CHAPTER 5

CONTAINMENT

5.1 CONTAINMENT SYSTEM STRUCTURES

5.1.1 Design Basis

The Reactor Containment completely encloses the entire reactor and Reactor Coolant System and ensures that essentially no leakage of radioactive materials to the environment would result even if gross failure of the Reactor Coolant System were to occur. The liner and penetrations were designed to prevent any leakage through the containment. The structure provides biological shielding for both normal and accident situations.

The Reactor Containment was designed to safely withstand several conditions of loading and their credible combinations. The major loading conditions were:

a) Occurrence of a gross failure of the Reactor Coolant System which creates a high pressure and temperature condition within the containment.
b) Coincident failure of the Reactor Coolant System with an earthquake or wind.

5.1.1.1 Principal Design Criteria

The General Design Criteria presented and discussed in this section are those which were in effect at the time when Indian Point 3 was designed and constructed. These general design criteria, which formed the basis for the Indian Point 3 design, were published by the Atomic Energy Commission in the Federal Register of July 11, 1967, and subsequently made a part of 10 CFR 50.

The Authority has completed a study of compliance with 10 CFR Parts 20 and 50 in accordance with some of the provisions of the Commission's Confirmatory Order of February 11, 1980. The detailed results of the evaluation of compliance of Indian Point 3 with the General Design Criteria presently established by the Nuclear Regulatory Commission (NRC) in 10 CFR 50 Appendix A, were submitted to NRC on August 11, 1980, and approved by the Commission on January 19, 1982. These results are presented in Section 1.3.

Quality Standards

Criterion: Those systems and components of reactor facilities which are essential to the prevention, or the mitigation of consequences, of nuclear accidents which could cause undue risk to the health and safety of the public shall be identified and then designed, fabricated, and erected to quality standards that reflect the importance of the safety function to be performed.

Where generally recognized codes and standards pertaining to design, materials, fabrication, and inspection are used, they shall be identified. Where adherence to such codes or standards does not suffice to assure a quality product in keeping with the safety function, they shall be supplemented or modified as necessary. Quality assurance programs, test procedures, and inspection acceptance criteria to be used shall be identified. An indication of the applicability of codes, standards, quality assurance programs, test procedures and inspection acceptance criteria used is

required. Where such items are not covered by applicable codes and standards, a showing of adequacy is required. (GDC 1 of 7/11/67)

The containment system structure is of primary importance with respect to its safety function in protecting the health and safety of the public. Quality standards of material selection, design, fabrication, and inspection governing the above features conformed to the applicable provisions of recognized codes and good nuclear practice. The concrete structure of the reactor containment conformed to the applicable portions of ACI-318-63. Further elaboration on quality standards of the reactor containment is given in Section 5.1.1.5.

Performance Standards

Criterion: Those systems and components of reactor facilities which are essential to the prevention or to the mitigation of the consequences of nuclear accidents which could cause undue risk to the health and safety of the public shall be designed, fabricated, and erected to performance standards that enable such systems and components to withstand, without undue risk to the health and safety of the public, the forces that might reasonably be imposed by the occurrence of an extraordinary natural phenomenon such as earthquake, tornado, flooding conditions, high wind or heavy ice. The design bases so established shall reflect: (a) appropriate consideration of the most severe of these natural phenomena that have been officially recorded for the site and the surrounding area and (b) an appropriate margin for withstanding forces greater than those recorded to reflect uncertainties about the historical data of their suitability as a basis for design. (GDC 2 of 7/11/67)

All components and supporting structures of the Reactor Containment were designed so that there is no loss of function of such equipment in the event of design basis ground acceleration acting in the horizontal and vertical directions simultaneously.

The dynamic response of the structure to ground acceleration, based on the site characteristics and on the system damping, was included in the design analysis.

The Reactor containment is defined as a seismic Class I structure for purposes of seismic design (Chapter 16). Its structural members have sufficient capacity to accept without exceeding specified stress limits, a combination of normal operating loads, functional loads due to a Loss-of-Coolant Accident, and the loadings imposed by the design basis earthquake.

Fire Protection

Criterion: A reactor facility shall be designed to ensure that the probability of events such as fires and explosions and the potential consequences of such events will not result in undue risk to the health and safety of the public. Non-combustible and fire resistant materials shall be used throughout the facility wherever necessary to preclude such risk, particularly in areas containing critical portions of the facility such as containment, control room, and components of engineered safety features. (GDC 3 of 7/11/67)

Fire protection in all areas of the nuclear electric plant is provided by structure and component design which optimizes the containment of combustible materials and maintains exposed combustible material below the ignition temperature. The station was designed on the basis of limiting the use of combustible materials in construction by using fire resistant materials to the

greatest extent practical. The Reactor Containment System was designed to maintain its capability in case of fire to safely shut down and isolate the reactor. Since containment recirculation ventilation charcoal filters are required, special manually-actuated sprays are installed which are operable from the Control Room. Containment liner thermal insulation does not support combustion. Fire headers are provided inside Containment and the Reactor Coolant Pumps are provided with an oil collection system. For additional details on fire protection features, see Section 9.6.2.

Records Requirements

Criterion: The reactor licensee shall be responsible for assuring the maintenance throughout the life of the reactor of records of the design, fabrication, and construction of major components of the plant essential to avoid undue risk to the health and safety of the public. (GDC 5 of 7/11/67)

Records of the design, fabrication, construction and testing of the reactor containment are maintained throughout the life of the reactor.

Reactor Containment

Criterion: The containment structure shall be designed (a) to sustain without undue risk to the health and safety of the public, the initial effects of gross equipment failures, such as a large reactor coolant pipe break, without loss of required integrity, and (b) together with other engineered safety features, as may be necessary, to retain for as along as the situation requires, the functional capability of the containment to the extent necessary to avoid undue risk to the health and safety of the public. (GCD 10 to 7/11/67)

The design pressure and temperature of the Containment exceed the peak pressure and temperature occurring as the 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 reactor coolant pipe. Energy contribution from the steam system was included in the calculation of the containment pressure transient due to reverse heat transfer through the steam generator tubes. The supports for the Reactor Coolant System were 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.

The containment structure and all penetrations were designed to withstand, within design limits, the combined loadings of the Design Basis Accident and design basis seismic conditions.

All piping systems which penetrate the vapor barrier are anchored at the liner. The penetrations for the main steam, feedwater, blowdown and sample lines were designed so that the penetration is stronger than the piping system and that the vapor barrier is not breached due to a hypothesized pipe rupture combined, for the case of the steam line, with the coincident internal pressure. The pipe capacity in the flexure was assumed to be limited to the plastic moment capacity based upon the ultimate strength of the pipe material. All lines, with the exception of small bore lines, 2" and smaller connected to the Primary Coolant System that penetrate the vapor barrier were also anchored at or within the secondary shield walls (i.e., walls surrounding the steam generators and reactor coolant pumps) and are each provided with at least one valve between the anchor and the Reactor Coolant System. These anchors were

designed to withstand the thrust, moment and torque resulting from a hypothesized rupture of the attached pipe.

All isolation valves are supported to withstand, without impairment of valve operability, the combined loadings of the design basis accident and design basis seismic conditions.

Appendix 4B includes a discussion of the details of the design of primary system supports. In addition, the design pressure will not be exceeded during any subsequent long-term pressure transient determined by the combined effects of heat sources, such as residual heat and limited metal-water reactions, structural heat sinks and the operation of the engineered safeguards: the latter utilizing only the emergency electric power supply.

Reactor Containment Design Basis

Criterion: The reactor containment structure, including openings and penetrations, and any necessary containment heat removal systems, shall be designed so that the leakage of radioactive materials from the containment structure under conditions of pressure and temperature resulting from the largest credible energy release following a Loss-of-Coolant Accident, including the calculated energy from metal-water or other chemical reactions that could occur as a consequence of failure of any single active component in the emergency core cooling system will not result in undue risk to the health and safety of the public. (GDC 49 of 7/11/67)

The following general criteria were followed to assure conservatism in computing the required structural load capacity:

a) In calculating the containment pressure, rupture sizes up to and including a double-ended severance of reactor coolant pipe were considered.

b) In considering post-accident pressure effects, various malfunctions of the emergency systems were evaluated. Contingent mechanical or electrical failures were assumed to disable one of the diesel generators, one of the five fan-cooler units and one of the two containment spray units. Equipment which can be run from diesel power is described in Chapter 8.

c) The pressure and temperature loadings obtained by analyzing various Loss-of-Coolant accidents, when combined with operating loads and maximum wind or seismic forces, do not exceed the load carrying capacity of the structure, its access opening or penetrations.

The most stringent case of these analyses is summarized below:

Discharge of reactor coolant through a double-ended rupture of the main loop piping, followed by operation of only these engineered safety features which can run simultaneously with power from two of the three on-site diesel generators (two high head safety injection pumps, one recirculation pump, four fan cooler units, one spray pump), results in a sufficiently low radioactive materials leakage from the containment structure that there is not undue risk to the health and safety of the public.

NDTT Requirement for Containment Material

Criterion: The selection and use of containment materials shall be in accordance with applicable engineering codes. (GDC 50 of 7/11/67)

The selection and use of containment materials compiled with the applicable codes and standards tabulated in Section 5.1.1.5.

The concrete containment is not susceptible to a low temperature brittle fracture.

The containment liner is enclosed within the Containment and thus is not exposed to the temperature extremes of the environs. The containment ambient temperature during normal operation is between 50°F and 130°F. This includes both hot operating and cold shutdown conditions. The minimum service metal temperature of the containment liner is at least 30^{O} F higher than the NDT temperature for the liner material. The Equipment Hatch, penetration sleeves and Personnel Lock meet the Charpy V-notch impact values for a minimum of 15 ft-lbs at -50°F. Penetration "SS" end plates were replaced in 1997 and the Charpy V-notch impact values were determined.

5.1.1.2 Supplementary Accident Criteria

Systems relied upon to operate under post-accident conditions, which are located external to the containment and were considered to be extensions of the leakage boundary.

The pressure retaining components of the containment structure were designed for the maximum potential earthquake ground motion of the site combined with the simultaneous loads of the design basis accident as follows:

1) The liner was designed to ensure that no average strains greater than the strain at the guaranteed yield point occur at the factored loads.

2) The mild steel reinforcement was generally designed to ensure that no strains greater than the strain at the guaranteed yield point occur at a cross section under the factored loads.

The pressure retaining components of containment subject to deterioration or corrosion in service were provided with appropriate protective means or devices (e.g., protective coatings).

5.1.1.3 Energy and Material Release

The design pressure is not exceeded during any subsequent long term pressure transient determined by the combined effects of heat sources such as residual heat and metal-water reactions, structural heat sinks and the operation of other engineered safety features utilizing only the emergency onsite electric power supply.

The design pressure and temperature on the containment structure are those created by the hypothetical Loss-of-Coolant Accident. The Reactor Coolant System contains approximately 512,000 lb of coolant at a weighted average enthalpy of 595 Btu/lb for a total energy of 304,000,000 Btu. In a hypothetical accident, this water is released through a double-ended break in the largest reactor coolant pipe, causing a rapid pressure rise in the containment. The reactor coolant pipe used in the accident is the 29 inch ID section because rupture of the 31

inch ID section requires that the blowdown go through both the 29 inch and the 27-1/2 inch ID pipes and would, therefore, result in a less severe transient.

Additional energy release was considered from the following sources:

a) Stored heat in the reactor core
b) Stored heat in the reactor vessel piping and other Reactor Coolant System components
c) Residual heat production
d) Limited metal-water reaction energy and resulting hydrogen-oxygen reaction energy

The following loadings were considered in the design of the containment in addition to the pressure and temperature conditions described above:

a) Structure dead load
b) Live loads
c) Equipment loads
d) Internal test pressure
e) Earthquake
f) Wind
g) Tornado

The capability of the Containment to withstand additional energy releases is discussed in Chapter 14.

5.1.1.4 Engineered Safety Features System Contributions

Five types of engineered safety features were included in the design of this facility to assure containment integrity. These systems are discussed in Chapter 6 and their effectiveness is analyzed in Chapter 14.

5.1.1.5 Codes and Classifications

The design, materials, fabrication, inspections, and proof testing of the containment vessel complies with the applicable parts of the following:

STRUCTURAL

	Code	Title
1.	ASTM A-333, Gr. 1	Specification for Seamless and Welded Steel Pipe for Low Temperature Service
2.	ASTM A-181	Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service
3.	ASTM A-300, C1. 1	Specification for Notch Toughness Requirements for Normalized Steel Plates for Pressure Vessels
	Firebox A-201, Gr. B	Specification for Carbon Silicon Steel Plates

	of Intermediate Tensile Ranges for Fusion Welded Boilers and Other Pressure Vessels
4. ASTM A-36, Gr. C	Specification for Structural Steel
5. ASTM A-131, Gr. C	Specification for Structural Steel for Ships
6. ASTM A-240	Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels
7. ASTM A-312	Specification for Seamless and Welded Austenitic Stainless Steel Pipe
8. ASTM 442, Grade 60	Standard Specification for Carbon Steel Plates with Improved Transition Properties
9. ASME Boiler & Pressure Vessel Code-Section III	Nuclear Vessels
10. ASME Boiler & Pressure Vessel Code-Section VIII	Unfired Pressure Vessels
11. ASME Boiler & Pressure Vessel Code-Section IX	Welding Qualifications
12. ASTM C-33	Standard Specifications for Concrete Aggregates
13. ASTM C-150	Standard Specifications for Portland Cement
14. ASTM C-172	Method of Sampling Fresh Concrete
15. ASTM C-31	Method of Making and Curing Concrete Compression and Flexure Test Specimen in Field
16. ASTM C-39	Method of Test for Compressive Strength of Molded Concrete Cylinders
17. ASTM C-350	Specification for Fly Ash for Use as an Admixture in Portland Cement Concrete
18. ASTM C-94	Recommended Practice for Winter Concreting
19. ASTM C-42	Methods of Securing, Preparing, and Testing Specimens from Hardened Concrete for Compressive and Flexural Strengths

20.	ASTM C-494	Specifications for Chemical Admixtures for Concrete
21.	ASTM A-305	Specifications for Miminum Requirements for Deformation of Deformed Bars for Concrete Reinforcement
22.	ASTM A-408	Specifications for Special Large Size Deformed Billet-Steel Bars for Concrete Reinforcement
23.	ASTM A-432	Specification for Deformed Billet Steel Bars for Concrete Reinforcement with 60,000 psi Minimum Yield Strength
24.	Research Council of Reveted & Bolted Structural Joints of the Engineering Foundation	Specification for Structural Joints Using ASTM A-325 Bolts
25.	ACI-613	Recommended Practice for Selecting Proportions for Concrete
26.	ACI-306	Recommended Practice for Winter Concreting
27.	ACI-318, Part IV-B	Structural Analysis and Proportioning of Members Ultimate Strength Design
28.	ACI-318	Building Code Requirements for Reinforced Concrete
29.	ACI-505	Reinforced Concrete Chimney Design
30.	ACI-315	Manual of Standard Practice for Detailing Reinforced Concrete Structures
31.	ASME Nuclear Vessels Code	---
32.	ASA N6.2	Safety Standards for the Design, Fabrication and Maintenance of Steel Containment Structures for Stationary Nuclear Power Reactors
33.	ASA A58.1	American Standard Code Requirements for Minimum Design Loads in Building and Other Structures
34.	--	State Building and Construction Code for the State of New York

35. SSPC-SP-6 — Commercial Blast Cleaning

36. ASME Boiler & Pressure Vessel Code-Section XI — Rules for in service inspection of Nuclear Power Plant Components.

5.1.2 Containment System Structure Design

5.1.2.1 General Description

The reactor containment structure is a reinforced concrete vertical right cylinder with a flat base and hemispherical dome. A welded steel liner with a minimum thickness of ¼ inch is attached to the inside face of the concrete to insure a high degree of leak-tightness. The design objective of the containment structure was to contain all radioactive material which might be released from the core following a Loss-of-Coolant Accident. The structure serves as both a biological shield and a pressure container.

The structure, as shown on Figure 5.1-1 and Plant Drawings 9321-F-25013, -25023, -25033, -25063, -25073, and -25083 [Formerly Figures 5.1-2 through 5.1-7], consists of side walls measuring 148 feet from the liner on the base to the springline of the dome, and has an inside diameter of 135 feet. The side walls of the cylinder and the dome are 4'-6" and 3'-6" thick, respectively. The inside radius of the dome is equal to the inside radius of the cylinder so that the discontinuity at the springline due to the change in thickness is on the outer surface. The flat concrete base mat is 9 feet thick with the bottom liner plate located on top of this mat. The bottom liner plate is covered with 3 feet of concrete, the top of which forms the floor of the Containment.

Where uplift from pressure occurs at the outer areas of the mat, the 9-ft thick mat has sufficient flexural capacity to resist the uplift until it is dissipated.

No hydraulic uplift exists since the bottom elevation of the mat is considerably higher than that of the high water level.

The large mass of the Containment including interior concrete and equipment makes the structure inherently stable from overturning due to seismic motion or tornado.

In addition, keying action from the reactor pit and sumps, plus friction between the concrete and rock, prevents sliding of the structure from horizontal ground motion.

The basic structural elements that were considered in the design of the containment structure are the base slab, side walls and dome acting as one structure under all possible loading conditions. The liner is anchored to the concrete shell by means of stud anchors. The reinforcing in the structure exhibits a total elastic response to all primary loads. The lower portion of the cylindrical liner is insulated to avoid thermal deformation of the liner under accident conditions.

The containment structure is inherently safe with regard to common hazards such as fire, flood and electrical storm. Internal structures consist of equipment supports shielding, reactor cavity and canal for fuel transfer, and miscellaneous concrete and steel for floors and stairs. All internal structures are supported on the 2'-8" thick floor slab.

A 3-foot thick concrete ring wall serving as a missile and partial radiation shield surrounds the Reactor Coolant System components and supports the polar-type reactor containment crane. A 2-foot thick reinforced concrete floor covers the Reactor Coolant System with removable gratings in the floor provided for crane access to the Reactor Coolant Pumps. The four steam generators, pressurizer and various pipings penetrate the floor. Spiral and scissor stairs provide access to the areas below the floor. There is a reinforced concrete missile shield wall around the pressurizer above the operating floor. The original design is to protect the containment steel liner from postulated valve piece or instrument missiles connected to the pressurizer. Currently these missiles have been shown not to be credible.

The refueling canal connects the reactor cavity with the fuel transport tube to the spent fuel pool. The floor and walls of the canal are concrete, with wall and shielding water providing the equivalent of 6 feet of concrete. The floor is 4-feet thick. The concrete walls and floor are lined with ¼-inch thick stainless steel plate. The linings provide a leakproof membrane that is resistant to abrasion and damage during fuel handling operation.

A sub-surface drainage system is provided around the Containment Building where the mat is below grade as shown in Figure 5.1-11. Since the containment is above the water table, no hydrostatic seepage will occur.

The detailed structural design and analysis of the Containment System is presented in Appendix 5A. See also Sections 16.1 and 16.4 for seismic analysis.

5.1.2.2 General Design Criteria

The following loads were considered to act upon the containment structure creating stresses within the component parts:

a) Dead load consisted of the weight of the concrete wall, dome, liner insulation, base slab and the internal concrete.

b) Live load consisted of snow and construction loads on the dome and major components of equipment in the containment. Snow and ice loads were assumed to be applied uniformly to the top surface of the dome. A construction live load of 50 pounds per square foot was used on the dome, but was not considered to act concurrently with the snow load. Equipment loads were considered as specified on the drawings supplied by the manufacturers of the various pieces of equipment.

c) The internal pressure transient used for the containment design and its variation with time is shown on the pressure-temperature transient curve, Figure 5.1-8. For the free volume of 2,610,000 cubic feet within the containment, the design pressure is 47 psig. This pressure transient is more severe than those calculated for various Loss-of-Coolant Accidents which are presented in Chapter 14.

d) Thermal expansion stresses due to internal temperature increase caused by a Loss-of-Coolant Accident were considered. This temperature and its variation with time are shown on the pressure-temperature transient curve, Figure 5.1-8. The maximum temperature at the uninsulated section of the liner under accident conditions is 247°F. For the 1.25 times and 1.50 times design pressure loading conditions, the corresponding liner temperatures will be 285°F and 306°F respectively. The pressure temperature transient curves for these loading conditions are shown in

Figures 5.1-9 and 5.1-10, respectively. The maximum operating temperature is 130°F. The design 24-hour mean-low ambient temperature is -5°F.

e) The ground acceleration for the operational basis earthquake was determined to be 0.1g applied horizontally and 0.05g applied vertically. These values were resolved as conservative numbers based upon recommendations from Dr. Lynch, then Director of Seismic Observatory, Fordham University.

A dynamic analysis was used to arrive at equivalent design loads. Additionally, a design basis earthquake ground acceleration of 0.15 horizontal and 0.10 vertical was used to analyze for the no-loss of function. This is discussed in Section 5.1.3.5, Seismic Design Summary.

f) The American Standards Association "American Standard Code Requirements for Minimum Design Loads in Buildings and Other Structures" (A58.1-1955) designated the site as being in a 25 psf zone. In this code, for height zones between 100 and 499 feet, the recommended wind pressure on a flat surface was 40 psf. Correcting for the shape of the containment by using a shape factor of 0.60, the recommended pressure becomes 24 psf. The State Building and Construction Code for the State of New York stipulated a wind pressure up to 30 psf on a flat surface for heights up to 600 feet. For design, a 30 psf basic wind load was used from ground level up.

g) Internal pressure was applied to test the structural integrity of the vessel up to 115 percent of the design pressure. For this structure, the test pressure was 54 psig.

h) Tornado loads consisted of 300 mph tangential wind traveling with a forward velocity of 60 mph. Also considered as a separate and as a combined loading combination was a 3.0 psi pressure drop external to the structure. In addition, horizontal and vertical missile loads were considered as specified in Section 2.1.5 of Appendix 5A.

5.1.2.3 Material Specifications

Basically, four materials were used for the construction of the containment vessel. These are:

a) Concrete
b) Reinforcing Steel
c) Plate Steel Liner
d) Insulation

Details of material properties, fabrication and erection requirements and material test results are presented in Appendix 5A, Section 5.0. Basic specifications for these materials were as follows:

a) Concrete is a dense, durable mixture of sound coarse aggregate, fine aggregate, cement and water. Aggregates conformed to American Society for Testing Materials Specification C-33 "Standard Specification for Concrete Aggregates." Aggregates consisted of inert materials that were clean, hard, durable, free from organic matter and uncoated with clay or dirt. Fine aggregate consisted of natural sand and the coarse aggregate of crushed stone. Fine aggregate tests performed include gradation, fineness modulus, specific gravity, unit weight, organic impurities, soundness (5 cycles Na_2SO_4) silt content and structural strength of sand in relation to Ottawa sand.

Coarse aggregate tests included gradation, fineness modulus, specific gravity, unit weight, soundness (5 cycles Na_2SO_4), soft particles and Los Angeles abrasion test.

Portland cement conformed to American Society for Testing and Material Specification C-150-65. Manufacturer's mill test reports were required covering each silo of cement drawn for the project.

Water was free from any injurious amounts of chloride, acid, alkali, salts, oil, sediment or organic matter, and fit for drinking.

A testing laboratory tested materials for concrete, designed mixes, tested check mix at batch plant and jobsite, and tested job concrete test cylinders. Design mixes were checked by the laboratory, including adjustments to obtain a workable mix based on specification requirements, and verified by trial batches and laboratory test.

