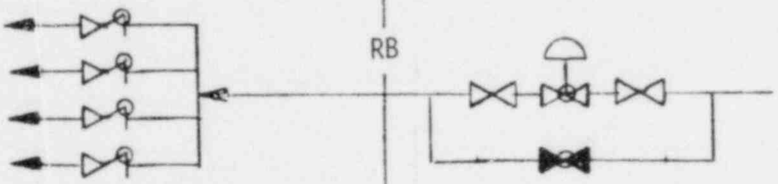
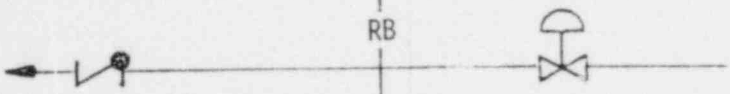
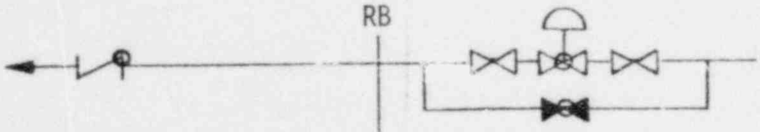
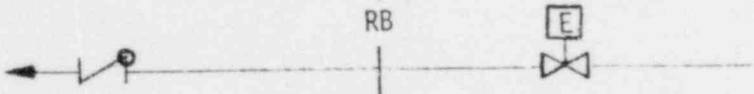
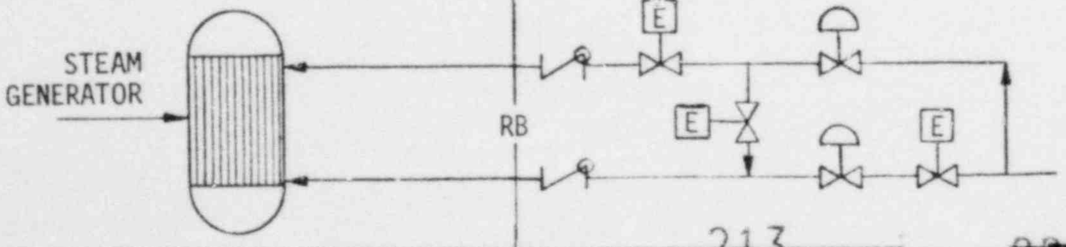
VALVE ARRGT	INSIDE REACTOR BUILDING	OUTSIDE REACTOR BUILDING	PENETRATION NO & TYPE
1			1,15,18,47 (TYPE I) 2 (TYPE III)
2			5,6,7,8 (TYPE III)
3			9,10,11,12 (TYPE III) 30,31 (TYPE IV)
4			3 (TYPE III)
5			13,14 (TYPE II)
6			16 (TYPE I)
7			25,26,42,43 (TYPE II)
8			17,19 (TYPE I)
9			20,21,22,23 27,28 (TYPE I)
10			36,37,38,39 (TYPE III)

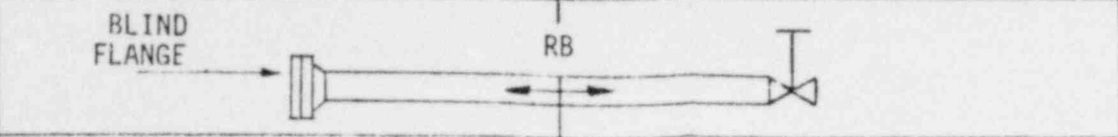
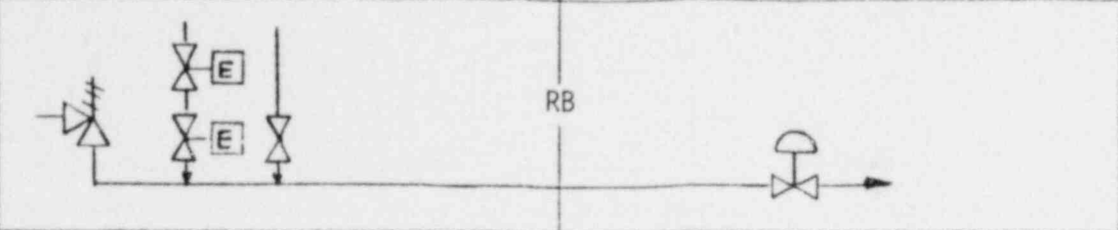
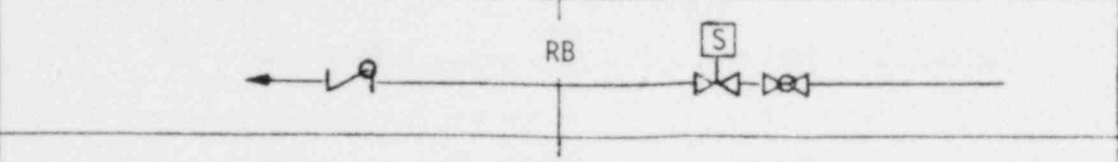
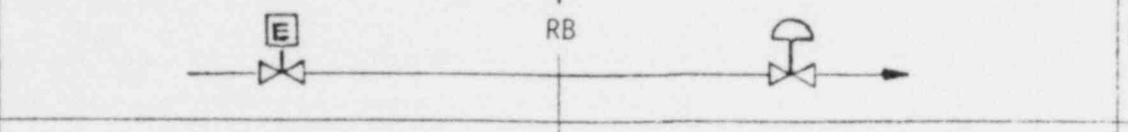
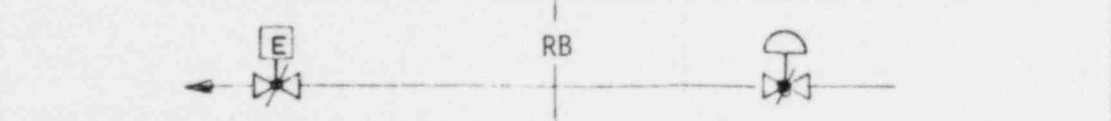
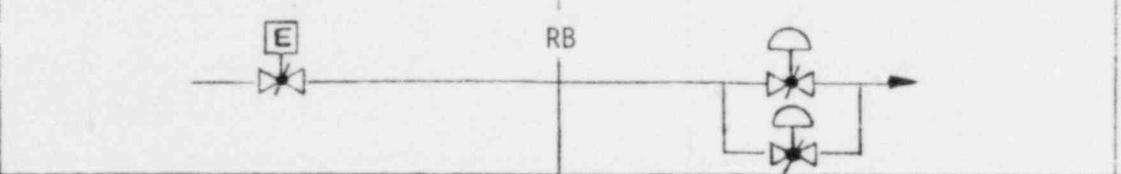
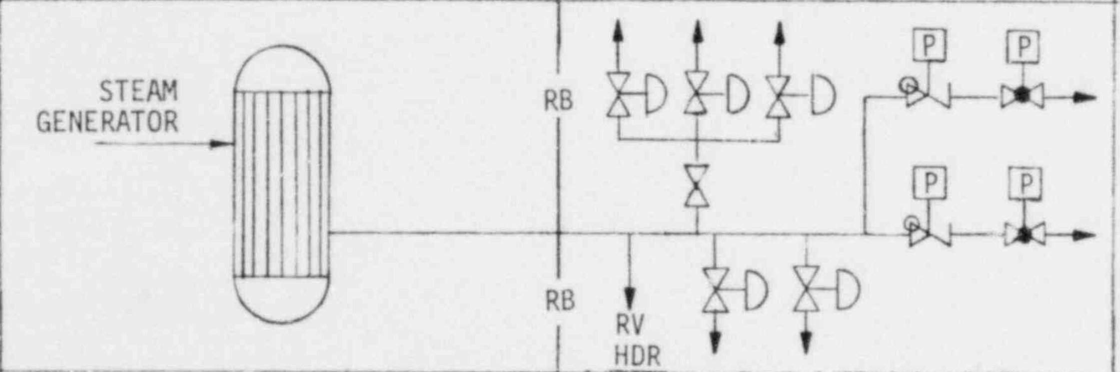
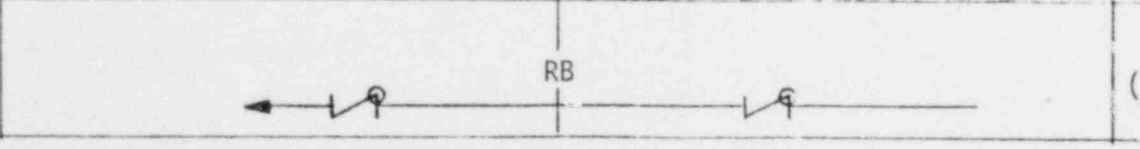
VALVE ARRGT	INSIDE REACTOR BUILDING	OUTSIDE REACTOR BUILDING	PENETRATION NO. & TYPE
11			24 (TYPE IV)
12			29 (TYPE I)
13			46 (TYPE I)
14			4,49,50 (TYPE III) 32,33,48 (TYPE I)
15			34 (TYPE II)
16			35 (TYPE II)
17			40,41 (TYPE III)
18			44,45 (TYPE III)