The only admixtures in the concrete were PLACEWELL and AIRECON, both products of Union Carbide. PLACEWELL is a liquid, water-reducing admixture and AIRECON is a liquid air-entraining admixture, both of which enhance the properties of plastic and hardened concrete. PLACEWELL conformed to all the requirements of ASTM C494 for a Type A water reducing admixture and contained no calcium chloride. AIRECON conformed to the requirements of ASTM C260 for Air Entraining Admixtures and also contained no calcium chloride. The mixing of concrete was done with a batch mixer of approved AGC type, or in ready-mix equipment conforming to ASTM Specification C94.

b) Reinforcing steel for the dome, cylindrical walls and base mat was high-strength deformed billet steel bars conforming to ASTM Designation A432-65 "Specification for Deformed Billet Steel Bars for Concrete Reinforcement with 60,000 psi Minimum Yield Strength" (Revised ASTM A615-68, Grade 60). This steel had 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. Reinforcing bars No. 11 and smaller in diameter were lapped spliced in the mat for flexural loadings and spliced by the Cadweld process in the walls and dome for tension loading. Bars No. 14S and 18S were spliced by the Cadweld process only. A certification of physical properties and chemical content of each heat of reinforcing steel delivered to the job site was issued from the steel supplier. The splices used to join reinforcing bars were sample tested to assure that they will develop at least 125% of the minimum yield point stress of the bar. The test program required cutting out, at random, approximately 2 percent of the completed splices and testing to determine their breaking strength, thus confirming the strength of both the bars and the splice.

In the Containment, vertical rebar splices were staggered a minimum of 1'-2". Seismic Diagonal Bar splices were staggered 1'-2" vertically in each direction. In the dome a 2'-0" stagger pattern was used throughout for the Cadweld splices as well as the reinforcing splice plates, except for final closure pieces at the apex of the dome. Horizontal rebar splices were splices were spliced in elevation and in cross-section (bars or bar pairs) with 2'-4" nominal and 2'-0" minimum stagger.

The above requirements were generally satisfied during construction except in special cases where physical or layout problems occurred in isolated areas in the containment.

For all other seismic Class I structures other than the Containment, rebars were lap spliced in accordance with the requirements of ACI-318-63 "Building Code Requirements for Reinforced Concrete." No specific stagger requirements were specified. In the Containment, mechanical splices were included because of the biaxial tensile stress conditions in the concrete, which eliminate bond and require continuous rebar, and the ACI-318 requirement that lapped splices in tension cannot be used for bars greater than No. 11.

c) The plate steel liner is carbon steel conforming to ASTM Designation A442-65 "Standard Specification for Carbon Steel Plates with Improved Transition Properties," Grade 60. This steel had a minimum yield strength of 32,000 psi and minimum tensile strength of 60,000 psi with an elongation of 22 percent in an 8-inch gauge length at failure.

   The liner is ¼-inch thick at the bottom, ½-inch thick in the first three courses and 3/8-inch thick for remaining portion of cylindrical walls except ¾-inch thick at penetrations and ½-inch thick in the dome. The liner material has been tested to assure an NDT temperature more than 30 F lower than the minimum operating temperature of the liner material.

   Impact testing was done in accordance with Section N331 of Section III of the ASME Boiler and Pressure Vessel Code. A 100 percent visual inspection of the liner anchors was made prior to pouring concrete.

d) The material for insulating the liner plate is urethane foam covered with gypsum board and a stainless steel jacket and backed with asbestos paper on the unexposed side. This insulation was selected to withstand the calculated temperature and pressure conditions associated with Figures 5.1-8, 5.1-9, 5.1-10.

e) Quality of both materials and construction of the containment vessel was assured by a continuous program of quality control and inspection. These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC. The Quality Assurance Program (described in Entergy's Quality Assurance Program Manual) covers modification and maintenance activities.

5.1.2.4 Structural Design Criteria

The design was based upon limiting load factors which were used as the ratio by which loads will be multiplied for design purposes to assure that the loading deformation behavior of the structure is one of elastic, tolerable strain behavior.

The load factor approach was 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 permitted 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. In the case of the containment structure, therefore, this approach placed minimum emphasis on

the fixed gravity loads and maximum emphasis on accident and earthquake or wind loads. The loads utilized to determine the required limiting capacity of any structural element on the containment structure are presented in Appendix 5A, Section 2.1.0.

The load factors utilized in this design were based upon the load factor concept employed in Part IV-B, “Structural Analysis and Proportioning of Members Ultimate Strength Design” of ACI 318-63. Because of the refinement of the analysis and the restrictions on construction procedures, the load factors in the design primarily provide for a safety margin on the load assumptions. Specific combined load equations used in design are presented in Section 2.1.14 of Appendix 5A. The load factors were chosen in a conservative manner to insure that the structure as designed would respond to design loads with elastic strain behavior.

The primary load in the containment structure analysis is the accident pressure load. Since the formulas for analysis were based on thin shell considerations, resulting in tensile loads resisted by reinforcing, the same results would be obtained regardless of whether a load factor (ultimate) or reduced allowable stress (working) approach was used in design.

The load factors utilized plus the conservative assumptions used in analysis insured that the design for this portion of the structure was conservative. Conservative analysis assumptions included use of full concrete section for determining flexural rigidity thus drawing moment and shear to the stiffer base and use of only hoop steel as the spring constant which controls cylinder growth in the unrestrained area above the discontinuity.

Earthquake and wind loads were based on analysis with the Containment modeled as a cantilever beam. The loads are resisted by tension in rebar thus the same results would be obtained by working strength or ultimate strength design. Secondary, thermal loads were also carried by tension in the rebar and are thus independent of ultimate or working strength design.

Equilibrium checks can be easily made for the containment shell since thin shell membrane analysis was used in the design and only the rebar was assumed to carry the load. In addition, overturning moment for earthquake and tension caused by temperature were assumed carried by rebar only and thus easily checked for equilibrium.

In addition to the above analysis, non-membrane portions of the cylinder such as the Equipment Hatch opening were analyzed by a Finite Element Computer analysis. The results were checked to insure that internal stresses times resisting rebar area gave resultant forces equal to the applied external forces.

In areas of the Containment where tensile stresses in more than one direction occur, all stresses are carried by continuous mechanically spliced rebar. Therefore, stress limits of ACI-318-63 were applicable since concrete strength and rebar bond provided by concrete were not considered in design. The f'_c dependent factors were specified in the ACI-318-63 Code used only in the design of the base mat where a uni-axial stress condition exists and in the base of the Containment cylinder wall where hoop stresses are minimal. In the cylinder, radial shear forces are resisted only by rebar. Seismic shear forces are also resisted by rebar with no account taken of resistance offered by concrete.

All structural components were designed to have a capacity required by the most severe loading combination.

Thus, the design included the consideration of both primary and secondary stresses, and the load capacity in structural members was based on the ultimate strength values presented in Part IVB of ACI-318, as reduced by the capacity reduction factor "ϕ" which provided for the possibility that small adverse variations in material strengths, workmanship, dimensions, and control, while individually within required tolerances and the limits of good practice, occasionally may combine to result in under capacity. For tension members, the factor "ϕ" was established as 0.95. The factor "ϕ" was 0.90 for flexure and 0.85 for diagonal tension, bond and anchorage.

For the liner steel the factor "ϕ" was 0.95 for tension. For compression and shear, the primary membrane liner stress was maintained below 0.95 yield and elastic stability was assured as a function of liner anchorage requirements.

The liner was designed to assure that no strains greater than the strain at the guaranteed yield point will occur at the factored loads except in regions of local stress concentrations or stresses due to secondary load effects, in which case the liner strain was limited to 0.5 percent. Sufficient anchorage was provided to assure elastic stability of the liner. The basic design concept utilized stud anchorage of the liner plate to the concrete structure which assures stud failure due to shear, tension or bending stress without the stud connection causing failure or tear of the liner plate. See References 1 and 2. The studs in the ½ inch plate were installed on 24" horizontal and 28" vertical grid and in the 3/8-inch plate on a 24" horizontal and 14" vertical grid. The design considered the possibility of daily stress reversals due to ambient temperature changes for the life of the plant, and fatigue limit of the studs exceeds the design requirements.

5.1.2.5 Missile Protection

High pressure Reactor Coolant System equipment is surrounded by the 3'-0" concrete shield wall enclosing the reactor coolant loop and pressurizer and by the 2'-0" concrete operating floor.

A structure is provided over the control rod drive mechanism to block any missiles generated from fracture of the mechanisms.

Systems containing hot pressurized fluids that might affect the engineered safeguards components were carefully checked against the possibility of being sources of missiles. The general criterion adopted was to make provision, when necessary, against the generation of missiles rather than allow missile formation and try to contain their effects.

Once the design requirement that the above systems were not to be sources of missiles had been set forth, identification of potential deficiencies and generation of adequate fixes took place through the quality assurance program.

The following examples illustrate how this approach was implemented:

Valves

Valves installed in the Nuclear Steam Supply System were evaluated for the probability of their stem becoming missiles. Valve stems are not considered credible missile since at least one feature (in addition to the steam threads) is included in their design that will prevent stem ejection. Valve steams with backseats are prevented from becoming missiles by the backseat feature. Also, valve plugs are secured and locked to the valve stems to prevent loosening in service. In addition, valve stems of valves with power actuators, such as air-operated or motor-

operated valves are effectively restrained by the valve actuator. Valve stems of rotary motion valves, such as plug valves, ball valves, and butterfly valves, as well as diaphragm-type valves are not considered as credible missiles. This is because these valves do not have a large reservoir of pressurized fluid acting on the valve stem; therefore there is insufficient stored energy available to produce a missile.

Valves with nominal diameter larger than 2” were designed against bonnet-body connection failure and subsequent bonnet ejection by means of: (a) using the design practice of ASME Section VIII, ASME Section III and USAS B16.5 and (b) by controlling the load during the bonnet body connection stud tightening process.

Stud and nut material is ASTM A193-B7 and A194-2H, or approved equal. The proper stud torquing procedures and/or the use of a torque wrench with indication of the applied torque, control the stress of the stud to acceptable limits established by industry standards. The complete valves were hydro tested per USAS B16.5 (1500 lbs. USAS valves are hydro to 5400 psi). The cast stainless steel bodies and bonnets were radiographed and dye penetrant tested to verify soundness.

Valves with nominal diameter of 2" or smaller were forged and have screwed bonnet with canopy seal. The canopy seal is the pressure boundary while the bonnet threads were designed to withstand the hydrostatic end forces. The pressure containing parts were designed per criteria established by USAS B16.5 specification.

Valves with nominal diameter of 2” or smaller may be supplied with a screwed bonnet and canopy seal. The canopy seal is the pressure boundary while the bonnet threads were designed to withstand the hydrostatic end force. The pressure containing parts were designed per criteria established by the USAS B16.5 specification.

Reactor Coolant Pump Flywheel

The reactor coolant pump flywheel was not considered to be a credible source of missiles because of conservative design and care in manufacture and inspection. The flywheel material is ASTM A-533 having an NDTT less than 10 F. The design results in a primary stress less than 50% of the material yield strength at operating speed. The flywheel was subjected to 100% volumetric ultrasonic inspections which are repeated at intervals during plant life. The finished machined bore was subjected to examination by approved method. The design overspeed of the pump is 125%. The maximum pump overspeed on loss of external load is 112%.

5.1.2.6 Protection From Long-Term Corrosion

Steel members embedded in reinforced concrete structures are protected from corrosion by concrete in accordance with normal code requirements and hence are not exposed to the atmosphere.

All other steel appurtenances are not main structural load carrying members and are visible and accessible for regular maintenance. These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC. They are generally shop painted with red lead and finish painted with a standard finish paint.

5.1.3 Stress Analysis

5.1.3.1 General

The structural design of the Containment met the requirements established by 1961 edition of "The State Building and Construction Code for the State of New York" so far as these provisions were applicable. All concrete structures were designed, detailed and constructed in accordance with the provisions of "Building Code Requirements for Reinforced Concrete" (ACI-318-63) so far as these provisions were applicable. A detailed description of containment component design is presented in Appendix 5A, Section 4.0.

5.1.3.2 Method of Analysis

Basically three separate structural components were analyzed, each in equilibrium with loads applied to it and with constraints occurring at the juncture of the structures. The three components were:

a) The 135-ft ID hemispherical dome
b) The 135-Ft ID Cylinder
c) The base slab.

Mathematically, the dome and cylinder were treated as thin-walled shell structures, which resulted in a membrane analysis. Since the thickness of the dome and cylinder is small in comparison with the radius of curvature (1/15) and there are no discontinuities such as sharp bends in the meridional curves, the stresses due to pressure, tornado wind or earthquake were calculated by assuming that they are uniformly distributed across the shell thickness.

Since the concrete was not assumed to resist any tensile or shear forces, radial shear reinforcing was introduced in the lower portion of the wall in the form of hooked diagonal stirrups and diagonally bent bars as shown in Figure 5.1-1. Likewise, diagonal shear reinforcing in the circumferential direction was included to resist earthquake shears for the full height of the wall and a distance above the springline into the dome until a point was reached where the dome liner and meridional and hoop reinforcing can resist the total shear. The base slab was treated as a flat circular plate supported on a rigid non-yielding foundation.

5.1.3.3 Dome Analysis

The analysis of the hemispherical dome was performed by the superposition of membrane forces resulting from gravity, accident pressure and accident thermal loads. In addition, tornado, earthquake or wind loading create both direct and shear stresses in the dome and operating temperature of the liner creates tension and compression. All of the combined direct stresses are developed in the reinforcing steel encased in the concrete. The liner of the dome above a certain point can resist shear load and the anchorages were designed to assure composite action. The dome reinforcing was spliced to the vertical steel in the cylindrical concrete wall, so that a continuity between the dome and the cylinder was realized.

Discontinuity effects at the springline are very slight due to the small difference in radial growth between the dome and cylinder. Since the circumferential reinforcing in the dome and cylinder vary, stresses and, therefore, deformations are essentially equal.

5.1.3.4 Cylinder Analysis

The analysis of the cylinder was done by superposition of membrane forces resulting from gravity, pressure and thermal loads, over-turning due to tornado, earthquake or wind and shears due to tornado, earthquake or wind. The concrete was reinforced circumferentially using steel hoops and vertically by straight bars. Diagonal bars were placed to resist the horizontal and vertical shears due to tornado, earthquake or wind. The required capacity of the diagonal bars was designed so that the horizontal component per foot of the diagonals equaled the maximum value of shear flow.

A check was made to insure that no net compressive force results in the diagonal bars because of the combination of seismic shear load and internal pressure load. Although, in the cylinder, the liner has some capacity available to resist the seismic shears, no credit was taken for this capacity.

Only in the upper area of the dome (beyond about 30 degrees above the springline), where the seismic shears are small, does the liner help to resist shear. For all of the cylinder and the lower areas of the dome, the diagonal reinforcing was designed to accommodate all seismic shears. No credit was taken for the dowel action of the vertical and horizontal bars in resisting seismic shear. The maximum stress in the rebar beyond about 30 degrees above the springline due to an earthquake was determined by resolution of the principal tensile stress into components parallel to the rebar. This rebar provides an adequate mechanism to resist shear. (See Section 16.1).

A detailed description of the methods of analysis used for the containment concrete structures is presented in Appendix 5A, Section 4.0.

5.1.3.5 Seismic Design Summary

The design of the Containment which is a seismic Class I structure (see Chapter 16) was based on a “response spectrum” approach in the analysis of the dynamic loads imparted by earthquake. The seismic design took into account the acceleration response spectrum curves developed by G. Housner. Seismic accelerations were computed as outlined in the AEC TID-7024[3] and Portland Cement Publication[4].

As indicated in Chapter 16, ground accelerations used for Operational Basis Earthquake are 0.1g horizontally and 0.05g vertically and for the Design Basis Earthquake are 0.15g horizontally and 0.10g vertically. The natural period of vibration was computed by a dynamic analysis; in this method, the containment structure was analyzed a simple cantilever, consisting of lumped masses and weightless elastic columns acting as spring restraints. Both bending and shear deformations were considered. The natural frequencies and mode shapes were computed from the equations of motion of the lumped masses. These equations were solved by iteration techniques by a fully tested digital computer program. Based on an uncracked concrete section, the period was determined to be 0.241 Sec.

The response of each mode of vibration to the earthquake ground motion was computed by the response spectrum technique. The participation of each mode was computed and the relative acceleration of each mass was determined using the response spectrum curves for 2% and 5% critical damping. The total response was computed as the square root sum of the squares of the individual modes.

Seismic shears are resisted by diagonal reinforcing except in the upper areas of the dome. No credit was taken for the reinforcing in compression.

From 30 degrees above the springline, the shear is resisted by the liner and rebar. The shear is transmitted to the liner by means of tees welded to the liner.

To facilitate construction, a retaining wall was built to carry the roadway at Elevation +95.0 to the northeast quadrant of the Containment Building. There is no backfill between the retaining wall and the Containment, consequently, there was no lateral earth pressure factored into the seismic design.

5.1.3.6 Tornado Design Summary

The design of the Containment, which is a seismic Class I structure, considered the effects resulting from tornado loads.

Tornado wind loading was taken as 300 mph tangential wind traveling with a forward velocity of 60 mph. Also considered as a separate and as a combined loading condition was a 3.0 psi pressure drop external to the structure.

The wind load was considered for three tornado conditions. One included a tangential velocity of 300 mph and a translational velocity of 60 mph. This load superposition depicts a tornado condition where the funnel coincides with the center of the Containment. Load pressure distribution patterns that resulted due to various locations of the funnel were considered. The structure was designed for a triangular and a rectangular wind distribution of 360 mph.

The above wind loading and pressure drop design criteria were consistent with the generally accepted tornado design criteria utilized on nuclear power plants in the eastern United States.

The forces from wind loadings were computed based on ASCE Paper 3269-"Transactions of the ASCE Vol. 126 Part II 1961."

The forces were converted to a shear per lineal foot around the circumference of the Containment by distributing the shear over the circumference of the seismic reinforcing.

The resulting stresses were limited to yield strength or its equivalent as defined in ACI-318, Part IV B and modified as required by the capacity reduction factor Ø.

The seismic bars provide a more than adequate mechanism to withstand the torsional effect from tornado winds, therefore, tornado winds were not a controlling factor in the design of the containment structure.

In addition, the containment structure will withstand the following Tornado generated missiles (only one missile was considered acting at any time simultaneously with the 360 mph wind load):

Horizontal Missiles

1) 4" x 12' wood plank at 300 mph
2) 4000 lb auto at 50 mph less than 25' above the ground (25 ft2 contact area).

Vertical Missiles

1) 4" x 12' x 12' wood plank at 90 mph

2) 4000 lb auto at 17 mph less than 25' above the ground (25 ft2 contact area).

Specific structural effects as the result of missile impact are: 1) missile penetration and 2) structural response to dynamic impact. In addition to the overall structural effects such as overturning moment and base shear, the local structural effects must be considered in the design for tornado wind and generated missile loads. For missile loads, limited local plasticity, structural dynamic response ductility and redistribution of stresses in redundant structures due to plastic action was permitted.

Consideration of tornado loads was not a factor in the design of the Containment structure. The 3 psig negative pressure is approximately 4% of the maximum internal pressure load (1.5P=70.5 psig) thus stresses introduced into the rebar from this load are very small.

5.1.4 Penetrations

5.1.4.1 General

In general, a penetration consists of a sleeve embedded in the concrete wall and welded to the containment liner. The weld to the liner is shrouded by a continuously pressurized channel which is used to demonstrate the integrity of the penetration-to-liner weld joint. The pipe, electrical conductor cartridge, duct or equipment access hatch passed through the embedded sleeve and the ends of the resulting annulus were closed off, either by welded end plates, bolted flanges or a combination of these.

Differential expansion between a sleeve and one or more hot pipes passing through it was accommodated by using a bellows type expansion joint between the outer end of the sleeve and the outer end plate, as shown on Figure 5.1-12.

The components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Pressurizing connections were provided to continuously demonstrate the integrity of the penetration assemblies.

5.1.4.2 Types

Electrical Penetrations

"Cartridge" type penetrations are used for all electrical conductors passing through the Containment. The penetrations are provided with a pressure connection to allow continuous pressurization. Insulating bushings or fused glass seals are used to provide a pressure barrier for the conductor.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Figure 5.1-13 shows a design of typical electrical penetrations. There are approximately 60 electrical penetrations.

Piping Penetrations

Double barrier piping penetrations are provided for all piping passing through the Containment. The pipe is centered in the embedded sleeve which is welded to the liner. End plates are welded to the pipe at both ends of the sleeve. Several pipes may pass through the same embedded sleeve to minimize the number of penetrations required. In this case, each pipe is welded to both end plates. A connection to the penetration sleeve is provided to allow continuous pressurization of the compartment formed between the piping and the embedded sleeve. In the case of piping carrying hot fluid, the pipe is insulated and cooling is provided to reduce the concrete temperature adjoining the embedded sleeve. Local areas are allowed to have increased temperatures not to exceed 250 F.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Cooling is provided for most hot penetrations through the use of air-to-air heat exchangers. These are made in accordance with the ASME UPV Code, Section VIII, by welding together two embossed sheets of 10 gage carbon steel material, the embossments forming coolant passages. The unit is rolled into the form of a cylinder with an outside diameter slightly smaller than the respective inside diameter of the penetration sleeve. The exchanger is placed inside the sleeve and outside the pipe insulation, with the inlet and outlet coolant connections penetrating the sleeve between the outside concrete wall surface and the bellows expansion joint. The coolant to be used is ambient air fed by a centrifugal blower which is backed up with a full sized spare. The isolation features and criteria for piping penetrations are given in Chapter 6. Figure 5.1-12 shows typical hot and cold pipe penetrations.

Loss of cooling for the sleeve is highly improbable. The heat shield has no moving parts, and the cooling air is at low pressure. There are redundant blowers to assure that cooling air is not lost for a significant time. The blowers operate off a diesel bus and can be manually started following a blackout. The thermal insulation on the pipe wall reduces heat flow to the liner sleeve. Operation of the cooling unit can be ascertained by opening the “flow through” connection of the penetration pressurization system on the penetration sleeve and observing the temperature of the cooling air emerging.

In order to lose significant structural properties, concrete must be held continuously at 500 to 600 F. The hottest penetrations are the main steam lines, which normally operate at a temperature of 507 F. The results of a two dimensional transient heat transfer analysis indicated that in the improbable case that all cooling air would be lost to the main steam penetrations, the surrounding concrete would reach a maximum temperature of 200 F in approximately 100 hours and 280 F in approximately 1000 hours. It is highly improbable that cooling air would be lost a very long period of time since the failure of any of the air blower drive motors is alarmed in the

control room. Even if the adjoining concrete did reach these temperatures (200 – 300 F), the strength of the structure would not be impaired for two reasons:

1) No credit was taken for the tensile strength of the concrete.

2) These temperatures have substantially no effect on the strength of the penetration sleeve or the reinforcing bar in the area of the penetration.

A total of approximately 80 pipes pass through approximately 50 penetration sleeves, 23 of which are considered thermally hot. In addition, several spare sleeves (capped and pressurized) are provided for the possible future addition of piping.