FIGURE 5.6-1
REACTOR BUILDING ISOLATION
VALVE ARRANGEMENTS

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5.7 VENTILATION SYSTEM

5.7.1 DESIGN BASES

5.7.1.1 Governing Conditions

The reactor building normal ventilation system is composed of the normal cooling system and the purge system and accomplishes two functions. One function is the removal of normal heat loss from equipment and piping in the reactor building, and the other is to clean the reactor building air and to purge the reactor building with fresh air whenever desired.

The reactor building emergency cooling units are described in Section 6, Engineered Safeguards. 2

5.7.1.2 Sizing

To provide for access to the reactor building, the normal ventilation system will be sized to control the interior air temperature to a maximum temperature of 120 F in accessible areas during operation and a minimum of 60 F during shutdown.

The purge system equipment will be sized to provide a minimum of two air changes per hour in the reactor building. The normal cooling units will be utilized and sized to distribute adequate air flow around all heat releasing equipment.

5.7.2 SYSTEM DESIGN

A flow diagram of the normal ventilation and purge systems is shown in Figure 5.7-1.

The normal cooling system will consist of six fan-cooler units each of which will contain a cooling coil, pre-filter, and a direct-driven fan, in addition, two of these units will have high efficiency and charcoal filters for air cleanup, located in the reactor building outside the secondary shielding. These will recirculate and cool the reactor building atmosphere. The coolers will use component cooling water as the heat removal medium. The fan units will discharge the cooled air through ducts to provide adequate distribution to the building and equipment. Three half capacity control rod mechanism cooling units with cooling coils will be provided for control rod drives. In addition, eight auxiliary circulating fan units will circulate air around the lower part of the secondary shielding. Two full capacity reactor cavity ventilators will circulate the air from the reactor cavity to the upper part of reactor building through the steam generator housings. 2

The purge system discharge to the plant vent will be monitored and alarmed to prevent release exceeding acceptable limits.