Equipment and Personnel Access Hatches

An Equipment Hatch was provided. It was fabricated from welded steel and furnished with a double-gasketed flange and bolted dished door. The hatch barrel is embedded in the containment wall and welded to the liner. Provision was made to continuously pressurize the space between the double gaskets of the door flanges and the weld seam channels at the liner joint, hatch flanges and dished door. Pressure is relieved from the double gasket spaces prior to opening the joints. The Personnel Hatch is a double door, mechanically-latched, welded steel assembly. A quick acting type, equalizing valve connects the Personnel Hatch with the interior of the containment vessel for the purposes of equalizing pressure in the two systems when entering or leaving the containment. The Personnel Hatch doors 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 annunciator situated in the Control Room indicate the door position status. An emergency lighting and communication system operating from an external emergency supply is provided in the lock interior. Emergency access to either the inner door from the containment interior or to the outer door from outside, is possible by the use of special door unlatching tools. The design was in accordance with Section VIII of the ASME Code.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Containment Equipment Hatch Closure Plug (CEHCP)

The Containment Equipment Hatch Closure Plug can be used in place of the Equipment Hatch at Elevation 95'-0" in the Containment Building during outages. [Deleted] The CEHCP can be installed and sealed in less than 18 minutes and is designed to withstand the radiation release from a fuel handling accident involving recently-irradiated fuel (i.e, fuel subcritical for less than 84 hours).

[Deleted]

Special Penetrations

1) 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 pit. The penetration consists of a 20-inch stainless pipe installed inside a 24-inch pipe. The inner pipe acts as the transfer tube. The transfer tube is fitted with a pressurized double gasketed blind flange on the refueling canal end to seal the reactor containment. The terminus of the tube outside the containment is closed by a standard gate valve. The outer pipe is welded to the containment liner and provision is made by use of a special seal ring for pressurizing all welds essential to the integrity of the penetration during plant operations. Bellows expansion joints are provided on the pipes to compensate for any differential movement between the two pipes or other structures. Figure 5.1-14 shows a sketch of the fuel transfer tube.

2) Containment Supply and Exhaust Purge Ducts

The ventilation system purge ducts are each equipped with two quick-acting tight-sealing valves (one inside and one outside of the containment) to be used for isolation purposes. The valves are manually opened for containment purging, but are automatically closed upon a signal of high containment pressure or high containment radiation level. The space between the valves is pressurized above calculated peak accident response pressure, while the valves are normally closed during plant operation. See Section 5-3, Containment Ventilation System, and Section 6.4, Containment Air Recirculation Cooling and Filtration System.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Two solenoid controlled, pneumatically operated butterfly valves are provided for each purge penetration, one on each side of the containment building wall. Two penetrations, one supply and one exhaust, are required. Valves are spring-loaded to fail closed.

The space between the valves is pressurized from the pressurization system through an electrically operated three-way solenoid valve. The pressure is maintained only when valves are closed and must be relieved before butterfly valves can be opened. Failure to release this pressure will prevent valves from opening.

Failure of any of the valves to open will prevent the fans from running. Tripping or either of the purge fans will automatically close the butterfly valves and pressurize the space between the valves. Failure of any of the valves to close will prevent the adjacent space from being pressurized, and sound the loss-of-pressurization alarm. Loss of pressure for either zone will be displayed by individual indicating lights at the Main Control Board.

The valve control solenoids and pressurization solenoids are controlled from a single control switch on the fan room control panel. The cycle is initiated by setting the control switch to “open” position. This will energize the pressurization alarm.

When the pressure between the valves has been relieved, the valves control solenoids are energized and the valves opened. If for any reason, any of the four valves fail to open within a given time after the cycle is initiated, all four valves will close and pressure will be restored. The circuit is interlocked to prevent inadvertent opening of the valves during S.I. condition.

Once all four valves have been opened, the operator has a pre-determined time (approximately one minute) to start the purge supply fan. Failure to do so will cause all four valves to close.

Position indicating lights for each of the four valves are provided on the Fan Room Control Panel and Main Control Board.

3) Sump Penetrations

The piping penetration in the containment sump area is not of the typical sleeve-to-liner design. In this case, the pipe is welded directly to the base liner. The weld to the liner is shrouded by a test channel which is used to demonstrate the integrity of the liner.

5.1.4.3 Design of Penetrations

Criteria

The liner is basically not a load-carrying member because it is subjected to strains imposed by the reinforced concrete; nevertheless, the liner was reinforced at each penetration in accordance with the ASME Code Section VII. The weldments of liner to penetration sleeve are of sufficient strength to accommodate stress concentrations and adhered strictly to ASME Code Section VIII requirements for both type and strength.

Liner stress is imposed on the cylindrical penetration as a circular uniform load acting around the circumference of the penetration. The penetration thicknesses were chosen to accommodate this load without causing severe distress at the opening.

The penetration sleeves and plates were designed to accommodate all loads imposed on them under operating conditions (thermal effects and internal penetrations and test pressures) and accident conditions (loads resulting from all strains, internal pressures, and seismic movements).

In the design of the piping penetration sleeves and the piping going through them, maximum total stress in all cases was limited to a value below the yield stress of the material involved; therefore, no plastic design criteria were employed. In particular, piping whose failure would result in a Loss-of-Coolant Accident and the main steam and feedwater pipe penetrations and pipe supports in the Containment Building were designed to prevent the formation of a plastic “hinge” in the pipe should any of these pipes rupture. This was accomplished by effectively anchoring these pipes at 90° elbows connected to all these pipes adjacent to the penetration both inside and outside the building, and by restraining these pipes along their run inside the

building and outside the building to the first stop valve. The anchors and restraints were designed to prevent a breach of containment at the piping penetrations should any of these pipes rupture inside, immediately outside, or within the penetration itself. The penetrations were designed to the strength of the pipe and no further considerations are necessary.

To insure that a Loss-of-Coolant Accident acting simultaneously with an earthquake would not result in a breach of containment by causing a failure of one or more pipe penetrations through the Containment Building wall, the following methods were used:

All auxiliary piping attached to the Reactor Coolant System which passes through penetrations in the Containment Building wall must also pass through the circular secondary shield wall approximately fifteen feet inside the building as illustrated in Plant Drawing 9321-F-25013 [Formerly Figure 5.1-2]. The total number of pipes in this category is very limited. They were examined individually and suitable restraints or anchors were used either at or within the secondary shield wall to prevent a Loss-of-Coolant Accident or a failure of one of these pipes within the secondary shield wall from causing the failure of the building penetrations through which the pipes pass. In some cases, it was physically impossible for any conceivable movement of the end of those pipes attached to the Primary Coolant System to be reflected at the building penetration and impose other than ordinary operating loads at these points. In other cases, it was necessary to design restraints for the pipes at the secondary shield wall to withstand the failure of the pipe within the wall in tension. Some auxiliary pipes attached to the Reactor Coolant System are attached at points which will not move; for instance, the reactor coolant pump seal water injection pipes and the steam generator blowdown pipes. In general, these have restraints at the secondary shield wall designed for normal loads plus the reaction forces resulting from the double ended rupture of these pipes within the shield wall.

All Containment Building piping penetrations except main steam and feedwater were designed as anchors for the pipes passing through them and transmit piping loads to the reinforced concrete wall. The anchorage strength exceeds the maximum combined forces imposed by the effects on the piping penetration of dead loads, loads induced from a Loss-of-Coolant Accident, thermal expansion of the pipe, penetration air pressure, and earthquake loads.

The piping penetrations were designed to transmit the above combined loadings to the concrete structure without exceeding the yield strength of the penetration steel. Typical penetration details are shown in Figure 5.1-12. Load transfer from the pipe to penetration anchorage is limited to the actual loads induced or to the ultimate strength capacity of the pipe in bending, shear, axial, or torsional loadings.

All piping penetrating the Containment meet the requirements of the USAS B31.1.0 Power Piping Code. In the case of the main steam and feedwater lines, the supports, inside and outside the Containment Buildings to the second isolation valve, were designed so that a failure of any one of these pipes does not result in breach of containment of the failure of any other main steam or feedwater pipe between the steam generator and the second isolation valve.

The design of all containment building piping penetration sleeves and end plates except the new Steam Generator Blowdown Penetrations (AA, BB, CC, and DD) and Service Water Penetration (SS) was in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII. The Steam Generator Blowdown Penetration Sleeves and end plates and the Service Water Penetration (SS) end plates were designed in accordance with the requirements of the 1986 edition of the ASME Boiler and Pressure Vessel Code, Section III subsection NC.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the AMSE Code, with certain exceptions whenever specific relief is granted by the NRC.

Pipes which penetrate the containment building wall and which are subject to machinery originated vibratory loadings, such as the Reactor Coolant Pumps, had their supports spaced in such a manner that the natural frequency of the piping system immediately adjacent to the penetrations is greater than the dominant frequencies of the pump. Pipe line vibration was checked during preliminary plant operation; and where necessary, vibration dampers were fitted. This checking and fitting effectively eliminates vibrating loads as a design consideration.

Materials

The material for penetrations including the Personnel and Equipment Access Hatches, together with the mechanical and electrical penetrations is carbon steel, conforming with the requirements of the ASME Pressure Vessels Code Section VIII, and exhibiting ductility and welding characteristics compatible with the main liner material. The Equipment Hatch, penetration sleeves and Personnel Lock meet the Charpy V-notch impact values for a minimum of 15 ft-lbs at -50°F.

The stainless steel expansion joints (bellows) of the hot penetration expansion joints were protected from damage in transit and during construction by sheet metal covers fastened in place at the fabricator's shop. These were left in place permanently if there was no interface with nearby piping or equipment.

Due to cracking in the bellows of the Main Steam and Boiler Feedwater penetrations, replacement bellows were installed. The replacement bellows are constructed of improved materials.

The materials making up the penetrations conform to the following specifications:

	Item	Specification	Minimum Yield Strength (PSI)	Minimum Tensile Strength (PSI)	Elongation
1.	Mech. Penetration Sleeve – 12" Dia. & under**	ASTM A333, Gr. 1	30,000	55,000	35% in 2"
2.	Mech. – Over 12" Dia.**	ASTM A201 Gr. B to A300	32,000	60,000	22% in 8"
3.	Rolled Shapes+	ASTM A36, ASTM A131 Gr. C	36,000 32,000	58,000 58,000	20% in 8" 21% in 8"

Item		Specification	Minimum Yield Strength (PSI)	Minimum Tensile Strength (PSI)	Elongation
4. End Plates***	a)	ASTM A300 C1.1 Fire Box A201, Gr B(1)	32,000	60,000	22% in 8"
	b)	ASTM A240 Type 304L+	25,000	70,000	40% in 2"
	c)	ASTM A516, Gr. 60	32,000	60,000	21% in 8"
5. Fuel Transfer Tube+		ASTM A240 Type 304L	25,000	70,000	40% in 2"
6. Bellows+	a)	ASTM A312 Type 304L	25,000	70,000	35% in 2"
	b)	ASME SB168 Inconel 600++	35,000	80,000	30% in 2"
7. Elec. Penetrations**		ASTM A333 Gr. 1	30,000	55,000	35% in 2"
8. Equip. Hatch Insert**		ASTM A300 C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
9. Equip. Hatch Flanges**		ASTM A300, C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
10. Equip. Hatch Head**		ASTM A300 Firebox A201, Gr. B	32,000	60,000	22% in 8"
11. Personnel Hatch**		ASTM A300, C1.1. Firebox A201, Gr. B	32,000	60,000	22% in 8"

Item	Specification	Minimum Yield Strength (PSI)	Minimum Tensile Strength (PSI)	Elongation
12. Piping Pene-tration Reinf.*	ASTM A442, Gr.60	32,000	60,000	22% in 8"

13. Containment Equipment Hatch Closure Plug is designed and built in accordance with Aluminum Association's Design Code and made of ALCOA Alloy 6061 T6 or higher Grade material. [Deleted]

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* The liner plates for the shell, bottom and dome were impact tested on a longitudinal section at 15 ft-lbs at a temperature 30 degrees below the service temperature of +50°F.

** The Equipment Hatch, penetration sleeves and Personnel Lock were Charpy tested to a minimum of 15 ft-lbs at -50°F.

\+ No specific NDTT requirements

++ Main Stream and Main Feedwater penetrations

*** Service Water Penetration SS end plates were Charpy V-notch tested to a minimum of 20 ft-lbs (1of 3 test only) at 0°F or lower with a minimum average of three tests of 25 lbs

Consideration of Jet Loads, Missile Impact and Tornado Loads for Openings

The 3'-0" thick crane wall, the 4'-0" and 6'-0" thick Refueling Canal and the 2'-0" thick operating floor are capable of resisting jet force loads and missiles from primary coolant piping. Thus, jet force loads and missiles from the potential failure of the Primary Coolant System are contained within the reactor coolant compartment shield walls and cannot impinge on the containment structure walls; consequently, these loads were not considered in design of large openings. All other missiles terminate inside these concrete shield walls and consequently were not factored into the large opening design. Large openings are shielded or are far enough away to preclude impingement from main steam and feedwater pipe break loads.

Tornado loads are small compared to the seismic loadings. The tornado shear loads from torsion and translational wind force and the overturning moments caused by wind load have a minimum factor of safety of approximately 2.5 when compared with earthquake shears and moments which were used to size the seismic reinforcing bars. The tornado moment and shears are in fact smaller than the minimum earthquake moments and shears considered in design. On this basis, the seismic bars provide more than an adequate mechanism for resisting tornado loads. In addition, tornado loads act independently of other severe loads; therefore, the Equipment Hatch and Personnel Lock reinforced concrete bosses were designed for

simultaneous design basis accident and earthquake loads, which were larger than tornado loads, are of more than adequate strength to resist tornado loads.

The containment structure will not be penetrated by the tornado-generated missiles. The concrete sections around large openings are thicker than the 4'-6" Containment wall and so no further consideration of tornado missiles at the large openings was necessary. The large openings have shielded walls of sufficient thickness to protect against tornado missiles.

Consideration of Curvature of the Wail in the Finite Element Analysis

Curvature of the containment cylinder wall was included in the finite element analysis for large openings by assigning three coordinates to each node point in the model. This in effect idealizes the structure as a series of chords of a circle with radii equal to the containment cylinder reference surface. Since the widest element in the fine model at the Equipment Hatch opening is 50", or approximately 1% of the total circumference, the chords adequately represent the curvature of the containment surface. Since the shape and stiffness of the structure was accurately represented in the model, all forces and effects were included in the computer output.

The procedures used to design for the six stresses and the justification for all structural elements (rebar) provided to resist the forces or stress resultants outputted by the computer are discussed in detail in Appendix 5A. All concrete in tension was considered cracked in the finite element analysis.

5.1.4.4 Leak Testing of Penetration Assemblies

A proof test was supplied to each penetration by pressurizing the necessary areas to 54 psig. This pressure was maintained for a sufficient time to allow soap bubble and Freon sniff tests of all welds and mating surfaces. Any leaks found were repaired and retested; this procedure was repeated until no leak existed.

5.1.4.5 Construction

The qualification of welding procedures and welders was in accordance with Section IX, “Welding Qualifications” of the ASME Boiler and Pressure Vessel Code. The repair of defective welds was in accordance with paragraph UW-38 of Section VIII “Unfired Pressure Vessels.”

For penetrations between 9" and 18", all the reinforcing bars including primary and secondary vertical bars and diagonal bars are grouped around the penetrations. Due to the continuity of the bars and the relatively small opening size, no special provisions were needed to resist normal, shear and bending stresses. The penetrations are keyed into the concrete, thus creating an edge loading which induces torsion into the walls. The loads are small and the rebar feels little effect from this torsional loading.

For penetrations greater than 18" to 4'-0" the bars are continuous. Since reinforcing is continuous around penetrations, steps were taken to insure that no local crushing of concrete occurred.

From an article, "Detailing and Placing Reinforcing Bars" by Paul F. Rice from Concrete Construction, January 1965, it was determined that in order to prevent local crushing of the concrete a minimum bend diameter of 31 times the bar diameter is required when the

reinforcing is stressed to yield. The angle of bend in the rebar determines the force which is transmitted to the concrete in the event the bar tries to straighten out due to tension. For this reason, most bars were bent at 10 degrees except at large penetrations, including the Equipment Hatch, Personnel Lock, main steam and feedwater, and air purge penetrations, where the deviation of the bar from its centerline is too large to permit a 10o bend. In these cases, the bars were bent at 30 degrees but a tie back system was used which prevents a build-up of forces. To further prevent this buildup (in all cases except the equipment hatch penetration) the line of force makes an angle of one-half of the angle of bend, from a horizontal line for the vertical bars and from a vertical line for the horizontal bars and is tangent to the outside of the penetration.

Details of the Personnel and Equipment Hatch design are presented in Section 3.4 of Appendix 5A.

Concrete was poured in nominal 5' lifts, 360 degrees with no stagger. Approximately one week was allowed to elapse between pours and the surface was left rough, thoroughly cleaned by air blowdown, and all laitance removed. Joints were thoroughly wetted and slushed with a coat of neat cement grout immediately before placing of new concrete except for the exterior of the containment where surfaces were thoroughly wetted but not grouted.

5.1.4.6 Testability of Penetrations and Weld Seams

All penetrations, the Personnel Air Lock and the Equipment Hatch were designed with double seals which are normally pressurized at a minimum pressure greater than the calculated peak accident pressure. Individual testing at 115% containment design pressure is also possible.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

The containment ventilation purge ducts are equipped with double isolation valves and the space between the valves is permanently piped up to the penetration pressurization system. The space can be pressurized to 115% of design pressure when the isolation valves are closed. The purge valves fail in the closed position upon loss of power (electric or air).

All welded joints in the liner have steel channels welded over them on the inside of the vessel. During construction, the channel welds were tested by means of pressurizing sections with Freon gas and checking for leaks by means of a Freon sniffer. Most welds are continuously pressurized during power operation at a minimum pressure greater than the calculated peak accident pressure. Liner welds that are not pressurized during power operation are those welds associated with disconnected sections of the Weld Channel Pressurization System. The integrity of the welds associated with any disconnected sections of the Weld Channel Pressurization System is verified by integrated leak rate testing.

Test connections are provided on the Penetration and Weld Channel Pressurization System lines to the Equipment Hatch and Personnel Airlock to allow for leak testing of the PWCP connections.

The use of the weld channel pressurization system may necessitate periodic relief of pressure buildup within the containment, should the system leak into the containment structure.

When pressure relief of the Containment is required during normal operation, it is accomplished using the containment pressure relief line and not the containment purge lines. However, the pressure relief exhaust is routed through charcoal filters which have an iodine removal efficiency of 90.0%. Prior to pressure relief operations, the Containment Auxiliary Charcoal Filter System (see Section 5.3) may be operated to reduce the activity in the containment atmosphere. Assuming 1% fuel defects and 50 lbs/day leakage of reactor coolant into the Containment, the containment atmosphere activity has the maximum value of 20.4 x MPC for iodines and 135.5 x MPC for noble gases after approximately 16 hours of operation of the containment auxiliary charcoal filter system whose efficiency for iodine removal is 90%.
The activity released to the environment as a result of depressurizing the Containment from 1.0 psig to 0 psig at 1500 CFM for 2 hours based on the above abnormal conditions is:

a) For iodines: 8.26 x 10^{-15} curies expressed as equivalent I-131
b) For noble gases: 6.68 curies expressed as equivalent Xe-133

The maximum expected operating conditions considered as normal are taken as 0.2% fuel defects and 14.4 gpd leakage of reactor coolant into the Containment. For these conditions, the containment atmosphere activity is 8.16 x MPC for iodines and 65.0 x MPC for noble gases after approximately 16 hours operation of the containment charcoal filter system whose efficiency for iodine removal is 99%. The activity released to the environment as a result of depressurizing the containment from 1.0 psig to 0 psig at 1500 cfm for 2 hours through the purge line carbon filters (iodine removal efficiency of 99.0%) based on these maximum operating conditions is:

a) For iodines: 2.49 x 10^{-6} curies expressed as equivalent I-131
b) For noble gases: 3.21 curies expressed as equivalent Xe-133

5.1.4.7 Accessibility Criteria

The Containment is completely closed whenever the core is critical or whenever the primary system temperature is above 200 F, except as required for brief periods necessary to relieve the Containment to keep the pressure below a reasonable level (1-2 psig) or to purge the Containment in preparation for Containment entry.

Limited access to the Containment through personnel air locks is possible with the reactor at power or with the primary system at hot shutdown for special maintenance or periodic inspections. Access at power would normally be restricted to the areas external to the reactor equipment compartment primarily for inspection and maintenance of the air recirculation equipment, incore instrumentation chamber drives, and instrument calibration.

After shutdown, the Containment vessel is purged to reduce the concentration of radioactive gases and airborne particulates. This purge system was designed to reduce the radioactivity level to doses defined by 10 CFR 20 for a 40-hour occupational work week, within 2-6 hours after plant shutdown. Since negligible fuel defects are expected for this reactor, much less than the 1% fuel rod defects used for design, purging of the Containment is normally accomplished in less than 2 hours. To assure removal of particulate matter the purge air will be passed through a high efficiency filter before being released to the atmosphere through the purge vent.

The primary reactor shield was designed so that access to the primary equipment is limited by the activity of the primary system equipment and not the reactor.

5.1.5 System Design Evaluation

5.1.5.1 Reliance on Interconnected Systems

The containment leakage limiting boundary is provided in the form of a single, carbon steel liner on the vessel having double barrier weld channels and penetrations. Each system whose piping penetrates this boundary was designed to maintain isolation of the Containment from the outside environment. Provisions are made to continuously pressurize penetrations and most weld channels and to monitor leakage from this pressurization.

5.1.5.2 System Integrity and Safety Factors

Pipe Rupture – Penetration Integrity

The penetrations for the main steam, feedwater, blowdown and sample lines were designed so that the penetration is stronger than the piping system and that the vapor barrier will not be breached due to a hypothesized pipe rupture.

Major Component Support Structures

The support structures for the major components were designed to resist all thrust forces, moments and torques associated with either a Reactor Coolant System or main steam pipe break. All primary structural steel elements were designed for stresses not exceeding yield stress due to these forces.

5.1.5.3 Containment Structure Components Analyses

The details of radial, longitudinal and horizontal shear analyses for the containment reinforced concrete are given in Section 5.1.3.

5.1.5.4. Performance Capability Margin

The containment structure was designed based upon limiting load factors which were used as the ratio by which accident and earthquake loads were multiplied for design purposes to ensure that the load/'deformation behavior of the structure is one of elastic, low strain behavior. This approach places minimum emphasis on fixed gravity loads and maximum emphasis on accident and earthquake loads. Because of the refinement of the analysis and the restrictions on construction procedures, the load factors primarily provide for a safety margin on the load assumptions. Tabulations of load combinations and load factors utilized in the design which provide an estimate of the margin with respect to all loads are referenced in Section 5.1.2.

5.1.6 Minimum Operating Conditions

The minimum operating conditions which are applicable to the Containment System are given in the Technical Specifications.

5.1.7 Containment System Structure-Inspection and Testing

Initial Containment Leakage Rate Testing

Criterion: Containment shall be designed so that integrated leakage rate testing can be conducted at the peak pressure calculated to result form the design basis accident after completion and installation of all penetrations and the leakage rate shall be measured over a sufficient period of time to verify its conformance with required performance. (GDC 54 of 7/11/67)

After completion of the containment structure and installation of all penetrations and weld channels, integrated leakage rate tests were performed prior to initial plant operations to establish the respective measured leakage rates and to verify that the leakage rate at the peak accident conditions is no greater than 0.075 percent by weight per day of the containment stream-air atmosphere at the calculated peak accident conditions. The leakage rate tests were performed using the absolute method. The duration of each test was not less than 24 hours.

Periodic Containment Leakage Rate Testing

Criterion: The containment shall be designed so that an integrated leakage rate can be periodically determined by test during plant lifetime. (GDC 55 of 7/11/67)

The peak accident pressure integrated leakage rate test is conducted at periodic intervals during the life of the plant, and also as appropriate in the event major maintenance or major plant modifications are made.