5.7.2.1 Isolation Valves

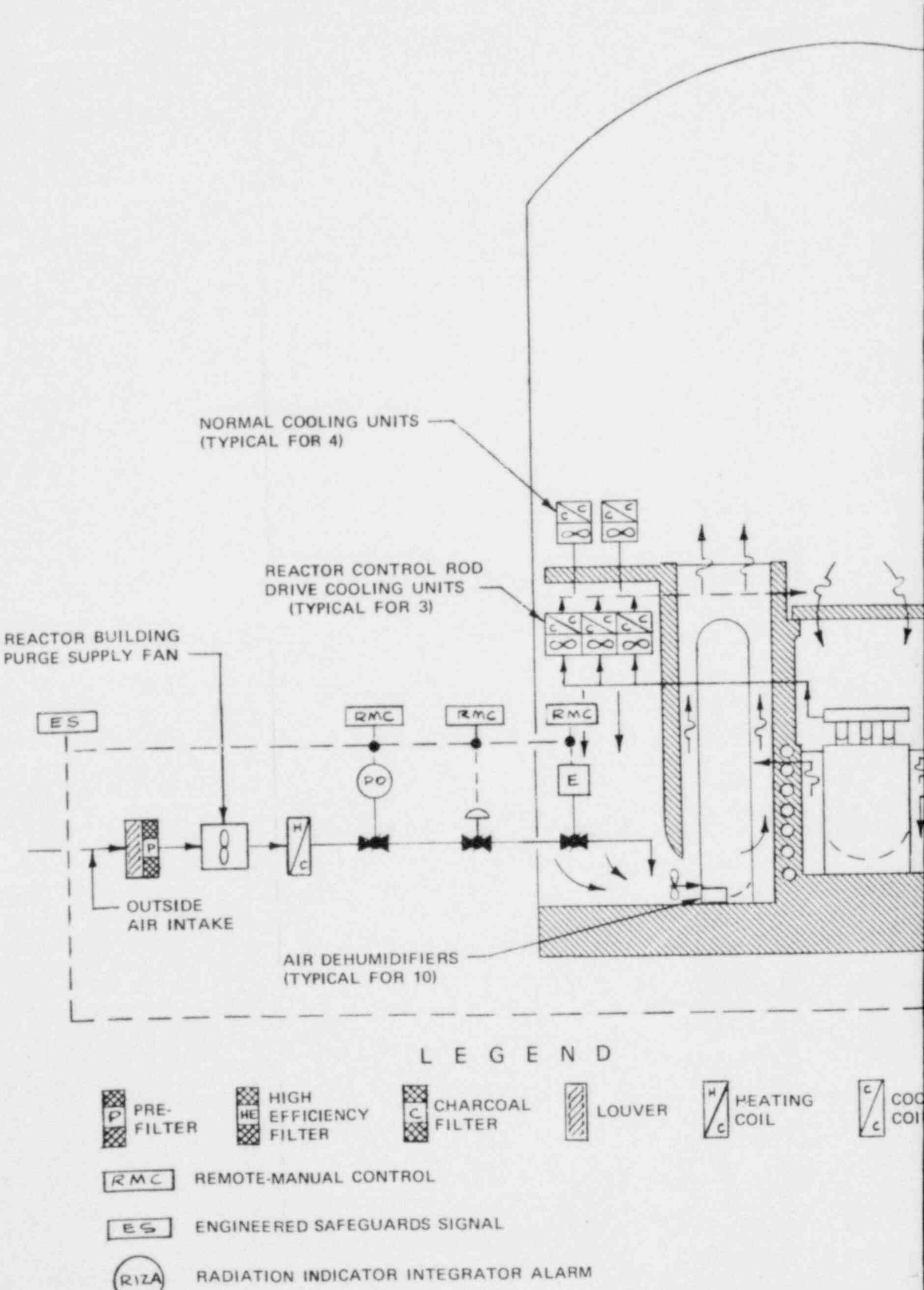
As the normal cooling system is contained completely within the reactor building, it will not include provisions for any isolation valves other than on cooling water lines. The purge system will be provided with double automatic isolation valves (or dampers) in both the supply and discharge ducts and the pressure equalizing valve in the discharge duct. These valves will be normally closed and will be opened only for the purging operation. They will be electrically actuated (by pressure and radiation signals) inside the reactor building and pneumatically actuated outside the reactor building.

The isolation signal and controls are discussed in 5.6.1. The closure times and sequence will be developed during detailed design and safety analyses. Operability testing of the isolation valves is accomplished each time the purge system is put into operation.

5.7.2.2 Pressure Equalizing Valves

The pressure equalizing valve by-passes the external isolation valve on the purge discharge line. When the reactor building is under positive pressure the equalizing valve is opened and the reactor building pressure allowed to bleed gradually to the plant vent. After equalization the purge fan will be started.

When the building is under negative pressure the building pressure will be equalized by starting the purge fan and opening the purge inlet line only. After building and atmospheric pressure is equalized the purge discharge line will be opened.