A leak rate test at the peak accident pressure using the same test method as the initial leak rate can be performed at any time during the operational life of the plant, provided the plant is not in operation and precautions are taken to protect instruments and equipment from damage.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Provisions for Testing of Penetrations

Criterion: Provisions shall be made to the extent practical for periodically testing penetrations which have resilient seals or expansion bellows to permit leak tightness to be demonstrated at the peak pressure calculated to result from occurrence of the design basis accident. (GDC 56 of 7/11/67)

Penetrations were designed with double seals which are continuously pressurized above accident pressure. The large access openings such as the Equipment Hatch and Personnel Air Lock are equipped with double gasketed doors and flanges with the space between the gaskets connected to the pressurization system. The system utilizes a supply of clean, dry, compressed air which places the penetrations under an internal pressure above the peak calculated accident pressure.

A permanently piped monitoring system is provided to continuously measure leakage from all penetrations.

Leakage from the monitoring system is checked by continuous measurement of the integrated makeup air flow. In the event excessive leakage is discovered, each penetration can then be checked separately at any time.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Provisions for Testing of Isolation Valves

Criterion: Capability shall be provided to the extent practical for testing functional operability of valves and associated apparatus essential to the containment function for establishing that no failure has occurred and for determining that valve leakage does not exceed acceptable limits. (GDC 57 of 7/11/67)

Capability is provided to the extent practical for testing the functional operability of valves and associated apparatus during periods of reactor shutdown.

Initiation of containment isolation employs coincidence circuits which allow checking of the operability and calibration of one channel at a time. Removal or bypass of one signal channel places that circuit in the half-tripped mode.

Local leak rate testing of containment isolation valves is performed in accordance with Technical Specification 5.5.15. The Containment Leakage Rate Program is in accordance with the guidance contained on Regulatory Guide 1.163, except as noted in the Technical Specification.

Field and operational inspection and testing were divided into three phases:

1) those taking place during erection of the Containment Building liner; construction tests
2) those taking place after the containment structure was erected and all penetrations were complete and installed; pre-operational tests
3) monitoring during reactor operation; post-operational tests

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

5.1.7.1 Construction Tests

During erection of the liner, the following inspection and tests were performed:

Bottom Liner Plates

All liner plate welds were tested for leak tightness by vacuum box. The box was evacuated to at least a 5 psi pressure differential with the atmospheric pressure.

After completion of a successful leak test, the welds were covered by channels. A strength test was performed by applying a 54 psig air pressure to the channels in the zone for a period of 15 minutes.

The zone of channel-covered welds was pressurized to 47 psig with a 20% by weight of Freon-air mixture. The entire run of the channel to plate welds was then traversed with a halogen leak detector.

The sensitivity of the leak detector is 1 x 10-9 standard CC per second. The sniffer was held approximately ½ inch from the weld and traversed at a rate of about ½-inch per second. The detection of any amount of halogen, indicating a leak, required weld repairs and retesting. After the halogen test was completed all liner welds not accessible for radiography were pressurized with air to 47 psig and soap-tested. Any leaks indicated by bubbles were repaired and retested. Where leaks occurred, welds were removed by arc gouging, grinding, chipping and/or machining, before rewelding. In addition, the zone of channels was held at the 47 psig air pressure for a period of at least two hours. The drop in pressure was not to exceed the equivalent of a leakage of 0.05% of the containment building volume per day. Compensation for change in ambient air temperature was made if necessary.

Vertical Cylindrical Walls and Dome

For the liner, a complete radiograph was made of the first 10 feet of full penetration weld made by each welder or welding operation. A minimum of a 12" film "spot" radiograph was made every 50 feet of weld thereafter on the side walls and dome, except where back-up plates are used. The radiograph films were given to United Engineers and Constructors for their review.

When a spot radiograph showed defects that required repair, two adjacent spots were radiographed. If defects requiring repair were shown in either of these, all of the welding performed by the responsible operator or welder was 100% radiographed to determine the end of defect.

The performance and acceptance standards for all radiography is ASME Section VIII, Paragraph UW51.

The liner plate to plate welds were tested for leak tightness by vacuum box techniques. After successful completion of the spot radiography and vacuum box tests and subsequent repair of all defects, the channels were welded in place over all seam welds in a pre-determined zone. A strength test was performed on the liner plate weld and the channel weld by pressurizing the channel with air at 54 psig for 15 minutes. In addition, each zone of channel covered weld was leak tested under the Freon-air mixture at 47 psig.

In location where radiography was not possible, such as the lower courses of shell plates where back-up plates were used, and where liner bottom welds and floor plates were made to angles and tees, the liner fabricator welded on a 2" long overrun coupon. The overrun coupon was chipped off, marked for location and given to United Engineers and Constructors for testing. These welds are also vacuum box tested.

Welded studs were visually inspected, and at least one at the beginning of each day's work and another at approximately mid-day were bend-tested to 45 degrees for each welder. Studs failing visual or bend-testing were removed.

While the liner is not a pressure vessel, industry experience has shown that leaks in pressure vessels normally occur at joints. For this reason and following current liner fabrication practice, there was no radiographic or other non-destructive examination of liner plate.

Liner Erection Tolerance

Deviations from the allowable erection tolerance standards were located, documented and, in most cases, eliminated during the normal erection of the liner. This was accomplished by jacking against the polar crane wall, utilizing tubular beams, capped by beams of sufficient cross-sectional area to insure against localized buckling of the liner plate. For areas above the concrete polar crane wall, the required tolerances were met and maintained by circular plate wind girders. For the isolated cases where the liner could not be jacked into tolerance, a Non-Conformance Report (NCR) was written and forwarded to the architect-engineer with a complete survey of the area for an engineering evaluation together with a waiver request. This documentation is maintained by the Authority. Only minor deviations were experienced.

Concrete Compression and Slump Testing

The compression test samples consisted of six 6" x 12" cylinders for each 100 cu. yd. or portion thereof, per class, per day. A minimum of one set of six cylinders was made for pours of less than 100 cu. yds. Three cylinders were broken at 7 days and 3 cylinders at 28 days. The basis for rejection was failure to develop a minimum compressive strength at 28 days of 15% above the nominal design strength as proven on an average of the three cylinders.

A slump test was performed on each truckload of concrete used in the first four lifts (20 feet) for the containment exterior wall and was recorded for each sample from which compression test cylinders were made. For all other concrete, a slump test was made and recorded for three truckloads of concrete from each class of concrete per 100 cubic yards (or portion thereof) placed per day. A Quality Control inspector was present during the pour and visually checked the concrete from each truck. Any concrete which appeared to be near or over the limit was slump tested. Wet loads were rejected. The maximum slump for all pours was 5 inches except for special pours when specific approval was received from the Architect-Engineer. In no case was the slump permitted to exceed 7 inches.

The statistical results of compression testing for the 28 day breaks were:

a) 100% of the cylinder break tests exceed the minimum requirement
b) 75% of the cylinder break tests exceeded the minimum requirement by at least 1000 psi
c) 50% of the cylinder break tests exceeded the minimum requirement by at least 1250 psi
d) 25% of the cylinder break tests exceeded the minimum requirement by at least 1750 psi
e) 10% of the cylinder break tests exceeded the minimum requirement by at least 2250 psi

The samples for compression and a slump testing of concrete were taken from the point of discharge from the truck. There was no occurrence of pour removal or concrete rejected from these test results.

Cadweld Splice Test Program

In the Cadweld Test Program, tests were performed on production Cadwelds which had been removed (specifically for testing) from the Containment Building after placement. Of the first 141 production Cadwelds tested in this program, all test results were in excess of the minimum specified strengths.

The following test results were obtained from the actual Cadweld test reports submitted to WEDCO from Consolidated Testing Laboratory. Of the Cadwelds tested:

100% had ultimate strengths of at least 79,000 pis
75% had ultimate strengths of at least 95,100 psi
50% had ultimate strengths of at least 97,600 psi
25% had ultimate strengths of at least 102,600 psi
10% had ultimate strengths of at least 105,100 psi

A statistical analysis of these results was performed using the methods outlined in Appendix 5A, Section 5.2.1.

The mean value of the ultimate strength of the splices was 99,580 psi with a standard deviation of 9.960 psi and a total range of 32,750 psi. Of the total at least 99% had an ultimate strength of 76,373 psi. No Cadwelds were rejected on the basis of test results from the Cadweld Test Program.

Penetrations

Strength and leak tests of individual penetration internals and closures and sleeve weld channels were performed in a similar manner to the above and all leaks repaired and the penetration or weld channel retested until no further leaks were found.

5.1.7.2 Pre-Operational Tests

All penetrations, and the welds joining these penetrations to the containment liner and the liner seam welds, were designed to provide a double barrier which can be continuously pressurized at a pressure higher than the calculated peak accident response pressure of the containment. This blocks potential sources of leakage with a pressurized zone and at the same time provides a means of monitoring the leakage status of the containment which is more sensitive to changes in the leakage characteristics of these potential leakage sources. Certain liner welds are no longer continuously pressurized. Therefore, the leakage status of these welds is no longer continuously monitored. The integrity of these welds is verified by integrated leak rate testing.

After the Containment Building was complete with liner, concrete structures, and all electrical and piping penetrations, Equipment Hatch and Personnel Lock in place, the following tests were performed:

1) Strength Test:

A pressure test was made on the completed building using air at 54 psig. This pressure was maintained on the building for a period of at least one hour. During this test, measurements and observations were made to verify the adequacy of

the structural design. For a description of observations, cracks, strain gauges, etc., refer to the Containment Report, Appendix 5A.

2) <u>Integrated Leakage Rate Tests:</u>

Integrated leakage rate tests were performed on the completed building using the absolute method. These leakage tests were performed with the double penetration and weld channel zones open to the containment atmosphere.

3) <u>Sensitive Leak Rate Test:</u>

After it had been assured that there were no defects remaining from construction, a sensitive leak rate test was conducted. The sensitive leak rate test included only the volume of the weld channels and double penetrations. This test is considered more sensitive than the integrated leakage rate test, as the instrumentation used permits a direct measurement of leakage from the pressurized zones. The sensitive leak rate test was conducted with the penetrations and weld channels at a minimum pressure greater than the calculated peak accident pressure and with the Containment Building at atmospheric pressure. The leak rate for the double penetrations and weld channel zones was equal to or less than 0.2% of the containment free volume per day.

In order to verify that the structural response of the Containment to pressure loads is in accordance with design assumptions and to provide assurance that the structure was constructed in accordance with the design to resist pressure loads, a Structural Integrity Test (SIT) was performed.

Readings and measurements were taken at 0 psig, 12 psig, 21 psig, 41 psig and 54 psig (the latter is 115% of the design pressure of 47 psig) during pressurization, and at 41, 18, 21, 41, and 0 psig during depressurization.

The following gross deformation measurements were taken during the SIT using invar wire extensometers. This provided a means for taking all measurements inside the containment structure thus eliminating effects of weather and temperature. All results were remotely recorded during the test and data was quickly reduced.

a) Radial deformation of the containment wall was measured at 15 locations in the thickened Equipment Hatch boss and the transition area from the thickened boss to the 4'-6" cylinder wall.

b) Diameter change in the containment structure was measured at 10 locations spaced at approximately 10'-0" between elevations 101'-0" and 191'-0".

c) Radial deflection of the containment cylinder wall was measured at elevation 91'-0".

d) Vertical deflection of the Containment was measured at elevations 95'-0", 143'-0" and 191'-0" and at the apex of the dome. Redundancy was provided for the measurement at the apex of the dome.

Detailed crack measurements were made prior to the test, at peak test pressure of 54 psig, and following depressurization at five areas of the exterior shell, each of at least forty square feet in area. The areas of detailed measurement were: a quadrant of the personnel lock concrete boss, and ten foot wide strips spanning elevations 43’-0" to 48’-0", 115’-0" to 120’-0", and 188’-0" to 193’-0".

In addition, the exposed surface of the containment shell was visually inspected prior to the test, at 41 psig during the ILRT, and following depressurization. These inspections were for purposes of monitoring the general crack pattern and for specifically following the behavior of the most significant crack.

5.1.7.3 Acceptability of Testing Program

AEC Safety Guide No. 18 “Structural Acceptance Test for Concrete Primary Reactor Containments” was followed for testing except in the following areas:

1) The pattern of measurement points around the largest opening (equipment hatch) were not as shown in Figure C of Safety Guide 18 which indicated 12 points symmetrically located to measure radial and tangential deflections. The Indian Point 3 Structural Integrity Test required taking of radial measurements at 15 locations around the equipment hatch.

   Due to access restrictions, no deflection readings were taken on the lower vertical axis of this opening; the 15 measurement locations were symmetrically positioned in the remaining accessible area around this opening. Tangential deflections were not taken, as they were insignificant compared to the radial deflections. The second largest opening (personnel hatch) was structurally loaded in a manner similar to the equipment hatch; no deflection measurements were taken for the personnel hatch opening. This program of radial deflection measurements provided the necessary data to verify that anticipated deformations were taken into account and were within acceptable limits.

[Deleted]

5.1.7.4 Post-Operational Tests

The double penetrations and most weld seam channels which were installed on the inside of the liner in the Containment are continuously pressurized to provide a continuous, sensitive and accurate means of monitoring their status with respect to leakage. Certain liner welds are no longer continuously pressurized. Therefore, the leakage status of these welds is no longer continuously monitored. The integrity of these welds is verified by integrated leak rate testing.

No periodic structural integrity tests of the Containment are planned. Periodic peak pressure containment integrated leakage rate test (ILRTs) are performed in accordance with the Technical Specifications. Peak pressure tests are to be conducted as appropriate in the event major maintenance or major plant modifications are made. As a prerequisite to the ILRT, a detailed visual examination of the accessible interior and exterior surfaces of the containment structure and its components is required to uncover any evidence of deterioration which may affect the containment integrity. However, no degradation of structural integrity is expected. The Authority does not consider periodic structural integrity tests as warranted either separately or in conjunction with other tests.

The Containment Leakage Rate Testing Program details requirements for inspection of the accessible interior and exterior surfaces of the containment structure and its components. This periodic surveillance of the Containment and associated structures is visual and includes critical areas as well as a general examination of the accessible surfaces for deterioration. The inspection is also performed prior to any integrated leak test. The insulation attached to the steel liner is designed so that sections can be removed to facilitate inspection of the liner.

These components are considered ASME Section XI Class MC or CC components and any repair or replacement activities shall be performed in accordance with ASME Section XI Subsections IWE and IWL of the ASME Code, with certain exceptions whenever specific relief is granted by the NRC.

Provisions have been made for access to the upper external parts of the containment structure. These provisions consider the use of movable scaffolding while performing periodic inspection and testing during the service life of the facility.

References

1. Stellmeyer, J. B., W. H. Munse and E. A. Selby, "Fatigue Tests of Plates and Beams with Stud Shear Connections." Highway Research Record, Number 76.

2. Singleton, Robert C. "The Growth of Stud Welding." Welding Engineer, July 1963.

3. United States Atomic Energy Commission – Nuclear Reactors and Earthquakes, TID-7024, 1963.

4. Blume, J., N. Newark, L. Corning – Design of Multistory Reinforced Concrete Building for Earthquake Motions – Portland Cement Association.

5. Timoshenko, S., and S. Woinowsky-Kreiger, Theory of Plates and Shells, Second Edition, McGraw-Hill, 1954.

6. American Concrete Institute, Code for Reinforced Concrete Chimney Design, ACI-505.

TABLE 5.1-1

FLOODED WEIGHTS – CONTAINMENT BUILDING

Item	Flooded/Equipment Weight, lb
Pressurizer –1	346,000
Steam Generators – 4	3,816,400
Reactor – 1	
(a) Vessel	868,000
(b) Internals	420,000
(c) Piping	1,000,000
Reactor Pumps – 4	824,000

Accumulator Tanks – 4	529,000
175 Ton Polar Crane – 1	650,000
Ventilation Fans – 5	656,000
Reactor Coolant Drain Tank – 1	20,000
Pressure Relief Tank – 1	129,000
Other Miscellaneous Equipment	100,000
TOTAL	9,358,400

5.2 CONTAINMENT ISOLATION SYSTEM

5.2.1 Design Basis

Each system whose piping penetrates the Containment's leakage limiting boundary was designed to establish or maintain isolation of the Containment from the outside environment under the following postulated conditions:

a) Any accident for which isolation is required (severely faulted conditions) coincident with

b) An independent single failure or malfunction (expected faulted condition) occurring in any active system component within the isolated bounds.

Piping penetrating the Containment was designed for pressures at least equal to the containment design pressure. Containment isolation valves were provided, as necessary, in lines penetrating the Containment to assure that no unrestricted release of radioactivity can occur. Such releases might be due to rupture of a line within the Containment concurrent with a Loss-of-Coolant Accident, or due to rupture of a line outside the Containment, which connects to a source of radioactive fluid within the Containment.

In general, isolation of a line outside the Containment protects against releases due to rupture of the line inside concurrent with a Loss-of-Coolant Accident, and closes off a line which communicates with the containment atmosphere in the event of a Loss-of-Coolant Accident.

Isolation of a line inside the Containment prevents flow from the Reactor Coolant System or any other large source of radioactive fluid in the event that a piping rupture outside the Containment occurs. A piping rupture outside the Containment at the same time as a Loss-of-Coolant Accident is not considered credible, as the penetrating lines are of seismic Class I design up to and including the second isolation barrier and are assumed to be an extension of the Containment.

Normally lines located inside the Containment building that are required to function after an accident are located outside the missile barrier. An exception to this is a portion of the closed loop Component Cooling Water system which is located along the inside of the Crane Wall by the 31 Steam Generator. This is acceptable based on the "Modification of the General Design Criteria 4 requirements for protection against Dynamic effects of postulated pipe ruptures." This

takes into account the Leak Before Break methodology, which relaxes the pipe rupture requirements for the Reactor Coolant Loop. The Component Cooling Water piping is also protected by concrete walls from the Pressurizer Surge line located on the other side of the Containment therefore the piping meets the intent of the original design criteria of being protected from credible missiles.

The isolation valve arrangement provides two barriers between the Reactor Coolant System or containment atmosphere, and the environment.

System design is such that failure of one valve to close will not prevent isolation.

The containment isolation valves were examined to assure that they are capable of withstanding the maximum potential seismic loads.

To assure their adequacy in this respect:

a) Valves were located in such a manner as to reduce the accelerations on the valves. Valves suspended on piping spans were reviewed for adequacy for the loads to which the span would be subjected. Valves were mounted in the position recommended by the manufacturer.

b) Valve yokes were reviewed for adequacy, and strengthened as required for the response of the valve operator to seismic loads.

c) Where valves are required to operate during seismic loading, the operator forces were reviewed to assure that system function is preserved. Seismic forces on the operating parts of the valve are small compared to the other forces present.

d) Control wires and piping to the valve operators were designed and installed to assure that the flexure of the line does not endanger the control system. Appendages to the valve, such as position indicators and operators, were checked for structural adequacy.

e) The design of control systems for automatic containment isolation valves is such that resetting the isolation signal will not result in the automatic reopening of containment isolation valves. Reopening of containment isolation valves requires deliberate operator action.

Containment Isolation Valves Criteria

Isolation valves were provided as necessary for all fluid system lines penetrating the Containment to assure at least two barriers for redundancy against leakage of radioactive fluids to the environment in the event of a Loss-of-Coolant Accident. These barriers, in the form of isolation valves or closed systems, are defined on an individual line basis. In addition to satisfying containment isolation criteria, the valving was designed to facilitate normal operation and maintenance of the systems and to ensure reliable operation of other engineered safeguards systems.

Valves utilized in systems for containment isolation service were selected based on tight shutoff requirements, speed of operations, and materials suitable for service in a particular environment relative to temperature, pressure and radiation activity.

The criteria for level of reliability for control valves listed were based on satisfactory operation of the containment isolation valves for the operating life of the plant with the required leak tightness assured by testing and corrective maintenance as required.

The criteria of reliability for swing stop, check, and gate valves listed were based on documented material, quality assurance, compliance for inspection, welding qualification, seismic criteria, testing, and technical specifications for required leak tightness complying with valve manufacturer's standard practice.

Table 5.2.1 provides a summary of containment isolation valve type, actuator, and closure time established for systems penetrating containment.

With respect to numbers and locations of isolation valves, the criteria applied were generally those outlined by the seven classes described in Section 5.2.2. Specific containment isolation valves are listed in FSAR Table 5.2-3.

5.2.2 System Design

The seven classes listed below are general categories into which line penetrating containment may be classified. The seal water referred to in the listing of categories is provided by the Isolation Valve Seal Water System described in Section 6.5. The following notes apply to these classifications:

1) The "not missile protected" designation refers to lines that are not protected throughout their length inside containment against missiles generated as the result of a Loss-of-Coolant-Accident. These lines, therefore, are not assumed invulnerable to rupture as a result of a Loss-of-Coolant Accident.

2) In order to qualify for containment isolation, valves inside the Containment must be located behind the missile barrier for protection against loss of function following an accident.

3) Manual isolation valves that are locked closed or otherwise closed and under administrative control during power operation qualify as automatic trip valves.

4) A check valve qualifies as an automatic trip valve in certain incoming lines not requiring seal water injection.

5) The double disk type of gate valve was used to isolate certain lines. When sealed by water or gas injection, this valve provides two barriers against leakage of radioactive liquids or containment atmosphere. In certain cases, a double disc valve was used in place of two valves in series having seal water or gas injection between them.

6) In lines isolated by globe valves in series (inboard and outboard) outside containment and provided with seal water injection, the following applies:

a) On process lines ingressing containment (incoming lines) IVSWS will be required to wet the stem packings on both the inboard and outboard valve. IVSW wets the valve plug as well as the stem packing of the RCP seal water injection line containment isolation valves (CH-MOV-250A through D),

b) On process lines egressing containment (outgoing lines) IVSWS will be required to wet only the stem packing on the inboard valve. One exception would be the Steam Generator Blowdown CIVs where both the inboard and outboard valves stem packings are wetted by IVSWS.

7) Excessive loss of seal water through an isolation valve that fails to close on signal is prevented by the high resistance of the seal water injection line. A water seal at the failed valve was assured by proper slope of the protected line, or a loop seal, or by additional valves on the side of the isolation valves away from the Containment.

8) Lines penetrating containment were designed to the same seismic criteria as the containment vessel up to and including the second isolation barrier. These portions of the penetrating lines are therefore to be considered extensions of the containment.

A review of the Containment Isolation System (NUREG-0578) indicated that there were a number of valves, which automatically reset to the previous position upon reset of containment Phase A isolation. These valves were under operator control via operating procedures to be placed in the closed position prior to resetting of Phase A. Circuits for these valves have been modified to preclude automatic opening on reset. The modification to the valve circuits entailed the installation of pushbuttons that work in conjunction with the containment isolation reset switches so that each valve control circuit has to be reset or the valve will be inhibited from opening.

Class 1 (Outgoing Lines, Reactor Coolant System)

Outgoing lines connected to the Reactor Coolant System which are normally or intermittently open during reactor operation were provided with at least two automatic trip valves in series located outside the Containment. Automatic seal water injection was provided for line in this classification.

Class 2 (Outgoing Lines)

Outgoing lines not connected to the Reactor Coolant System which are normally or intermittently open during reactor operation, and not missile protected or which can otherwise communicate with the containment atmosphere following an accident, were provided, as a minimum, with two automatic trip valves in series outside containment. Automatic seal water injection was provided for lines in this classification with the exception of the reactor coolant pump seal water return line, which was provided with manual seal water injection. Most of these lines are not vital to plant operation following an accident.

Class 3 (Incoming Lines)

Incoming lines connected to open systems outside containment, and not missile protected or which can otherwise communicate with the containment atmosphere following an accident were provided with one of the following arrangements outside containment:

1) Two automatic trip valves in series, with automatic seal water injection. This arrangement was provided for lines, which are not necessary to plant operation after an accident.

2) Two manual isolation valves in series, with manual seal water injection. This arrangement was provided for lines, which remain in service for a time, or are used periodically, subsequent to an accident.

Incoming lines connected to closed systems outside containment, and not missile protected or which can otherwise communicate with the containment atmosphere following an accident were provided either with two isolation valves in series outside containment with seal water injection between them or, at a minimum with one check valve or normally closed isolation valve located either inside or outside containment.

The closed piping system outside containment provides the necessary isolation redundancy for lines, which contain only one isolation valve.

Exceptions are the containment spray headers and the safety injection header associated with the boron injection tank, which was valved in accordance with safeguards requirements. The containment spray headers have locked-open double disk gate valves while the safety injection header has either single normally-open double disk gate valves or two normally open gate valves arranged in series.

Class 4 (Missile Protected)

Incoming and outgoing lines which penetrate the Containment and which are normally or intermittently open during reactor operation and are connected to closed systems inside the Containment and protected for missiles throughout their length were provided with at least one isolation valve located outside the Containment. Seal water injection was provided for certain lines in this classification.

Class 5 (Normally Closed Lines Penetrating the Containment)

Lines which penetrate the Containment and which can be opened to the containment atmosphere but which are normally closed during reactor operation were provided with two isolation valves in series or one isolation valve and one blind flange.

Class 6 (Special Service)

There are a number of special groups of penetrating lines and containment access openings. Some of these are discussed below.

Each ventilation purge duct penetration was provided with two tight-closing butterfly valves, which are closed during reactor power operation and are actuated to the closed position automatically upon a containment isolation or a containment high radiation signal.

One valve is located inside and one valve is located outside the Containment at each penetration. The space between valves is pressurized by air from the Penetration and Weld Channel Pressurization System, whenever they are closed.

The containment pressure relief line is similarly protected. However, since the line can be opened during reactor power operation, three tight closing butterfly valves in series are provided, one inside and two outside the Containment. These valves also are actuated to the closed position upon a containment isolation or containment high radiation signal. The two intravalve spaces are pressurized by air from the Penetration and Weld Channel Pressurization System whenever they are closed.

The equipment access closure is a bolted, gasketed closure, which is sealed during reactor operation. The personnel air locks consist of two doors in series with mechanical interlocks to assure that one door is closed at all times. Each air lock door and the equipment closure were provided with double gaskets to permit pressurization between the gaskets by the Penetration and Weld Channel Pressurization System, Section 6.6.

The fuel transfer tube penetration inside the Containment was designed to present a missile protected and pressurized double barrier between the containment atmosphere and the atmosphere outside the Containment. The penetration closure was treated in a manner similar to the equipment access hatch. A positive pressure is maintained between the double gaskets to complete the double barrier between the containment atmosphere and the inside of the fuel transfer tube. The interior of the fuel transfer tube is not pressurized. Seal water injection is not required for this penetration.

The following lines would be subjected to pressure in excess of the Isolation Valve Seal Water System design pressure (150 psig) in the event of an accident, due to operation of the recirculation pumps:

1) Residual heat removal loop return line
2) Bypass line from residual heat exchanger outlet to safety injection pumps suction
3) Residual heat removal loop sample line
4) Recirculation pump discharge sample line
5) Residual heat removal pump miniflow line
6) Residual heat removal loop outlet line

Lines 1, 2, and 6 are isolated by double disc gate valves, while line 3, 4 and 5 are each isolated by two valves in series. These valves can be sealed by nitrogen gas from the high pressure nitrogen supply of the Isolation Valve Seal Water System.

A self contained pressure regulator operates to maintain the nitrogen injection pressure slightly higher than the maximum expected line pressure. The nitrogen gas injection is manually initiated.

Lines which communicate with the containment atmosphere at all times (normally filled with air or vapor) include:

1) Steam jet air ejector return line to containment
2) Containment radiation monitor inlet and outlet lines.

In an accident condition, the space between the two containment isolation valves in each line is sealed by pressurizing with air from the Penetration and Weld Channel Pressurization System. The air is introduced into each space above the containment calculated peak accident response pressure through a separate line from the Penetration and Weld Channel Pressurization System. Parallel (redundant) fail open valves in each injection line open on the appropriate containment isolation signal to provide a reliable supply of pressurizing air. A flow

limiting orifice in each injection line prevents excessive air consumption if one of these valves spuriously fails open, or if one of the containment isolation valves fails to respond to the “trip” signal.

Class 7 (Steam and Feedwater Lines)

These lines and the shell side of the steam generator are considered basically as an extension of the containment boundary and as such must not be damaged as a consequence of Reactor Coolant System damage. This required that the steam generator shell, feed and steam lines within the Containment be classified and designed for the Reactor Coolant System missile-protected category. The reverse is also true in that a steam line break is not to cause damage to the Reactor Coolant System.

5.2.2.1 Isolation Valves and Instrumentation Diagrams

Plant Drawings 9321-F-27473, -27203, -27353, -27453, -27503, -27513 Sh. 1, -27363, -27193, -27233, -27473, -20253, -27263, -70453, -20173, -20193, -27293 Sh. 1 & 2, -27223, -20353, -40223, -26533, -20363, -26533, and -27243 [Deleted] show all valves in lines leading to the atmosphere or to closed systems on both sides of the containment barrier, valve actuation and preferential failure modes, the application of “trip” (containment isolation) signals, relative location of the valves with respect to missile barriers, and the boundaries of seismic Class I designed lines. Figure 5.2-29 defines the nomenclature and symbols used. Individual containment isolation valves are listed in Section 5.2 of the FSAR and Table 5.2-3.

5.2.2.2 Normally Closed Isolation Valves

Table 5.2-3 identifies those isolation valves which are either locked closed, or normally closed, (under administrative control) in normal position and relates to Figures 5.2-1 through 5.2-29.

5.2.2.3 Valve Parameters Tabulation

A summary of the fluid systems lines penetrating containment and the valves and closed systems employed for containment isolation is presented in Table 5.2-3. Each valve is described as to type, operator, position indication and open or closed status during normal operation, shutdown and accident conditions. Information is also presented on valve preferential failure mode, automatic trip by the containment isolation signal, and the fluid carried by the line.

Containment isolation valves were provided with actuation and control equipment appropriate to the valve type. For example, air operated globe and diaphragm (Saunders Patent) valves are generally equipped with air diaphragm operators, with fail-safe operation provided by the control devices in the instrument air supply to the valve. Motor operated gate valves are capable of being supplied from reliable onsite emergency power as well as their normal power source. Manual and check valves, of course, do not require actuation or control systems.

The automatically tripped isolation valves are actuated to the closed position by one of two separate containment isolation signals. The first of these signals is derived in conjunction with automatic safety injection actuation, and trips the majority of the automatic isolation valves. These are valves in the so-called “non-essential”** process lines penetrating the containment. This is defined as a “Phase A” isolation and the trip valves are designated by the letter “T” in the

isolation diagrams, Figures 5.2-1 through 5.2-29. This signal also initiates automatic seal water injection (See Section 6.5). The second, or "Phase B," containment isolation signal is derived upon actuation of the Containment Spray System, and trips the automatic isolation valves in the so called "essential"* process lines penetrating the containment. These trip valves are designated by the letter "P" in the isolation diagrams.

NOTE:

* "Essential" are those lines required to mitigate an accident, or which, if unavailable, could increase the magnitude of the event. Also, those lines which, if available, would be used in the short term (24 to 36 hours) to restore the plant to normal operation following an event which has resulted in containment isolation.

** "Non-Essential" are those lines which are not required to mitigate or limit an accident, which if required at all would be required for long-term recovery only, i.e., days or weeks following an accident.

A manual containment isolation signal can be generated from the Control Room. This signal performs the same functions as the automatically derived "T" signal, i.e., "Phase A" isolation and automatic seal water injection.

Non-automatic isolation valves, i.e., remote stop valves and manual valves, are used in lines which must remain in service, at least for a time, following an accident. These are closed manually if and when the lines are taken out of service.

Standard closing times available with commercial valve models are adequate for the sizes of containment isolation valves used. Valves equipped with air-diaphragm operators generally close in approximately two seconds. The typical closing time available for large motor operated gate valves is ten to thirty seconds. These general closure times are shown on Table 5.2-1. They are not used for determining valve stroke time limits. Specific design assumptions, closure times for design basis accidents, containment response analyses and resulting off-site dose calculations are contained in specific analyses.

The large butterfly valves used to isolate the containment ventilation purge ducts are each equipped with spring-assisted air pistons capable of closing the valve in two seconds. These valves fail to the closed position on loss of control signal. They also fail closed upon loss of instrument air through use of a local air reservoir as an energy source.

5.2.2.4 Valve Operability

All containment isolation valves, actuators and controls are located so as to be protected against missiles which could be generated as a result of a Loss-of-Coolant Accident. Only valves so protected are considered to qualify as containment isolation valves.

Only isolation valves located inside containment are subject to the high pressure, high temperature, steam laden atmosphere resulting from an accident. Operability of these valves in the accident environment is ensured by proper design, construction and installation, as reflected by the following considerations:

1) All components in the valve installation, including valve bodies, trim and moving parts, actuators, instrument air and control and power wiring, were constructed of materials sufficiently temperature resistant to be unaffected by the accident environment. Special

attention was given to electrical insulation, air operator diaphragms and steam packing material.

2) In addition to normal pressures, the valves were designed to withstand maximum pressure differentials in the reverse direction imposed by the accident conditions. This criterion was particularly applicable to the butterfly type isolation valves used in the containment purge lines.

5.2.2.5 Valve Position Indication and Monitoring

In general, all remote operated valves have visual position indication in the Control Room. Table 5.2-4 lists the containment isolation valves and the location of each valve's position indicator lights. Two different types of indicating lights are used: 1) red and green lights and 2) white and red monitoring lights. The red position indicating light is on when the valve is fully open and the green position indicating light is on when the valve is fully closed. At all other positions, both the red and green position indicating lights are on. The red monitor light is on when the valve is in its safeguard position and the white monitor light is on when the motive power is available to the valve. For those valves that are normally de-energized, the white monitor light indicates that power is available to the monitor indicating circuit.

Remote operated containment isolation valves, which are under remote manual control and do not receive a signal from the ESF actuation system, were provided with visual indication of position. An audible alarm feature was provided for remote operated safeguards valves under remote manual control for safeguards functions to denote their off-normal positions.

5.2.2.6 Local Leak Rate Testing of Containment Isolation Valves

Local leak rate testing of containment isolation valves is performed in accordance with Technical Specification 5.5.15. The Containment Leak Rate Program is in accordance with the guidance contained in Regulatory Guide 1.163, except as noted in the Technical Specification.

Amendment No. 195 to the Technical Specifications relocated information concerning containment isolation valves from the Technical Specifications to the FSAR.

Subsequent to implementation of Option B of 10 CFR 50, Appendix J, a third-party review of NYPA's (Option B) implementation program was completed. That review, confirmed by NYPA Nuclear Safety Evaluation, determined the scope of the Appendix J, "Type C," Local Leak Rate Test Program was greater than required by regulation. Specifically:

1) Leakage testing of SI-MOV-888A and B and SI-MOV-1835A and B is not required. The valves are not required to be LLR tested for purposes of compliance with Appendix J. These valves do not represent potential primary containment atmospheric leak paths following a single active failure. Since IVSWS nitrogen will only be applied to these valves in the event of a passive failure, but in no case sooner than 24 hours post-LOCA, there are no requirements for performance of leak rate tests.

2) Leak rate testing of the remaining valves penetrations served by the high-pressure nitrogen sub-system IVSWS is not required for compliance with Appendix J. Continued testing is required to ensure adequate nitrogen supply to the affected CIVs for the initial twenty-four hour period following a LOCA.

3) Local leak rate (Type C) testing of SI-1814 A, B, and C is not required for compliance with Appendix J. These valves do not represent potential primary containment atmospheric leak paths following a single active failure.

   Note: It is understood the body and packing of the SI-1814 A, B, and C valves are an extension of the containment pressure boundary and are exposed to containment pressure during Type A tests. If that pressure boundary is "broken," i.e., to facilitate calibration of the transmitters, then appropriate testing will be performed to confirm the integrity of the pressure boundary.

4) Local leak rate (LLR) testing of AC-741 is not required for compliance with Appendix J. This valve does not represent a potential primary containment atmospheric leak path following a single active failure.

5) Local leak rate testing of SI-MOV-885 A & B is not required for compliance with Appendix J. These valves do not represent potential primary containment atmospheric leak paths following a single active failure.

6) LLR testing of the SES CIVs is not required for compliance with Appendix J. Continued testing is required to assure the potential for in-leakage of service water into the containment following a postulated breach of the SWS integrity during the long-term post-LOCA recovery phase is within analyzed limits.

5.2.2.7 Containment Isolation During Refueling Outage

The Containment Equipment Hatch Closure Plug (CEHCP) may be used during an outage, when the permanent Equipment Hatch is removed.

The CEHCP will maintain containment closure during core alterations and during movement of irradiated fuel assemblies within containment building. [Deleted] The CEHCP is a [Deleted] device that is capable of rapid closure for cold shutdown including the reactor head lift, the reactor internals lift, and fuel movement. It is effectively an airtight, but not pressure-resistant, device that when installed prevents direct communication between the containment atmosphere and the outside atmosphere.

Subsequent to a loss of RHR cooling as defined in ITS 3.9.4 and 3.9.5, the CEHCP provides rapid containment closure until either cooling is restored, or the main equipment hatch [Deleted] may be installed within four hours.

TABLE 5.2-1

CONTAINMENT CONTROL ISOLATION VALVES

Valve Type	Actuator	Closure*
1500# Globe	Reverse Diaphragm	6 sec
1500# Globe	Motor	10 sec
1500# D.D.V.	Motor	10/30 sec
150# Gate	Motor	10 sec
150# Saunders	Direct Diaphragm	2 sec
150# Saunders	Reverse Diaphragm	2 sec
150# Globe	Solenoid	1.5 sec
150# D.D.V.	Motor	10 sec
150# Globe	Reverse Diaphragm	6 sec
150# Butterfly	Air & Spring	2 sec
600# Plug	Air Piston	4 sec
150# Butterfly	Air Piston	3.5 sec
300# Gate (RHR V 744)	Motor	30 sec
150# Gate (Aux Coolant V 769 and V 797)	Motor	30 sec

*Note: Closure times listed are general closure times for valve types shown. They do not form the basis of the safety analysis and are not used in determining valve stroke criteria.

TABLE 5.2-2

NORMALLY CLOSED ISOLATION VALVES

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TABLE 5.2-3
(Sheet 1 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR. DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-1	PRESSURIZER RELIEF TANK TO GAS ANALYZER Penetration "V"	RC-AOV-549 RC-AOV-548	1	GLOBE GLOBE	AIR AIR	FC FC	T T	Yes Yes	G	H	C C	O O	C C	No No	Water (A)(4) Water (A)(4)	47	W W
5.2-1	PRESSURIZER RELIEF TANK N_2 SUPPLY Penetration "Y"	RC-518 RC-AOV-550	3	CHECK DIA.	- AIR	- FC	- T	No Yes	G	C	- O	- O	- C	No No	- -	43	G G
5.2-1	PRESSURIZER RELIEF TANK MAKE-UP Penetration "Y"	RC-AOV-552 RC-AOV-519	3	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	W	C	C(9) C(9)	C C	C C	No No	Water (A)(4) Water (A)(4)	47	W W
5.2-2	RESIDUAL HEAT REMOVAL RETURN Penetration "J"	AC-741 AC-MOV-744	6	CHECK DDV	- MOTOR	- FAI	- -	No Yes	W	H	- O(8)	- O	- O	No Yes	(5) Nitro(M)(32)	N/A 43 (15)	N/A N
5.2-2	RESID. HEAT REMOVAL LOOP TO SI PUMPS Penetration "QQ"	SI-MOV-888A SI-MOV-888B CS	6	DDV DDV -	MOTOR MOTOR -	FAI FAI -	- - -	Yes Yes	W	H	C(8) C(8)	LC(28) LC(28)	O O	Yes Yes	Nitro(M)(31) Nitro(M)(31)	N/A	N/A N/A
5.2-2	RESID. HEAT REMOVAL LOOP TO SAMPLING SYS. Penetration "QQ"	SP-AOV-958 SP-AOV-959 SP-990C	6	GLOBE GLOBE GLOBE	AIR AIR MANUAL	FC FC -	T T -	Yes Yes No	W	H	C C LC(8)	C(12) C(12) C(12)	C(12) C(12) C(12)	No(12) No(12) No(12)	Nitro(M)(32) Nitro(M)(32) Nitro(M)(32)	50	N N N
5.2-2	RESID. HEAT REMOVAL LOOP TO RHR PUMP MINIFLOW Penetration "QQ"	AC-MOV-1870 AC-MOV-743	6	GLOBE GATE	MOTOR MOTOR	FAI FAI	- -	Yes Yes	W	H	LTh(8) O(8)	LTh O	O O	Yes Yes	Nitro(M)(32) Nitro(M)(32)	50	N N
5.2-2	RESID. HEAT REMOVAL LOOP OUT Penetration "K"	AC-732	6	DDV	MANUAL	-	-	No	W	H	LC(8)	O	C	No	Nitro. (M)(32)	50 (15)	N
5.2-2	CONTAINMENT SUMP RECIRC. LINE Penetration "OO"	SI-MOV-885A SI-MOV-885B	5	DDV(23) DDV(23)	MOTOR MOTOR	FAI FAI	- -	Yes Yes	W	H	C(8) C(8)	C LC(28)	C(18) C(18)	No(18) No(18)	(5) (5)	N/A	N/A N/A
5.2-3	LETDOWN LINE Penetration "X"	CH-AOV-201 CH-AOV-202 CS	1	GLOBE GLOBE -	AIR AIR -	FC FC -	T T -	Yes Yes -	W	H	O O	C(9) C(9)	C C	No No	Water (A)(4) Water (A)(4)	47	W W
5.2-3	CHARGING LINE Penetration "R"	CH-MOV-205 CH-MOV-226 CH-227 CS	3	GATE GATE GLOBE -	MOTOR MOTOR MANUAL -	FAI FAI - -	- - - -	No No No -	W	C	O(8) O(8) LC(8)	C(9) C(9) C	C C C	No No No	Water(M)(4) Water(M)(4) Water(M)(4)	47	W W W
5.2-4	REACTOR COOLANT PUMP SEAL WATER SUPPLY LINES Penetration "Z"	CH-MOV-250A CH-MOV-250B CH-MOV-250C CH-MOV-250D CH-MOV-441 CH-MOV-442 CH-MOV-443 CH-MOV-444	3	GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE	MOTOR MOTOR MOTOR MOTOR MOTOR MOTOR MOTOR MOTOR	FAI FAI FAI FAI FAI FAI FAI FAI	- - - - - - - -	No No No No No No No No	W	C	O(8) O(8) O(8) O(8) O(8) O(8) O(8) O(8)	C(9) C(9) C(9) C(9) C(9) C(9) C(9) C(9)	C(11) C(11) C(11) C(11) C(11) C(11) C(11) C(11)	No(11) No(11) No(11) No(11) No(11) No(11) No(11) No(11)	Water(M)(4) Water M)(4) Water(M)(4) Water(M)(4) Water(M)(4) Water(M)(4) Water(M)(4) Water(M)(4)	47	W W W W W W W W

TABLE 5.2-3
(Sheet 2 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-4	REACTOR COOLANT PUMP SEAL WATER RETURN Penetration “R”	CH-MOV-222	2	DDV	MOTOR	FAI	P	Yes	W	C	O(11)	O	C(11)	No(11)	Water (M)(4)	47	W
5.2-5	REACTOR COOLANT SYSTEM SAMPLE LINES Penetration “W”	SP-AOV-956E SP-AOV-956F	1	GLOBE GLOBE	AIR AIR	FC FC	T T	Yes Yes	W	H	O O	C C	C C	No No	Water (A)(4) Water (A)(4)	47	W
5.2-5	FUEL TRANSFER TUBE Penetration “HH”	-	6	BLIND FLANGE (27)	-	-	-	-	W	H	-	-	-	-	(17)	-	-
5.2-6	CONTAINMENT SPRAY HEADERS Penetrations “GG” and “P”	SI-869A SI-869B SI-867A SI-867B SI-878A SI-878B	3	DDV DDV CHECK CHECK GLOBE GLOBE	MANUAL MANUAL - - MANUAL MANUAL	- - - - - -	- - - - - -	No No No No No No	W	C	LO(8) LO(8) - - LC(8) LC(8)	C C - - C C	O O - - C C	Yes Yes Yes Yes Yes Yes	Water(M)(4) Water(M)(4) - - - -	47 47 43 43 43 43	W W G G G G
5.2-7	SAFETY INJECTION HEADERS Penetrations “Q” and “NN”	SI-MOV-1835A SI-MOV-1835B SI-MOV-851A SI-MOV-850C SI-MOV-850A	3	DDV DDV DDV GATE GATE	MOTOR MOTOR MOTOR MOTOR MOTOR	FAI FAI FAI FAI FAI	S S - - -	Yes Yes Yes Yes Yes	W	H	O(8) O(8) O(8) LO(8) LO(8)	C C C C C	O(19) O(19) O(19) O(19) O(19)	Yes(33) Yes(33) Yes(19) Yes(19) Yes(19)	Nitro.(M)(33) Nitro.(M)(33) Water (M)(4) Water (M)(4) Water (M)(4)	N/A N/A 47 47 47	N/A N/A W W W
5.2-7	SAFETY INJECTION TEST Penetration “Y”	SI-859A SI-859C	5	GLOBE GLOBE	MANUAL MANUAL	- -	- -	No No	W	C	LC(8) LC(8)	C C	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-8	ACCUMULATOR NITROGEN SUPPLY Penetration “RR”	NNE-1610 NNE-AOV-863	5	CHECK GLOBE	- AIR	- FC	- T	No Yes	G	C	- C(9)	- C	- C	No No	- -	43 43	G G
5.2-8	ACCUMULATOR SAMPLE Penetration “RR”	SP-AOV-956G SP-AOV-956H	2	GLOBE GLOBE	AIR AIR	FC FC	T T	Yes Yes	W	C	C(12) C(12)	C C	C(12) C(12)	No(12) No(12)	Water (A)(4) Water (A)(4)	47 47	W W
5.2-9	PRIMARY SYSTEM VENT AND NITROGEN SUPPLY Penetration “V”	WD-AOV-1786 WD-AOV-1787 WD-AOV-1610 WD-1616	2 3	DIA DIA . DIA. CHECK	AIR AIR AIR -	FC FC FC -	T T T -	Yes Yes Yes No	G	H	O(9) O(9) O -	C C O -	C C C -	No No No -	Water (A)(4) Water (A)(4) - -	47 47 43 43	W W G G
5.2-9	REACTOR COOLANT DRAIN TK. TO GAS ANALYZER Penetration “V”	WD-AOV-1788 WD-AOV-1789	2	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	G	H	C(13) C(13)	O C(13)	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-9	RCDT PUMP DISCHARGE Penetration “Z”	WD-AOV-1702 WD-AOV-1705	2	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	W	C	C(9) C(9)	O O	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-10	REACTOR COOLANT PUMP COOLING WATER IN Penetration “N”	AC-MOV-797 AC-MOV-769	3	GATE GATE	MOTOR MOTOR	FAI FAI	P P	Yes Yes	W	C	O(11) O(11)	C(11) C(11)	C(11) C(11)	No(11) No(11)	Water (M)(4) Water (M)(4)	47 47	W W