NORMAL COOLING UNITS (TYPICAL FOR 4)
REACTOR CONTROL ROD DRIVE COOLING UNITS (TYPICAL FOR 3)
REACTOR BUILDING PURGE SUPPLY FAN
ES
RMC
RMC
RMC
PO
E
P
H
C
OUTSIDE AIR INTAKE
AIR DEHUMIDIFIERS (TYPICAL FOR 10)
LEGEND
P PRE-FILTER
HE HIGH EFFICIENCY FILTER
C CHARCOAL FILTER
LOUVER
H C HEATING COIL
RMC REMOTE-MANUAL CONTROL
ES ENGINEERED SAFEGUARDS SIGNAL
RIZA RADIATION INDICATOR INTEGRATOR ALARM

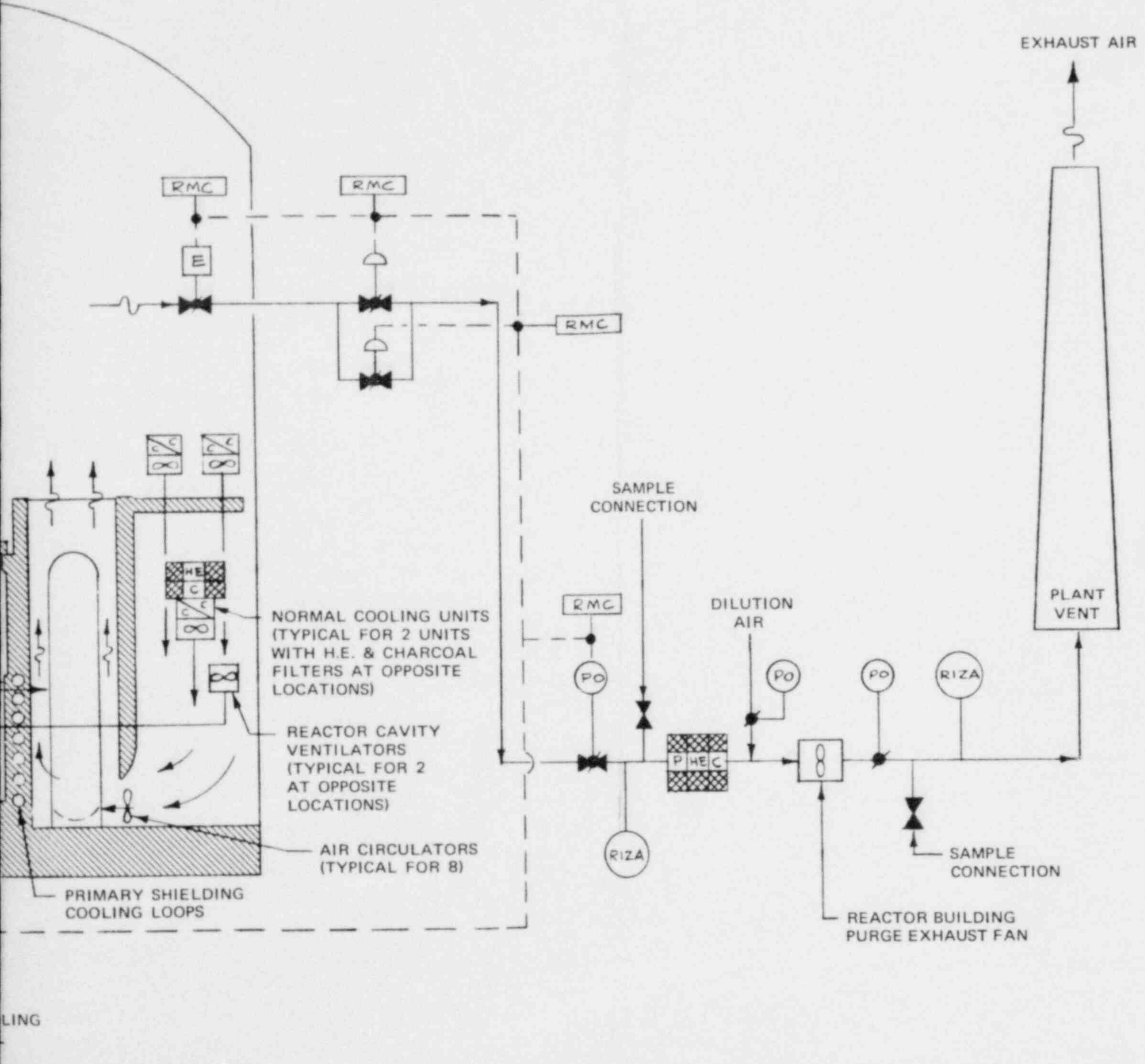


FIGURE 5.7-1
REACTOR BUILDING NORMAL
VENTILATION SYSTEM

5.8 LEAKAGE MONITORING SYSTEM

The barrier to leakage from the reactor building is the prestressed concrete containment and steel liner plate. The steel liner plate is securely attached to the prestressed concrete reactor building and is an integral part of this structure.