TABLE 5.2-3
(Sheet 3 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-10	REACTOR COOLANT PUMP COOLING WATER OUT 6" Penetration "O"	AC-MOV-784 AC-MOV-786	2	GATE GATE	MOTOR MOTOR	FAI FAI	P P	Yes Yes	W	C	O(11) O(11)	C(11) C(11)	C(11) C(11)	No(11) No(11)	Water (M)(4) Water (M)(4)	47 47	W W
5.2-10	REACTOR COOLANT PUMP COOLING WATER OUT 3" Penetration "O"	AC-FCV-625 AC-MOV-789	2	GATE GATE	MOTOR MOTOR	FAI FAI	P P	Yes Yes	W	C	O(11) O(11)	C(11) C(11)	C(11) C(11)	No(11) No(11)	Water (M)(4) Water (M)(4)	47 47	W W
5.2-11	RESIDUAL HEAT EXCHANGERS COOLING WATER IN Penetrations "KK" and "VV"	AC-751A AC-751B CS	4	CHECK CHECK -	- - -	- - -	- - -	No No -	W	C	- -	- -	- -	Yes Yes	- -	N/A N/A	N/A N/A
5.2-11	RESIDUAL HEAT EXCHANGERS COOLING WATER RETURN Penetrations "JJ" and "UU"	AC-MOV-822A AC-MOV-822B CS	4	GATE GATE -	MOTOR MOTOR -	FAI FAI -	S S -	Yes Yes -	W	C	C(8) C(8)	O O	O O	Yes Yes	- -	N/A N/A	N/A N/A
5.2-12	RECIRC. PUMP COOLING WATER SUPPLY Penetration "LL"	AC-752F AC-753F CS	4	GLOBE GLOBE -	MANUAL MANUAL -	- - -	- - -	No No -	W	C	O(8) O(8)	O O	O O	Yes Yes	- -	N/A N/A	N/A N/A
5.2-12	RECIRC. PUMP COOLING WATER RETURN Penetration "LL"	AC-752J AC-753J CS	4	GLOBE GLOBE -	MANUAL MANUAL -	- - -	- - -	No No -	W	C	O(8) O(8)	O O	O O	Yes Yes	- -	N/A N/A	N/A N/A
5.2-13	EXCESS LETDOWN HEAT EXCHANGER COOLING WATER IN Penetration "U"	AC-AOV-791 AC-AOV-798	4	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	W	C	C(9) C(9)	O O	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-13	EXCESS LETDOWN HEAT EXCHANGER COOLING WATER OUT Penetration "R"	AC-AOV-796 AC-AOV-793	4	GLOBE DIA.	AIR AIR	FC FC	T T	Yes Yes	W	C	C(9) C(9)	O O	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-13	CONTAINMENT SUMP PUMP DISCHARGE Penetration "Y"	WD-AOV-1728 WD-AOV-1723	2	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	W	C	O O	O O	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W
5.2-14	CONTAINMENT AIR SAMPLE IN- RAD. MONITORING SYSTEM Penetration "RR"	VS-PCV-1234 VS-PCV-1235	6	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	G	C	O O	O O	C(20) C(20)	No(20) No(20)	Air (A)(7) Air (A)(7)	43 43	G G
5.2-14	CONTAINMENT AIR SAMPLE OUT – RAD. MONITORING SYSTEM Penetration "RR"	VS-PCV-1236 VS-PCV-1237	6	DIA. DIA.	AIR AIR	FC FC	T T	Yes Yes	G	C	O O	O O	C(20) C(20)	No(20) No(20)	Air (A)(7) Air (A)(7)	43 43	G G
5.2-14	AIR EJECTOR DISCHARGE TO CONTAINMENT Penetration "R"	CA-PCV-1229 CA-PCV-1230	6	GLOBE GLOBE	AIR AIR	FC FC	T T	Yes Yes	G	C	C C	C C	C C	No No	Air (A)(7) Air (A)(7)	43 43	G G

TABLE 5.2-3
(Sheet 4 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-15	MAIN STEAM HEADERS Penetrations "A,B,C and D"	CS	7	-	-	-	-	-	G	H	-	-	(22)	Yes(22)	-	-	-
	MAIN STEAM TO AUX. FW PUMP TURBINE	CS	-	-	-	-	-	-	G		-	-	-	Yes	-	-	-
5.2-15	MAIN FEEDWATER HEADERS Penetrations "E,F,G and H"	CS	7	-	-	-	-	-	W	H	-	-	-	Yes	-	-	-
	AUXILIARY FW TURBINE DRIVEN	CS	-	-	-	-	-	-	W		-	-	-	Yes	-	-	-
	AUXILIARY FW MOTOR DRIVEN	CS	-	-	-	-	-	-	W		-	-	-	Yes	-	-	-
5.2-15	STEAM GENERATOR BLOWDOWN Penetrations "AA,BB, CC, and DD"	BD-PCV-1214		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1215	2	GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1216		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1217		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
									W	H							
		BD-PCV-1214A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1215A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1216A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1217A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
5.2-15	STEAM GENERATOR BLOWDOWN SAMPLE Four Lines @ Penetration "W"	BD-PCV-1223	2	GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1224		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1225		GLOBE	AIR	FC	T	Yes	W	H	O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1226		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1223A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1224A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1225A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
		BD-PCV-1226A		GLOBE	AIR	FC	T	Yes			O	C	C	No	Water (A)(4)	47	W
5.2-16	VENTILATION SYSTEM COOLING WATER IN Penetrations "La,Lb,Lc, Ld and Le"	SWN-41-1		BV	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-41-2		BV	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-41-3		BV	MANUAL	-	-	No	W	C	O(8)	O	O	Yes	(6)	47	W
		SWN-41-4		BV	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-41-5		BV	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-43-1		GATE	MANUAL	-	-	No			C(8)	C	C	No	(6)	47	W
		SWN-43-2		GATE	MANUAL	-	-	No			C(8)	C	C	No	(6)	47	W
		SWN-43-3	4	GATE	MANUAL	-	-	No			C(8)	C	C	No	(6)	47	W
		SWN-43-4		GATE	MANUAL	-	-	No			C(8)	C	C	No	(6)	47	W
		SWN-43-5		GATE	MANUAL	-	-	No			C(8)	C	C	No	(6)	47	W
		SWN-42-1		RV	-	-	-	No			-	-	-	-	(6)	47	W
		SWN-42-2		RV	-	-	-	No			-	-	-	-	(6)	47	W
		SWN-42-3		RV	-	-	-	No			-	-	-	-	(6)	47	W
		SWN-42-4		RV	-	-	-	No			-	-	-	-	(6)	47	W
		SWN-42-5		RV	-	-	-	No			-	-	-	-	(6)	47	W
		CS		-	-	-	-	-			-	-	-	-			

TABLE 5.2-3
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CONTAINMENT PIPING PENETRATIONS AND VALVING

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FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-16	VENTILATION SYSTEM COOLING WATER OUT Penetrations "Ma, Mb, Mc, Md, Me, and SS"	SWN-44-1		BV	MANUAL	-	-	No			LTh(8)	LTh	LTh	Yes	(6)	47	W
		SWN-44-2		BV	MANUAL	-	-	No	W	C	LTh(8)	LTh	LTh	Yes	(6)	47	W
		SWN-44-3		BV	MANUAL	-	-	No			LTh(8)	LTh	LTh	Yes	(6)	47	W
		SWN-44-4		BV	MANUAL	-	-	No			LTh(8)	LTh	LTh	Yes	(6)	47	W
		SWN-44-5		BV	MANUAL	-	-	No			LTh(8)	LTh	LTh	Yes	(6)	47	W
		SWN-51-1		GATE	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-51-2	4	GATE	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-51-3		GATE	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-51-4		GATE	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-51-5		GATE	MANUAL	-	-	No			O(8)	O	O	Yes	(6)	47	W
		SWN-71-1		GLOBE	MANUAL	-	-	No			Th(8)	Th	Th	Yes	(6)	47	W
		SWN-71-2		GLOBE	MANUAL	-	-	No			Th(8)	Th	Th	Yes	(6)	47	W
		SWN-71-3		GLOBE	MANUAL	-	-	No			Th(8)	Th	Th	Yes	(6)	47	W
		SWN-71-4		GLOBE	MANUAL	-	-	No			Th(8)	Th	Th	Yes	(6)	47	W
		SWN-71-5		GLOBE	MANUAL	-	-	No			Th(8)	Th	Th	Yes	(6)	47	W
		CS		-	-	-	-	-									
5.2-17	STATION AIR Penetration "Y"	SA-24-1	3	DIA.	MANUAL	-	-	No	G	C	LC(8)	LC(8)	LC	No	Water (A)(4)	47	W
		SA-24-2		DIA.	MANUAL	-	-	No			LC(8)	LC(8)	LC	No	Water (A)(4)	47	W
5.2-17	WELD CHANNEL PENETRATION PRESSURE SYSTEM Penetration "Y"	PS-PCV-1111-1	4	BALL	MANUAL	-	-	No			LO(8)	LO	LO	Yes	(17)	N/A	N/A
		PS-PCV-1111-2		BALL	MANUAL	-	-	No	G	C	LO(8)	LO	LO	Yes	(17)	N/A	N/A
		CS (inside)		-	-	-	-	-			-	-	-	-			
		CS (outside)		-	-	-	-	-			-	-	-	-			
5.2-19	PURGE SUPPLY DUCT VENTILATION Penetration "EE"	VS-FCV-1170	6	BV	AIR	FC	T (2)	Yes	G	C	C	O	C	No	Air (A)(7)	43	G
		VS-FCV-1171		BV	AIR	FC	T (2)	Yes			C	O	C	No	Air (A)(7)	43	G
5.2-19	PURGE EXHAUST DUCT VENTILATION Penetration "FF"	VS-FCV-1172	6	BV	AIR	FC	T (2)	Yes	G	C	C	O	C	No	Air (A)(7)	43	G
		VS-FCV-1173		BV	AIR	FC	T (2)	Yes			C	O	C	No	Air (A)(7)	43	G
5.2-19	CONTAINMENT PRESSURE RELIEF VENTILATION Penetration "PP"	VS-PCV-1190		BV	AIR	FC	T (2)	Yes	G	C	C(14)	C	C	No	Air (A)(7)	43	G
		VS-PCV-1191	6	BV	AIR	FC	T (2)	Yes			C(14)	C	C	No	Air (A)(7)	43	G
		VS-PCV-1192		BV	AIR	FC	T (2)	Yes			C(14)	C	C	No	Air (A)(7)	43	G
5.2-20	RECIRCULATION PUMP DISCHARGE SAMPLE LINE Penetration "TT"	SP-MOV-990A	6	GATE	MOTOR	FAI	-	No	W	C	LC(8)	C	LC (12)	No	Nitro(M)(32)	50	N
		SP-MOV-990B		GATE	MOTOR	FAI	-	No			LC(8)	C	LC (12)	No	Nitro(M)(32)	50	N
5.2-20	PRESSURIZER STEAM SAMPLE LINE Penetration "W"	SP-AOV-956A	1	GLOBE	AIR	FC	T	Yes	W	H	C	C	C	No	Water (A)(4)	47	W
		SP-AOV-956B		GLOBE	AIR	FC	T	Yes			C	C	C	No	Water (A)(4)	47	W
5.2-20	PRESSURIZER LIQUID SAMPLE LINE Penetration "W"	SP-AOV-956C	1	GLOBE	AIR	FC	T	Yes	W	H	C	C	C	No	Water (A)(4)	47	W
		SP-AOV-956D		GLOBE	AIR	FC	T	Yes			C	C	C	No	Water (A)(4)	47	W

TABLE 5.2-3
(Sheet 6 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

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FIGURE NO.	SERVICE AND PENETRATION	VALVE ID or CLOSED SYSTEM	PENET CLASS (1)	VALVE TYPE	OPER. TYPE	PWR. FAIL POSITION	CONT. ISOL. TRIP	POSITION INDIC. CONT. RM	FLUID GAS / WTR.	PENETR DESIGN (25)	NORM. POSITION	SHUT-DOWN POSITION	POST ACCID. POSITION	POST ACCID. USAGE	SEALING METHOD	MIN. TEST PRESS. (psig)	TEST FLUID (16)
5.2-21	CONTAINMENT PRESSURE INSTRUMENTATION LINE Penetration “RR”	SI-1814A CS	6	GLOBE -	MANUAL -	- -	- -	No -	G	C	LO(8)	O	O	Yes	- -	(34)	N/A
5.2-21	CONTAINMENT PRESSURE INSTRUMENTATION LINE Penetration “LL”	SI-1814B CS	6	GLOBE -	MANUAL -	- -	- -	No -	G	C	LO(8)	O	O	Yes	- -	(34)	N/A
5.2-21	CONTAINMENT PRESSURE INSTRUMENTATION LINE Penetration “O”	SI-1814C CS	6	GLOBE -	MANUAL -	- -	- -	No -	G	C	LO(8)	O	O	Yes	- -	(34)	N/A
5.2-22	POST ACCIDENT CONTAINMENT SAMPLING SUPPLY AND RETURN LINES Penetrations “R, TT, LL, Z, and O”	SP-SOV-506 SP-SOV-507 SP-SOV-508 SP-SOV-512 SP-SOV-513 SP-SOV-511 SP-SOV-516 SP-SOV-509 SP-SOV-510 SP-SOV-514 SP-SOV-515	5	GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE GLOBE	SOL. SOL. SOL. SOL. SOL. SOL. SOL. SOL. SOL. SOL. SOL.	FC FC FC FC FC FC FC FC FC FC FC	T(10) T(10) T(10) T(10) T(10) T(10) T(10) T(10) T(10) T(10) T(10)	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	G	C	C(8) C(8) C(8) C(8) C(8) C(8) C(8) C(8) C(8) C(8) C(8)	C C C C C C C C C C C	C(12) C(12) C(12) C(12) C(12) C(12) C(12) C(12) C(12) C(12) C(12)	Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12) Yes (12)	Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7) Air (A)(7)	43 43 43 43 43 43 43 43 43 43 43	G G G G G G G G G G G
-	CONTAINMENT SUMP RECIRCULATION (SPARE) Penetration “O_1 O_1”	CS (3)	6	-	-	-	-	-	-	C	-	-	-	-	(17)	-	-
5.2-25	INSTRUMENT AIR – P. A. VENTING SYSTEM SUPPLY Penetration “Y”	IA-39 IA-PCV-1228	6	CHECK DIA.	- AIR	- FC	- T	No Yes	G	C	- O	- O	- C (24)	No No (24)	- -	43 43	G G
5.2-25	POST ACCIDENT VENTING SYSTEM EXHAUST LINE Penetration “LL” (Retired)	CS(3)	-	-	-	-	-	-	G	C	-	-	-	No	(17)	-	-
5.2-26	CONTAINMENT LEAK TEST INSTRUMENT SENSOR LINE Three lines @ Penetration “RR”	CS (3)	-	-	-	-	-	-	G	C	-	-	-	No	(17)	-	-
5.2-26	CONTAINMENT LEAK TEST AIR LINE Penetrations “XX and YY”	CS (3)	6	-	-	-	-	-	G	C	-	(30)	-	No	(17)	-	-
5.2-27	EQUIPMENT ACCESS	CB-7 CB-8 CB-5 CB-6	6	BALL BALL CHECK(26) CHECK(26)	MANUAL MANUAL - -	- - - -	- - - -	(29)	G	C	C(8) C(8) - -	C C - -	C C – -	No No	(17) (17) - -	43 43 43 43	G G G G
5.2-27A	PERSONNEL AIR LOCK	CB-3 CB-4 CB-1 CB-2	6	BALL BALL CHECK(26) CHECK(26)	MANUAL MANUAL - -	- - - -	- - - -	(29)	G	C	C(8) C(8) - -	C C - -	C C - -	No No	(17) (17) - -	43 43 43 43	G G G G
5.2-28	DEMIN. WTR. INTO CONTAINMENT Penetration “Y”	DW-AOV-1 DW-AOV-2	6	PLUG PLUG	AIR AIR	FC FC	T T	Yes Yes	W	C	C C	C(21) C(21)	C C	No No	Water (A)(4) Water (A)(4)	47 47	W W

TABLE 5.2-3
(Sheet 7 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

ABBREVIATIONS:

A	Automatic
AMB	Ambient
BV	Butterfly Valve
C	Cold
CS	Closed System
COL	Check Off List
DDV	Double Disc Gate Valve
DIA	Diaphragm Valve
FAI	Fail As Is
FC	Fail Closed
FO	Fail Open
G	Gas
H	Hot
LC	Locked Closed
LO	Locked Open
LTh	Locked Throttled
M	Manual
N	Nitrogen
POP	Plant Operating Procedures
P	Containment Isolation Signal Phase B
T	Containment Isolation Signal Phase A
Th	Throttled
RV	Relief Valve
S	Safety Injection Signal (Opens valves on SI signal)
SOP	System Operating Procedures
SOL	Solenoid Operated Valves
W	Water

TABLE 5.2-3
(Sheet 8 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

DEFINITIONS:

NORMAL POSITION: Defined as RCS operation above 200^{0}F to Full Power. Valve positions as defined by POP's, SOP's, and COL's

SHUTDOWN POSITION: Defined as RCS 200^{0}F and below, not in refueling and not at reduced inventory. Valve positions as defined by POP's and SOP's.

POST ACCIDENT POSITION: Defined as SI with Phase A and B isolation. Note: valve position may differ based on the accident in progress (i.e. phase B may not be required).

POST ACCIDENT USAGE: Defined as Design Basis Accident valve usage based on position during long term recirculation, assuming no failures. Note: valve position may differ based on the accident in progress, equipment failure, and recommendations during the recovery phase.

NOTES:

1.Penetration class is described in subsection 5.2.2.	**16**. Test Fluid "G" signifying Gas indicates either air or nitrogen as test medium.
2.Also tripped closed by high radiation in containment.	**17**. Seal air via WCCPP, continuously pressurized.
3.Penetration sealed at both ends.	**18.** May be opened Post Accident if normal path from recirc. pumps not available.
4. Sealed by Isolation Valve Seal Water System.	**19.** Valves may be closed Post Accident if not in service.
5. "Sealed" by Residual Heat Removal System or recirculation sump fluid. Not a "seal system" as defined in 10 CFR 50, Appendix J.	**20.** May be opened Post Accident when the containment pressure is below 5 psig.
6. "Sealed" by Service Water System fluid. Not a "seal system" as defined in 10 CFR 50, Appendix J. LLR testing is not required for Appendix J compliance but is required to limit in-leakage to the containment given a postulated breech of SWS integrity during the long-term recovery phase.	**21.** Valves may be opened for maintenance.
7. Sealed by Weld Channel and Containment Penetration Pressurization System.	**22.** Valves outside containment in these lines will automatically isolate for steamline break or Hi-Hi containment pressure.
8.Non-Automatic Containment Isolation Valves open continuously or intermittently for plant operation (under administrative control).	**23.** DDV modified due to press. locking to function as a std.gate valve. 885A upstream disc drilled with 3/16"dia. hole, 885B bonnet connection bypasses downstream disc.
9.Valves may be operated as required to support plant operation.	**24.** Valves may be opened intermittently during Post Accident venting.
10.These series valves have non-redundant phase A automatic signals and therefore are treated as non-automatic containment isolation valves.	**25.** Penetrations identified as H (hot) indicates designed with expansion bellows or expansion coil, C (cold) indicates designed without an expansion bellows or expansion coil.
11.Isolated when Reactor Coolant Pumps are stopped.	**26.** Spring-loaded check valves (pressure relieving).
12.Valves opened intermittently to take samples.	**27.** Flange is double gasketed type, located in refueling canal.
13.Valve opened periodically by the Gas Analyzer.	**28.** Necessary to LC & de-energize if AC-730 & 731 are de-energized open.
14.Opened intermittently for pressure relief.	**29.** Control Rm. Annunciator "Personnel hatches not shut" alarm indication provided.
15. Testable only at Cold Shutdown.	

TABLE 5.2-3
(Sheet 9 of 9)
CONTAINMENT PIPING PENETRATIONS AND VALVING

Numbers shown in brackets () refer to footnotes

NOTES:

30. A Seismic Class I QA Augmented Quality Related temporary fiber optic penetration flange (TFP) may be installed in cold shutdown / refueling conditions to satisfy containment isolation function for refueling operations.	
31. Once opened to facilitate high head or hot leg recirculation, valves would remain open unless closed to isolate a postulated passive failure during the long-term recovery phase. LLR testing is not required.	
32. LLR testing performed to verify adequacy of on-site nitrogen inventory. LLR is not required for Appendix J compliance.	
33. Valves remain open to facilitate high head or hot leg recirculation unless closed to isolate a postulated passive failure during the long-term recovery phase. LLR testing is not required.	
34. LLRT is not required. Valve / penetration is open during Type A ILR test.	

TABLE 5.2-4

CONTAINMENT ISOLATION
VALVE POSITION INDICATION

Valve Number	Control Board Panel Location Red & Green Indicating Lights	Control Board Panel Location (Two-is-True) Monitor Lights
AC-MOV-743	SNF	SB1F
AC-MOV-744	SGF & SB1F	SB1F
CH-AOV-201	SFF & SNF	SNF
CH-AOV-202	SFF & SNF	SNF
CH-MOV-222	SFF & SNF	SNF
RC-AOV-519	SAF	SNF
RC-AOV-548	SNF	SNF
RC-AOV-549	SNF	SNF
RC-AOV-552	SAF	SNF
AC-FCV-625	SGF & SNF	SNF
AC-MOV-769	SGF & SNF	SNF
AC-MOV-784	SGF & SNF	SNF
AC-MOV-786	SGF & SNF	SNF
AC-MOV-789	SGF & SNF	SNF
AC-AOV-791	SGF & SNF	SNF
AC-AOV-793	SGF & SNF	SNF
AC-AOV-796	SGF	SNF
AC-MOV-797	SGF & SNF	SNF
AC-AOV-798	SGF & SNF	SNF
SP-AOV-956A	Sampling System Panel *	SNF
SP-AOV-956B	Sampling System Panel *	SNF
SP-AOV-956C	Sampling System Panel *	SNF
SP-AOV-956D	Sampling System Panel *	SNF
SP-AOV-956E	Sampling System Panel *	SNF
SP-AOV-956F	Sampling System Panel *	SNF
SP-AOV-956G	Sampling System Panel *	SNF
SP-AOV-956H	Sampling System Panel *	SNF
SP-AOV-959	Sampling System Panel *	SNF
VS-FCV-1170	SLF and Fan Room Ctr. Cab.*	SNF
VS-FCV-1171	SLF and Fan Room Ctr. Cab *	SNF
VS-FCV-1172	SLF and Fan Room Ctr. Cab *	SNF
VS-FCV-1173	SLF and Fan Room Ctr. Cab *	SNF
VS-PCV-1190	SLF and Fan Room Ctr. Cab *	SNF
VS-PCV-1191	SLF and Fan Room Ctr. Cab *	SNF
VS-PCV-1192	SLF and Fan Room Ctr. Cab *	SNF
BD-PCV-1214	SCF	SNF
DW-AOV-1	SKF	SNF
DW-AOV-2	SKF	SB1F
RC-AOV-550	SKF	SB1F

* Not located in control room

TABLE 5.2-4
(Cont.)

CONTAINMENT ISOLATION
VALVE POSITION INDICATION

Valve Number	Control Board Panel Location Red & Green Indicating Lights	Control Board Panel Location (Two-is-True) Monitor Lights
SP-AOV-958	CR Isolation Valve Panel JK1	-
WD-AOV-1610	SKF	SNF
SI-MOV-850A	SB2F&WD Extension *	-
SI-MOV-850C	SB2F&WD Extension *	-
BD-PCV-1214A	SCF	SNF
BD-PCV-1215	SCF	SNF
BD-PCV-1215A	SCF	SNF
BD-PCV-1216	SCF	SNF
BD-PCV-1216A	SCF	SNF
BD-PCV-1217	SCF	SNF
BD-PCV-1217A	SCF	SNF
BD-PCV-1223	Sampling System Panel*	SNF
BD-PCV-1223A	Sampling System Panel *	SNF
BD-PCV-1224	Sampling System Panel *	SNF
BD-PCV-1224A	Sampling System Panel *	SNF
BD-PCV-1225	Sampling System Panel *	SNF
BD-PCV-1225A	Sampling System Panel *	SNF
BD-PCV-1226	Sampling System Panel *	SNF
BD-PCV-1226A	Sampling System Panel *	SNF
IA-PCV-1228	SNF	SNF
CA-PCV-1229	SNF	SNF
CA-PCV-1230	SNF	SNF
VS-PCV-1234	SNF	SNF
VS-PCV-1235	SNF	SNF
VS-PCV-1236	SNF	SNF
VS-PCV-1237	SNF	SNF
WD-AOV-1702	Waste Disposal System Panel*	SNF
WD-AOV-1705	Waste Disposal System Panel *	SNF
WD-AOV-1723	Waste Disposal System Panel *	SNF
WD-AOV-1728	Waste Disposal System Panel *	SNF
WD-AOV-1786	Waste Disposal System Panel *	SNF
WD-AOV-1787	Waste Disposal System Panel *	SNF
WD-AOV-1788	SNF	SNF
WD-AOV-1789	SNF	SNF
AC-MOV-822A	SGF & SB1F	SB1F
AC-MOV-822B	SGF & SB1F	SB1F
SI-MOV-851A	SB2F	SB2F
NNE-AOV-863	SMF	SNF

*Not located in control room

TABLE 5.2-4
(Cont.)

CONTAINMENT ISOLATION
VALVE POSITION INDICATION

Valve Number	Control Board Panel Location Red & Green Indicating Lights	Control Board Panel Location (Two-is-True) Monitor Lights
SI-MOV-885A	SB1F	SB1F
SI-MOV-885B	SB1F	SB1F
SI-MOV-888A	SB1F	SB1F
SI-MOV-888B	SB1F	SB1F
SI-MOV-1835A	SB2F	SB2F
SI-MOV-1835B	SB2F	SB2F
AC-MOV-1870	SNF	SB1F
CH-MOV-205	WD Extension *	-
CH-MOV-226	WD Extension *	-
CH-MOV-250A	WD Extension *	-
CH-MOV-250B	WD Extension *	-
CH-MOV-250C	WD Extension *	-
CH-MOV-250D	WD Extension *	-
CH-MOV-441	WD Extension *	-
CH-MOV-442	WD Extension *	-
CH-MOV-443	WD Extension *	-
CH-MOV-444	WD Extension *	-
SP-MOV-990A	WD Extension *	-
SP-MOV-990B	WD Extension *	-
SP-SOV-506	CR Isolation Valve Panel JK1	-
SP-SOV-507	CR Isolation Valve Panel JK1	-
SP-SOV-508	CR Isolation Valve Panel JK1	-
SP-SOV-509	CR Isolation Valve Panel JK1	-
SP-SOV-510	CR Isolation Valve Panel JK1	-
SP-SOV-511	CR Isolation Valve Panel JK1	-
SP-SOV-512	CR Isolation Valve Panel JK1	-
SP-SOV-513	CR Isolation Valve Panel JK1	-
SP-SOV-514	CR Isolation Valve Panel JK1	-
SP-SOV-515	CR Isolation Valve Panel JK1	-
SP-SOV-516	CR Isolation Valve Panel JK1	-

*Not located in control room

5.3 CONTAINMENT VENTILATION SYSTEM

5.3.1 Design Basis

5.3.1.1 Performance Objectives

The Containment Ventilation System was designed to accomplish the following:

a) Remove the normal heat loss from all equipment and piping in the Reactor Containment during plant operation and maintain a normal ambient temperature of 130°F or less

b) Provide sufficient air circulation and filtering throughout all containment areas to permit safe and continuous access to the reactor containment within two hours after reactor shutdown, assuming defects exist in 1% of the fuel rods.

c) Provide for positive circulation of air across the refueling water surface to assure personnel access and safety during shutdown

d) Provide a minimum containment ambient temperature of 50°F during reactor shutdown

e) Provide for purging of the containment vessel to the plant vent for dispersion to the environment. The rate of release is controlled by IP3 RECS / ODCM, such that automatic termination of release occurs prior to impacting 10 CFR 20 limits.

f) Provide for depressurization of the containment vessel following an accident. The post-accident design and operating criteria are detailed in Chapter 6

g) Provide ventilation to remove radiogas when steam generator primary man ways are removed

h) Provide means for measurement of flow in main plant ventilation exhaust duct

In order to accomplish these objectives the following systems were provided:

a) Containment Air Recirculation Cooling and Filtration System
b) Control Rod Drive Mechanism Cooling System
c) Reactor Compartment Cooling System
d) Containment Purge System
e) Containment Auxiliary Charcoal Filter System
f) Containment Post-Accident Charcoal Filter System (Described in Section 6.4)
g) Steam Heating System
h) Steam Generator Maintenance Exhaust System.

5.3.1.2 Design Characteristics – Sizing

The design characteristics of the equipment required in the Containment for cooling, filtration and heating to handle the normal thermal and air cleaning loads during normal plant operation are presented in Table 5.3-1. In certain cases where engineered safeguards functions also are

served by the equipment, component sizing was determined from the heavier duty specifications associated with the Design Basis Accident (DBA), detailed further in Chapter 6.

The fan motors match the power requirements of the fans, which require a maximum power input of 219 horsepower under accident operation. The fan cooler heat removal rate, as a function of the containment pressure, is presented in Section 14.3.6 covering the Containment Integrity Evaluation. For example, this rate at 271°F and 47 psi containment temperature and pressure is 49.0 x 10^6 Btu/hr per air handling unit. As noted in the Containment Integrity Evaluation, the ability of the Containment Air Recirculation Cooling and Filtration System to function properly in the accident environment was demonstrated by the computer code "HECO." The code determines the plate fin coil heat removal rate when operating in a saturated steam-air mixture.

5.3.2 System Design

5.3.2.1 Piping and Instrumentation Diagram

The containment ventilation, purging and recirculation cooling and filtration systems flow diagram is shown in Plant Drawing 9321-F-40223 [Formerly Figure 6.4-2]. The containment ventilation systems and main plant vent were designed as seismic Class I structures.

5.3.2.2 Containment Recirculation Ventilation

Air recirculation cooling and filtering during normal operation is accomplished using all five air handling units discharged to a common headered ductwork distribution system to assure adequate flow of filtered and cooled air throughout the Containment. The cooling coils in each air handling unit transfer up to 2.3 x 10^6 Btu/hr to the Service Water System during normal plant operation and 49.0 x10^6 Btu/hr/FCU in the event of an accident when supplied with 1400 gpm cooling water at 95°F inlet temperature.

Each air handling unit consists of the following equipment arranged so that during normal operation air flows through the unit in the following sequence: cooling coils, centrifugal fan with direct-drive motor, and distribution header.

The fans and motors of these units are equipped with vibration sensors to detect abnormal operating conditions in the early stages of the disturbance. In the event of an accident, the flow path will be diverted automatically by air operated dampers through a compartment containing moisture separators, HEPA filters and charcoal filters. It will then flow through the cooling coils and centrifugal fan and into the distribution header. The normal air flow rate per air handling unit is approximately 70,000 cfm and the post-accident flow rate will be approximately 34,000 cfm, with a 8,000 cfm through the filtration section. Section 6.4.2 provides additional information on the operation of this system.

The recirculating ductwork located in the annulus of the Containment Building was provided with spring loaded relief dampers designed to open inward when the external pressure on the ductwork reaches 2 psig. This is discussed in Section 6.4

The Control Rod Drive Cooling System supplements the main containment recirculation system. The Control Rod Drive Cooling System consists of fans and ductwork to circulate air through the control drive mechanism shroud and discharge it to the main containment volume. Four 1/3 capacity direct driven axial flow fans are used.

5.3.2.3 Containment Purge System

The Containment Purge System includes provisions for both supply and exhaust air. The purge system is maintained isolated whenever the plant is above the cold shutdown condition. The supply system includes roughing filters, heating coils, fan, supply penetration with two butterfly valves for bubble tight shutoff, and a purge supply distribution header inside containment. The exhaust system includes exhaust penetration with two butterfly valves identical to those above, exhaust ductwork, filter bank with roughing, HEPA and charcoal filters, fans and exhaust vent. Provision was made to measure isokinetic flows at the radiation monitor using pitot tubes. The purge system flow rate is 28,000 cfm; however, the isolation valves will be shut prior to going above cold shutdown and will remain closed during normal operation. The quick closing purge isolation valves are capable of closing within two seconds of receipt of the accident signal. The weld channel and penetration pressurization system pressurizes the space between the purge valves and therefore serves as a continuous on-line monitoring system for valve leakage.

During power operation, containment integrity is maintained with no release from the containment ventilation system to the atmosphere. Prior to purging the Containment, air particulate and gas monitor indications of the closed containment activity levels are used as a guide to making routine releases from the Containment. During power operation, the containment air particulate and gas monitor indications help determine the desirability of using either one or both of two auxiliary particulate and charcoal filter units installed in the Containment primarily for pre-access cleanup.

When the containment purging for access following reactor shutdown is in progress, releases from the plant vent are continuously monitored for radiogas and particulates and sampled for iodine and tritium. A wide range plant vent gas monitor (Section 11.2.3.1) provides continuous indication of noble gas releases passing through the plant vent to the atmosphere.

5.3.2.4 Isolation Valves

The purge supply and exhaust ducts butterfly valves, both inside and outside the containment, are closed during power operation. The spaces between the closed valves are pressurized with air by the Penetration and Weld Channel Pressurization System. The valves were designed for rapid automatic closing by the containment isolation signal (derived from any automatic safety injection signal), or upon a signal of high activity level within the Containment in the event of a radioactivity release when the purge line is open.

5.3.2.5 Containment Pressure Relief Line

The normal pressure changes in the Containment during reactor power operation will be handled by the containment pressure relief line. This line is equipped with three quick-closing butterfly type isolation valves, one inside and two outside the Containment. The valves will be automatically actuated to the closed position by the containment isolation signal, or by a containment high radioactivity signal. The two intra-valve spaces are pressurized with air by the Penetration and Weld Channel Pressurization System when the valves are closed. The pressure relief line discharges through roughing, HEPA, and charcoal filters to the plant vent. While the valves are fully capable of closing from a 60° open position during accident conditions, mechanical stops prevent the valves from opening more than 40° (90° = full open).

5.3.2.6 Steam Generator Maintenance Exhaust System

Steam generator maintenance ventilation is accomplished by use of two 3000 cfm fans driven by 5 hp motors. These fans connect to 14" diameter exhaust ducts, which allow maintenance on the steam generators when the manways are removed. The fans exhaust into the containment purge exhaust duct.

5.3.2.7 Pressurizer Relief Tank Venting

During shutdown conditions, the potential exists for radioactive gases to be vented from the Pressurizer Relief Tank. These gases are therefore routed to the containment purge exhaust duct where their radioactive content can be monitored (see Section 11.2).

The system uses a jet eductor, using station air to vent the tank. The system is shut down during normal operation.

TABLE 5.3-1

PRINCIPAL COMPONENT DATA SUMMARY

System	Units Installed	Unit Capacity	Units Required for Normal Operation
Containment Recirculation			
Demister	5	8,000 cfm	0
Cooling Coils – Normal	5	2.3×10^6 Btu/hr	5
Cooling Coils – DBA	5	49.0×10^6 Btu/hr	0
HEPA Filters	5	8,000 cfm	0
Fans	5	70,000* cfm	5
[Deleted]			
[Deleted]			
DBA Charcoal Filters	5**	8,000 cfm	0
Temperature Switches	30**		
Control Rod Drive Mechanism Cooling			
Fans, Standard Conditions	4	15,000 cfm	3
[Deleted]			
[Deleted]			
Reactor Compartment Cooling			
Part of CB Recirculation System	-	12,000 cfm	
Refueling Canal Air Sweep			
Part of CB Recirculation System	-	17,5000 cfm	

TABLE 5.3-1
(Cont.)

PRINCIPAL COMPONENT DATA SUMMARY

System	Units Installed	Unit Capacity	Units Required for Normal Operation
Containment Ventilation/Purge Supply			
Fans, Standard Conditions	1	40,000 cfm	Optional
[Deleted]			
[Deleted]			
Pre-heat Coils	1 Set		Optional
Air Filters, Roughing	1	40,000 cfm	1
Exhaust			
Fans,* Standard Conditions	2	70,000 cfm**	Optional
[Deleted]			
[Deleted]			
Plenums	2	40,000 cfm	
HEPA Filters	1 Bank	40,000 cfm	Optional
Roughing Filters	1 Bank	40,000 cfm	Optional
Charcoal Filters	1 Bank	40,000 cfm	Optional
Containment Auxiliary Charcoal Filters			
Fans, Standard Conditions	2	8,000 cfm	Optional
[Deleted]			
[Deleted]			
Filters; Roughing, HEPA and Charcoal Filters	2	8,000 cfm	Optional

*Note: The two exhaust fans are used interchangeably or as backup for:
1. Ventilation of Primary Auxiliary Building (70,000 cfm)
2. Containment Building Purge System (40,000 cfm)

**Note: Normal System Flow for Containment Building Purge Exhaust is 28,000 cfm.

TABLE 5.3-1
(Cont.)

PRINCIPAL COMPONENT DATA SUMMARY

System	Units Installed	Unit Capacity	Units Required for Normal Operation
Steam Heating			
Heaters, 25 psig steam	2	400,000 Btu/hr each	Optional
Steam Generator Maintenance Exhaust System			
Centrifugal Fan	2	3000 cfm	2
[Deleted]			
[Deleted]			
Containment Building Pressure Relief			
Fan, Standard Conditions	1	1500 cfm	Optional
[Deleted]			
[Deleted]			
Filters; Roughing, HEPA and Charcoal Filters	1	1500 cfm	Optional

Note: The operating configuration for the Containment Building Pressure Relief system involves limiting the three containment isolation valves to a minimum position of 40° open. This causes a decrease in system flow.

5.4 POST ACCIDENT CONTAINMENT VENTING SYSTEM [Historical Information]

*NOTE: The Post Accident Containment Venting System was retired 04/02/03.

5.4.1 Function

Following a Design Basis Accident, hydrogen gas may be generated inside the Containment by reactions such as zirconium metal with water, corrosion of materials of construction, and radiolysis of aqueous solution in the sump and core. The Post-Accident Containment Venting System permits controlled venting of the containment atmosphere to maintain the hydrogen concentration at a safe level.

5.4.2 Design Basis

The Post-Accident Containment Venting System was designed to limit the hydrogen concentration in the Containment to three percent by volume.

5.4.3 System Description

The Post-Accident Containment Venting System consists of a single line penetrating the Containment, which will be used alternately to supply hydrogen free air to the Containment or exhaust hydrogen bearing gases from the Containment. These exhaust gases are directed through roughing, HEPA, and charcoal filters to the plant vent. The major components of the Post-Accident Containment Venting System are as follows:

5.4.3.1 Containment Air Supply

Hydrogen free air is admitted to the Containment through the single supply/exhaust line. The supply air is provided from the Instrument Air System, which is in use during normal plant operation. The nominal flow rate from either of the two instrument air compressors is 200 scfm. If the Instrument Air System is not available, the Station Air System with a nominal capacity of 600 scfm is available as a backup.

5.4.3.2 Containment Air Exhaust

From inside the Containment, hydrogen bearing gases are exhausted through the single supply/exhaust line. Outside containment is a normally closed, manually operated containment isolation valve followed by a branch connection with an additional manual isolation valve in each branch. Between these adjacent isolation valves, there is a connection through parallel redundant manual valves to the containment penetration pressurization system. Thus, the exhaust line at the containment penetration can be manually sealed with air following a LOCA. Following this valve in each line are:

a) Local pressure indicator for containment pressure
b) Remote manual air operated stop valve
c) Self-contained pressure control valve
d) Manual flow control valve.

The two branches go into a common header and the single line to the plant vent passes through the following:

a) Flow indicator/integrator which provides remote readout of both instantaneous flow rate and integrated flow

b) Local temperature indicator
c) Roughing filter
d) HEPA filter
e) Carbon filter.

The latter three components are shielded by 16 inches of normal concrete.

All the components inside the Containment Building, the penetrations, and the piping and valves to the second isolation valves are seismic Class I design. The remaining components in the exhaust line (except the plant vent, which is seismic Class I) are seismic Class III.

All active components of the system, namely, valves, instruments, controls and associated electrical supplies, are redundant. All passive components, namely, piping and the three filters, are not and need not be redundant.

The system was designed to obtain a flow of 200 scfm with containment pressure at 1.9 psig. For this flow rate, the residence time in the charcoal filters is approximately 0.4 seconds.

5.4.4 Operation

The flow rate and the duration of venting required to maintain the hydrogen concentration at or below 3 percent of the containment volume are determined from the containment hydrogen concentration measurements and the hydrogen generation rate (Section 6.8). The containment pressure necessary to obtain the required vent flow is then determined. Using one of the two instrument air compressors, hydrogen free air is pumped into the Containment until the required containment pressure is reached. The air supply is then stopped and the supply/exhaust line is isolated by valves outside the Containment.

The addition of air to pressurize the Containment will also dilute the hydrogen; therefore, the Containment will remain isolated until analysis of samples indicates that the concentration is again approaching 3 percent by volume. Venting is then started by opening either the primary or bypass exhaust line, and adjusting the hand controlled throttle valve to obtain the required flow.

This process of containment pressurization followed by venting is repeated as may be necessary to maintain the hydrogen concentration at or below 3 percent by volume.

Post Loss-of-Coolant Accident purging provides a backup method to the hydrogen recombiners in the Containment (Section 6.8) for controlling the potential hydrogen accumulation in the Containment. The analysis of offsite doses using purging to control hydrogen was based on the Westinghouse model for hydrogen production and accumulation discussed in Section 14.3.7.

The purging system requires a differential pressure between the Containment and the outside atmosphere in order to permit purging. If required, the containment is pressurized with diluent air when the hydrogen reaches 3 percent by volume after the Loss-of-Coolant Accident. The hydrogen concentration is reduced by this pressurization. Purging is thus delayed until the hydrogen concentration in the Containment has once again built up to 3 percent by volume. The 3 percent hydrogen level was selected as the point of starting the purge because of the following factors:

1) This level allows a sufficient margin of safety below the lower flammability limit of 4.1 percent

2) It provides a sufficient margin so that purging could be delayed a few days if so desired. With neither containment purging nor recombiner operation, the hydrogen generation rate is sufficiently low so that 45 days are required for the hydrogen concentration in the Containment to build up from the 3 percent level to the 4.1 percent level

3) The optimum starting time for the purge, from the standpoint of minimizing the doses, is the latest time.

The hydrogen concentration in the Containment will slowly decrease from 3 percent as purging continues. The required purge rate is based on the hydrogen production rate at the time of purge initiation.

The dose analysis is based on the activity released from the Containment after the time of the postulated Loss-of-Coolant Accident until all the activity in the Containment is either removed or released. The infinite-time thyroid, beta and gamma doses as a function of distance from the plant due to activity release from containment leakage following the postulated Loss-of-Coolant Accident are computed using the core activity release model described in Section 14.3.5. Then the analysis is repeated except that the doses are based on activity released from both containment leakage and purging. The offsite doses due to purging are then determined by subtraction of the doses due to containment leakage and purging. The parameters used to compute the activity releases from containment leakage and from purging are given in Tables 5.4-1 and 5.4-2.

The dose models discussed in Reference (1) and the atmospheric dispersion factor given in Section 14.3.5 are used in determining doses following the Loss-of-Coolant-Accident. In the evaluation of doses from activity released to the atmosphere after 720 hours (30 days), the annual average dispersion factor at the site boundary of 2.6×10^{-5} sec/m^3 was used. The thyroid beta and gamma doses at the site boundary due to containment purging to control hydrogen are given in Table 5.4-4.

The thyroid, beta and gamma doses due to containment purging to control hydrogen were also determined using the assumptions outlined in Reference (2) and the dos models given in Reference (1). The parameters used to determine the activity release resulting from leakage and purging using the model in Reference (2) are given in Tables 5.4-1 and 5.4-3, and the boundary doses are listed in Table 5.4-4.

<u>References</u>

1) "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant-Accident for Pressurized Water Reactors," Safety Guides for Water Cooled Nuclear Power Plants, Safety Guide No. 4, Division of Reactor Standards, U.S. Atomic Energy Commission, November 1971.

2) "The Control of Combustible Gas Concentrations in Containment Following a Loss of Coolant Accident," Safety Guides for Water Cooled Nuclear Power Plants, Safety Guide No. 7, Division of Reactor Standards, U.S. Atomic Energy Commission.

TABLE 5.4-1

PARAMETERS USED TO DETERMINE CONTAINMENT LEAKAGE ACTIVITY RELEASE

Plant Power	3216 MWt	
Containment free volume	2.61×10^6 ft^3	
Unsprayed containment volume	5.22×10^5 ft^3	
Mixing rate between sprayed and unsprayed containment volume	2.4×10^4 cfm (filtered) 1.26×10^5 cfm (unfiltered)	
Spray removal coefficient for elemental iodine	32 hr^{-1} until DF=100	
Containment design leak rate	0.1% per day (0-24 hours)	
	0.045% per (>24 hours)	
Containment Air Recirculation and Cooling System filter efficiencies	Westinghouse Model	AEC Model
Elemental Iodine	90%	90%
Methyl Iodine	70%	5%
Particulate Iodine	90%	90%

TABLE 5.4-2

PARAMETERS USED TO DETERMINE
HYDROGEN PURGING ACTIVITY RELEASE – W MODEL

1. Westinghouse Basis H_2 Generation*

2. Pressurize Containment to 2.14 psig, if required, when H_2 reaches 3.0 percent by volume (day 36)

3. Purge at 15.3 scfm continuously once H_2 reaches 3.0 percent by volume again (day 50)

4. Containment Air Recirculation and Cooling System filter efficiencies

Elemental Iodine	90%
Organic Iodine	70%
Particulate Iodine	90%

*NOTE: Discussed in Section 14.3.7.