All penetrations through the containment shell for pipes, ducts, electrical conductors, and access will be welded to the liner plate before the concrete is placed. Insofar as possible, the penetrations, nozzles and reinforcing plates will be shop-welded assemblies. All electrical penetrations canisters in the reactor building will be of the double barrier type and will be equipped for periodic leakage monitoring with means provided to isolate and locate a leaking penetration canister. All penetrations, as shown typically in Figure 5.1-2 will be designed, fabricated, and tested so as to ensure leak tightness.

The liner plate will be anchored to the concrete shell so as to ensure elastic stability under all loading conditions and composite action between the liner and the concrete. Elastic stability will be ascertained by analyzing the liner as a flat plate between supports subjected to the biaxial stresses. Should liner stresses under the factored load conditions exceed yielding in compression, the analysis will assume plastic behavior at a stress of 1.2 times the minimum guaranteed yield stress.

Thorough control will be maintained over the quality of all materials and workmanship during all stages of fabrication and erection of the liner plate and penetration nozzles and during construction of the entire reactor building. During construction, the entire length of every seam weld in the liner plate is leak-tested. Individual penetration nozzle assemblies are shop-tested. Welded connections between penetration nozzle assemblies and the liner plate are individually leak-tested after installation. Following completion of construction, the entire reactor building, the liner and all its penetrations are tested at 115 percent of the design pressure to establish structural integrity. The initial leak rate test of the entire reactor building is conducted at 100 percent of the design pressure and at successively lower pressures to demonstrate vapor tightness and to establish a reference for periodic leak testing for the life of the station.

Where the liner abuts concrete, it will be in an environment which will minimize any possible corrosion. Cathodic protection will be provided if required to minimize any ground corrosion influences. Where the liner is exposed, it will be protected with a suitable coating. The concrete shell will protect the liner from weather influences and potential externally-generated missiles and insulate the liner plate from low temperatures. The liner surface on the interior of the vessel will be protected from internally-generated missiles.

As described in 5.2.1.3, the personnel access hatches will be interlocked so as to ensure that one barrier will always remain intact, and that annunciators will be provided in the control room to indicate when a door is open. The permanent equipment access hatch cannot be opened except by extensive deliberate action which cannot be taken except at plant shut down. The purge system will be provided with double automatic isolation valves (or dampers) in both the supply and discharge ducts. These valves will be normally closed and will be opened only for the purging operation. They will be electrically actuated inside the reactor building and pneumatically actuated outside the reactor building. Should there be any indications of abnormal leakage, individual major penetrations or groups of penetrations will be tested by means of permanently-installed pressure connections. The source of excessive leakage will be located and such corrective action as necessary, will be taken. This will consist of repair or replacement. Leak testing will be continued until a satisfactory leak rate has again been demonstrated.

This reactor building is conservatively designed and rigorously analyzed for the extreme loading conditions of a highly improbable hypothetical accident, as well as for all other types of loading conditions which could be experienced.

Under all normal operating conditions and under accidental conditions virtually no possibility exists that any leakage could occur or that the integrity of the vapor barrier could be violated in any way that would be significant to the public health and safety or to that of the station personnel. Adequate administrative controls will be enforced to minimize the possibility of human error. Station operators will be trained and licensed in accordance with regulations. Safety analyses are presented in Section 14.

A considerable background of operating experience is being accumulated on containments and penetrations. Full advantage of this knowledge will be taken in all phases of design, fabrication, installation, inspection, testing and operation. Three stations with similar containment designs will immediately precede this station. Practical improvements in design and details will be incorporated as they are developed, where applicable.

[redacted]

5.9 SYSTEM DESIGN EVALUATION

The reactor building, including extensions of the containment boundary will, with the functioning of the additional engineered safeguards, prevent an uncontrolled release of radioactivity to either the plant site or the surrounding areas during normal operation or any accident conditions up to the most severe hypothetical accident.

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[redacted]