TABLE 5.4-3

PARAMETERS USED TO DETERMINE HYDROGEN PURGING ACTIVITY RELEASE – AEC MODEL

1. AEC Basis H_2 Generation*

2. Pressurize Containment to 2.14 psig, if required, when H_2 reaches 4.0 percent by volume (day 23)

3. Purge at 21.8 scfm continuously once H_2 reaches 4.0 percent by volume again (day 33)

4. Containment Air Recirculation and Cooling System filter efficiencies

Elemental Iodine	90%
Organic Iodine	5%
Particulate Iodine	90%

*Safety Guide No.7

TABLE 5.4-4

DOSES FROM CONTAINMENT PURGING TO CONTROL HYDROGEN

Dose at Site Boundary (Rem)

	Westinghouse Model	AEC Model
Thyroid	4.5×10^{-1}	5.1
Beta	1.4	1.6
Gamma	1.7×10^{-2}	5.0×10^{-2}

5.5 CONTAINMENT PARAMETERS

The description of the instrumentation system included in the Indian Point 3 design for remote monitoring of post-accident conditions within the primary containment is presented in Appendix 6F. Non-nuclear process instrumentation of the containment is described in Section 7.5.

Containment Building Pressure

The containment pressure is transmitted to the main control board for post accident monitoring. Six transmitters, two in each of three safety channels, are installed outside the containment to prevent potential missile damage. The pressure is indicated on the main control board; the range is –5 psig to 75 psig.

In addition, monitoring of the containment building pressure during and following an accident is effected by two Safety Related redundant systems. Pressure signals are obtained at the pipe penetration area and brought to transmitters outside containment. These same signals are transmitted to the two-recorders at the control room recorder cabinet. Continuous monitoring of containment pressure is possible in the –5 to 200 psig range. Power requirements for the two systems are met from vital instrument buses. The installation of cable and conduit is consistent with separation criteria, as outlined in Section 8.4.

Two local high accuracy, narrow range pressure gauges, capable of directly monitoring containment pressure, are provided in the PAB Fan House, at Elevation 41 ft. These local gauges can be used by Operations, when required, to maintain containment pressure within more restrictive limits, based on RWST and containment temperatures, as defined in Technical Specification 3.6.4, “Containment Pressure”. Two pressure gauges are provided for increased reliability only, as these gauges do not perform a safety-related indication function.

Containment Building Water Level Monitoring

There are three sumps in the Containment Building: Reactor Pit Sump, Recirculation Sump and Containment Sump. Associated with the Recirculation Sump and Containment Sump, there are two redundant, separately channeled and powered level measurement loops. Associated with the Reactor Pit is a level sensor, alarmed on the Control Room Supervisory Panel. These provide continuous level and alarm indication in the Control Room. Additionally, a water level transmitter installed at the top of Containment Sump will provide a Containment Sump overflow alarm indication in the Control Room.

Containment Building Hydrogen Concentration

Hydrogen concentration indication is provided by a measuring system which consists of the following: redundant analyzers and continuously recording two (2) single pen recorders. The recorders are located in the control room and the analyzers are located in the pipe penetration area of the fan house. Samples are drawn from containment recirculation fans via the retired post-accident sample system and returned to the general area of the containment building.

APPENDIX 5-A

[Historical Information]

WESTINGHOUSE NUCLEAR ENERGY SYSTEMS
UNITED ENGINEERS AND CONSTRUCTORS

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3

CONTAINMENT DESIGN REPORT

September 1970

B. Scott
J. Slotterback
J. D. Stevenson

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1.0 INTRODUCTON

1.1.0 PURPOSE & SCOPE OF REPORT

The object of this report is to illustrate the design adequacy of the containment structure for the Indian Point Nuclear Generating Unit No. 3. To this end, this documentary report describes the design of the structure, as well as the construction procedures, to demonstrate fulfillment of the design criteria.

The following sections of this report enumerate the basic criteria that were used, the analyses that were developed to satisfy these criteria, the various loading combinations under normal and postulated accident conditions (including seismic effects), and the construction and testing procedures that were employed to ultimately construct the containment structure at the site.

1.2.0 FUNCTION OF CONTAINMENT STRUCTURE

The containment structure completely encloses the entire reactor and reactor coolant system and ensures that essentially no leakage of radioactive materials to the environment would result even if gross failure of the reactor coolant system were to occur. The structure will provide biological shielding for normal and accident situations.

The containment structure is designed to safely withstand several conditions of loading and their credible combinations. The limiting extreme conditions are:

a) Occurrence of a gross failure of the reactor coolant system which creates a high pressure and temperature condition within the containment.

b) Coincident failure of the reactor coolant system with an earthquake or wind.

The design pressure and temperature of the containment will be, as a minimum, equal to the peak pressure and temperature occurring as the result of the complete blowdown of the reactor coolant through any rupture of the reactor coolant system up to and including the hypothetical severance of a reactor coolant pipe. Energy contribution from the steam system is included in the calculation of the containment pressure transient due to reverse heat transfer through the steam generator tubes. 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. In addition, the design pressure will not be exceeded during any subsequent long term pressure transient determined by the combined effects of heat sources such as residual heat and limited metal-water reactions, structural heat sinks and the operation of the engineered safeguards; the latter utilizing only the emergency electric power supply.

The design pressure and temperature on the containment structure will be those created by the hypothetical loss-of-coolant accident. The reactor coolant system will contain approximately 512,000 lbs. of coolant at a weighted average enthalpy of 595 Btu/lb. for a total energy of 304,000,000 Btu. In a hypothetical accident, this water is released through a double-ended break in the largest reactor coolant pipe, causing a rapid pressure rise in the containment. The reactor coolant pipe used in the accident will be the 29-in. ID section because rupture of the 31-in. ID section requires that the blowdown go through both the 29-in. and the 27-1/2-in. ID pipes and would, therefore, result in a less severe transient.

Additional energy release was considered from the following sources:

a) Stored heat in the reactor core.

b) Stored heat in the reactor vessel piping and other reactor coolant system components.

c) Residual heat production.

d) Limited metal-water reaction energy and resulting hydrogen-oxygen reaction energy.

The following loadings will be considered in the design of the containment in addition to the pressure and temperature conditions described above:

a) Structure dead load.

b) Live loads.

c) Equipment loads.

d) Internal test pressure.

e) Earthquake.

f) Wind. (Tornado)

The containment structure is inherently safe with regard to common hazards such as fire, flood and electrical storm. The thick concrete walls are invulnerable to fire and only an insignificant amount of combustible material, such as lubricating oil in pump and motor bearings, is present in the containment.

Internal structures consist of equipment supports, shielding, reactor cavity and canal for fuel transfer, and miscellaneous concrete and steel for floors and stairs. All internal structures are supported on the containment mat.

A 3-ft. thick concrete ring wall serving as a partial radiation shield surrounds the reactor coolant system components and supports the polar-type reactor containment crane. A 2-ft. thick reinforced concrete floor covers the reactor coolant system with removable gratings in the floor provided for crane access to the reactor coolant pumps. The four steam generators, pressurizer and various piping penetrate the floor. Spiral stairs provide access to the areas below the floor.

The refueling canal connects the reactor cavity with the fuel transport tube to the spent fuel pool. The floor and walls of the canal are concrete. The floor is 5 ft. thick. The concrete walls and floor are lined with ¼ inch thick stainless steel plate. The linings provide a leak- proof membrane that is resistant to abrasion and damage during fuel handling operation.

1.3.0 CONTAINMENT DESCRIPTION

The reactor containment structure is a reinforced concrete vertical right cylinder with a flat base and a hemispherical dome. A welded steel liner with a minimum thickness of ¼ inch is attached to the inside face of the concrete shell to insure a high degree of leak-tightness. The design objective of the containment structure is to contain all radioactive material which might be released from the core following a loss-of-coolant accident. The structure serves as both a biological shield and a pressure container.

The structure consists of side walls measuring 148-feet from the liner on the base to the springline of the dome, and has an inside diameter of 135-feet. The side walls of the cylinder and the dome is 4-ft. 6-in. and 3-ft. 6-in. thick respectively. The inside radius of the dome is equal to the inside radius of the cylinder so that the discontinuity at the springline due to the change in thickness is on the outer surface. The flat concrete base mat is 9-ft. thick with the bottom liner plate located on top of this mat. The bottom liner plate is covered with 3-ft. structural slab of concrete which serves to carry internal equipment loads and forms the floor of the containment. The internal pressure within the containment is self-contained in that the vector sum of the pressure forces is zero; therefore, there is no need for mechanical anchorage between the bottom mat and underlying rock. The base is supported directly on rock.

The basic structural elements considered in the design of the containment structure is the base slab, side walls and dome acting as one structure under all possible loading conditions. The liner is anchored to the concrete shell by means of stud anchors so that it forms an integral part of the entire composite structure under all membrane loadings. The reinforcing in the structure has an elastic response to all primary loads with limited maximum strains to insure the integrity of the steel liner. The lower 20 feet of the cylindrical liner is insulated to avoid excess deformation of the liner due to restricted radial growth when subjected to a rise in temperature.

2.0 CONTAINMENT STRUCTURAL DESIGN BASIS

2.1.0 DESIGN LOAD CRITERIA

The following loads were considered to act upon the containment structure creating stresses within the component parts.

2.1.1 DEAD LOADS

Dead load consists of the weight of the concrete wall, dome, liner, insulation, base slab and the internal concrete. Weights used for dead load calculations were as follows:

a) Reinforced Concrete : 150 lb/ft^3

b) Steel Lining : 490 lb/ft^3 using nominal cross-sectional area

d) Insulation : 6 lb/ft^3 including stainless steel jacket.

2.1.2 OPERATING LIVE LOADS

Operating live loads consist of the weight of major components of equipment in the containment. Equipment loads were those specified on the drawings supplied by the manufacturers of the various pieces of equipment.

All major pieces of equipment are supported on the 3'-0" base slab or on the interior concrete, which in turn bears directly on the 9'-0" mat.

Item		Flooded Operating Weight, lb.
Pressurizer	-1	346,000
Steam Generators	-4	3,746,000
Reactor	-1	
a) Vessel		868,000
b) Internals		420,000
RCS Piping		1,000,000
Reactor Pumps	-4	824,000
Accumulator Tanks	-4	529,000
175 Ton Polar Crane	-1	650,000
Ventilation Fans	-4	656,000
Reactor Coolant Drain Tank	-1	20,000
Pressure Relief Tank	-1	100,000
Other Misc. Equipment		100,000
		9,259,000

Other Uniform Live Loads

@ El. 68' – 10 ft. strip adjacent to crane wall = 600 psf

Remaining strip = 100 psf

@ El. 95' - 0" – Concrete Slab = 500 psf

Grating areas = 100 psf

2.1.3 SNOW LOADS

Snow and ice loads have been applied uniformly to the top surface of the dome at an estimated value of 20 pounds per square foot of horizontal projection of the dome. This loading represents approximately 2-ft. of snow, which was considered to be a conservative amount since the slope of the dome tends to cause much of the snow to slide off.

2.1.4 CONSTRUCTION LOADS

A construction live load of 50 pounds per square foot has been used on the dome, but was not considered to act concurrently with the snow load.

A load equivalent to the weight of wet concrete, placed in sections during construction of the concrete dome, was used for the design of the stiffened dome liner plate. During the pressure test of containment, the concrete will crack and thereby relieve the effects of shrinkage and creep.

2.1.5 WIND LOADS

The American Standards Association "American Standard Code Requirements for Minimum Design Loads in Buildings and Other Structures" (A58.1-1955) designates the site as being in a 25 psf zone. In this code, for height zones between 100 and 499 feet, the recommended wind pressure on a flat surface is 40 psf. Correcting for the shape of the containment by using a shape factor of 0.60, the recommended pressure becomes 26 psf. The State Building and Construction Code for the State of New York stipulates a wind pressure up to 30 psf on a flat surface for heights up to 300 feet. For design, a uniform 30 psf basic wind load has been used from ground level up.

The tornado loads considered in design are as follows:

a. cyclonic wind velocity = 300 mph
b. translational wind velocity = 60 mph
c. differential pressure drop = 3 psi in 3 seconds
d. missile - 4" x 12" x 12' plank at 300 mph horizontal, or at 90 mph, vertical.
e. Missile – 4000 lb passenger car, not exceeding 25 feet above the ground, at 50 mph horizontal or at 17 mph vertical (25 ft^2 contact area).

2.1.6 OPERATING TEMPERATURE LOADS

The operating temperature assumed in the design of the containment structure in 120°F, with a -5°F outside winter temperature. Thermal loads induced in the containment as a result of operating temperature effects are composed of a) the steady state temperature gradient through the wall as shown in Figure 2.1 for Winter conditions for both the insulated and

uninsulated portions of the liner and b) the effective load induced in the concrete shell as the concrete acts to restrain the steel liner when the mean temperature of the concrete differs from that of the liner.

2.1.7 CREEP AND SHRINKAGE LOADS

The containment structure has been investigated for end of life creep and shrinkage factor as follows:

(a) $k_{(creep)} = 0.22\, x\, 10^{-6}\ in/in/psi$

(b) $k_{(shrinkage)} = 70\, x\, 10^{-6} in/in$

The maximum stress induced in the steel reinforcement by this maximum condition is less than 4000 psi. Since the limiting case for design is accident pressure load which effectively cracks the concrete and places the reinforcement into membrane tension creep and shrinkage induced stress are not a limiting factor in design.

2.1.8 SEISMIC LOADS

The ground acceleration for the Operational Basis Earthquake, “OBE” was determined to be 0.1g applied horizontally and 0.05 applied vertically. These values were resolved as conservative numbers based upon recommendation from Dr. Lynch, Director of Seismic Observatory, Fordham University. A dynamic analysis has been used to arrive at equivalent design loads. Additionally, a Design Basis Earthquake, “DBE” acceleration of 0.15 horizontally and 0.10 vertically has been used to analyze for the no-loss of function.

A damping factor of 2 percent was assumed for the reinforced concrete containment structure for the OBE and 5 percent for the DBE. The response spectra used were based on the Spectrum curves presented in Figures A.1-1 and A.1-2 of Appendix A1 normalized to 0.15g zero period ground acceleration as required.

2.1.9 ACCIDENT PRESSURE LOADS

The design basis accident pressure load is shown in Figure 5.1-8 of the FSAR as a function of time. This design value is at least 5 percent in excess of maximum calculated containment pressure.

2.1.10 ACCIDENT TEMPERATURE LOADS

The design basis accident containment temperature assumed in the design of the containment is also shown in Figure 5.1-8 of the FSAR as a function of time. This containment temperature induces loads in the concrete shell as the concrete acts to restrain liner thermal expansion. This thermal load effect on the liner is combined with pressure load effects to develop design basis accident design load requirements as a function of time. Accident temperature induced thermal gradients through the wall are not a factor in concrete shell design since the accident temperature effect penetrates approximately 10 percent of the containment wall thickness during the significant overpressure phase of the accident and the cracking of the concrete shell due to containment pressurization acts to relieve secondary stresses induced by thermal gradient effect.

2.1.11 LOADS AT PENETRATIONS

The effect of growth of the liner due to accident conditions has been considered in the design of penetrations and sleeves together with the effects of lateral loads due to thermal expansion of pipes, seismic motion, pipe break loads and pressure loads. In addition, stress concentration effects on large penetrations have been considered.

2.1.12 MISSILE LOADS

Potential external missiles (tornado; turbine failure) have been considered in design as described in Appendix 14A to the Report.

2.1.13 TEST PRESSURE LOADS

Internal pressure will be applied to test the structural integrity of the vessel up to 115 per cent of the design pressure of 47 psi. For this structure the test pressure will be 54 psig.

2.1.14 COMBINED FACTORED LOAD EQUATIONS

The design was based upon limiting load factors which were used as the ratio by which loads were multiplied for design purposes to assure that the loading formation behavior of the structure was one of elastic, tolerable strain behavior. The load factor approach was 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. In the case of the containment structure, therefore, this approach places minimum emphasis on the fixed gravity loads and maximum emphasis on accident and earthquake or wind loads. The loads utilized to determine the required limiting capacity of any structural element on the containment structure are computed as follows:

a) $C = 1.OD \pm 0.05D + 1.5P + 1.0 (T + TL)$ (2.1.1)

b) $C = 1.OD \pm 0.05D + 1.25P + 1.0 (T' + TL') + 1.25E$ (2.1.2)

c) $C = 1.OD \pm 0.05D + 1.OP + 1.0 (T'' + TL'') + 1.OE'$ (2.1.3)

d) $C = 1.OD \pm 0.05D + 1.OW'$ (2.1.4)

Symbols used in these formulas are defined as follows:

C: = Required load capacity section.

D: = Dead load of structure and equipment loads.

P: = Accident pressure load as shown on pressure-temperature transient curves.

T: = Load due to maximum temperature gradient through the concrete shell and mat based upon temperatures associated with 1.5 times accident pressure.

TL: = Load exerted by the liner based upon temperatures associated with 1.5 times accident pressure.

T': = Load due to maximum temperature gradient through the concrete shell and mat based upon temperatures associated with 1.25 times accident pressure.

TL': = Load exerted by the liner based upon temperatures associated with 1.25 times accident pressure.

E: = Load resulting from operational basis earthquake.

T": = Load due to maximum temperature gradient through the concrete shell, and mat based upon temperature associated with the accident pressure.

TL": = Load exerted by the liner based upon temperatures associated with the accident pressure.

E': = Load resulting from design basis earthquake.

W': = Tornado wind load and the pressure drop effect.

Load condition a) indicates that the containment has the capacity to withstand loadings at least 50 per cent greater than those calculated for the postulated loss-of-coolant accident alone.

Load condition b) indicates that the containment has the capacity to withstand loadings at least 25 per cent greater than those calculated for the design basis accident with a coincident operational basis earthquake.

Load condition c) indicates the containment will withstand loads at least equal to those calculated for the design basis accident coincident with a design basis earthquake. The Indian Point Unit No. 3 containment has the capacity to withstand loadings associated with the design basis accident and a coincident earthquake within ACI specified Ultimate Strength Design stress level allowable limits.

Load condition d) indicates the containment will withstand loads at least equal to those calculated for the design basis tornado within ACI specified Ultimate Strength Design stress level allowable limits.

All structural components have been designed to have a capacity required by the most severe loading combination. The loads resulting from the use of these equations will hereafter be termed "factored loads." Specific resultant loading diagrams are presented in Figures 2.2 through 2.9.

The load factors utilized in these equations are based upon the load factor concept employed in Part IV-B, "Structural Analysis and Proportioning of Members Ultimate Strength Design" of ACI 318-63. Because of the refinement of the analysis and the restrictions on construction procedures, the load factors in the design primarily provide for a safety margin on the load assumptions.

2.2.0 STRESS, STRAIN OR DEFORMATION CRITERIA

The containment is designed such that under all factored load conditions the behavior of the structure will be in the small deformation elastic range. This behavior range is defined by the stress limits contained in the ACI-318-63 code to include additional margin as provided by the capacity reduction factor, $\varnothing$.

2.2.1 CAPACITY REDUCTION FACTOR $\varnothing$

The theoretical member capacity is lowered by the reduction factor $\varnothing$ to recognize variation in quality of materials and permissible tolerances in bar and plate areas and section dimensions, as well as approximations inherent in theoretical analysis. In theory the capacity reduction factor should be divided into the calculated load effect to determine actual design load requirements. Since $\varnothing$ is less than one this always results in a design load requirement in excess of calculated requirements.

As a practical matter in the design of this containment the capacity reduction factor has been applied as a multiplier to the theoretical stress criteria. This has the result of reducing the allowable stress as a function of the type of load being carried.

The following $\varnothing$ factors for both concrete and steel are used in design:

$\varnothing$ = .95 (tension)
$\varnothing$ = .90 (flexure)
$\varnothing$ = .85 (diagonal tension, bond and anchorage)

2.2.2 CONCRETE STRESS CRITERIA

The stress criteria governing behavior are as specified in Part IV-B of the ACI-318-63 Code. Specifically the code limitations on concrete compression, tension, shear strength with and without web reinforcement, bond and anchorage are followed. These values are further reduced by applicable capacity reduction factors.

2.2.3 CONCRETE REINFORCING STEEL

The calculated structural capacity of reinforced concrete sections is based on the specified minimum yield strength of the reinforcement using the design methods specified in Part IV-B of the ACI-318-63 Code. This limiting stress value is further reduced by the applicable capacity reduction factor.

2.2.4 STEEL LINER PLATE

The maximum steel stress is limited to 0.95 yield under all primary loading conditions. In regions of local stress concentrations or stresses due to localized secondary load effects the maximum liner strain is limited to 0.5 per cent. (Detailed finite element computer analysis has identified regions of high localized liner stresses which would not have been detected using conventional analytical techniques.)

2.2.5 PENETRATIONS

The steel penetration elements not backed up by concrete are designed to carry design basis accident loads plus operational basis earthquake loads (unfactored) within the stress limitations of the ASME Section VIII Unfired Pressure Vessel Code stress limitations. It should be noted the ASME Code is a “working stress” design code and as such has safety margin contained in the reduced stress levels rather than in the factored load concept.

2.2.6 SUMMARY OF MATERIAL STRESS STRAIN PROPERTIES

The materials used in containment conform to stress-strain limitations as follows:

	Item	Specification	Min. Yield Strength (PSI)	Min Ultimate Strength (PSI)	Elongation
1.	Concrete	ACI-318	-	3,000	-
2.	Reinforcing Steel	ASTM A432 ACI-318	60,000	90,000	7% in 8"
3.	Liner Plate	ASTM A442, Gr.60	32,000	60,000	22% in 8"
4.	Mech. Penetration Sleeve-12" Dia. & under	ASTM A333 Gr. I	30,000	55,000	35% in 2"
5.	Mech. – Over 12" Dia.	ASTM A201 GR. B to A300	32,000	60,000	22% in 8"
6.	Rolled Shapes	ASTM A36	36,000	58,000	20% in 8"
		ASTM A131 GR. C	32,000	58,000	21% in 8"
7.	End Plates a)	ASTM A300 C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
	b)	ASTM A240 Tp. 304L	25,000	70,000	40% in 2"
8.	Fuel Transfer Tube	ASTM A240 Tp. 304L	25,000	70,000	40% in 2"
9.	Bellows a)	ASTM A312 Tp. 304L	25,000	70,000	35% in 2"
	b)	ASME SB168 Inconel 600	35,000	80,000	30% in 2"
10.	Elec. Penetrations	ASTM A333 Gr.1	30,000	55,000	35% in 2"
11.	Equip. Hatch Insert	ASTM A300 C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
12.	Equip, Hatch Flanges	ASTM A300 C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
13.	Equip. Hatch Head	ASTM A300 C1.1 Firebox A201, Gr. B	32,000	60,000	22% in 8"
14.	Personnel Hatch	ASTM A300 C1.1-Firebox	32,000 A201, Gr. B	60,000	22% in 8" 5A-16

3.0 CONTAINMENT ANALYSIS METHODS AND COMPARISON WITH CRITERIA

3.1.0 GENERAL CONTAINMENT LOADS

3.1.1 DEAD LOAD

The weight of the concrete structure above the point under consideration based on a density of 150#/ft^3 which includes only the weight of the reinforced concrete structure. Since the maximum rebar stress occurs in tension it is conservative not to consider snow loads or any other non-permanent load which will add to the dead load.

The formula for dead load in k/ft at any point is

$$T_{DL_i} = .150 V_i / 2\pi R \qquad (3.1.1)$$

where:

V_i = the volume of concrete in feet cubed above point i

R = mean radius in feet

T_{DL_i} = the dead load at any point in the structure (k/ft) of wall

i = the point under consideration

The horizontal thrust from the dead weight of the dome is computed by considering

$$H = -T + wr\cos\varnothing_O \qquad (3.1.2)$$

and

$$T = W / 2\pi r \sin^2\varnothing_O \qquad (3.1.3)$$

where:

W	=	$2\pi r^2 w(1 - cos\varnothing_o)$; the total weight of the dome above the point defined by $\varnothing_O$ in kips (3.1.4)
H	=	the horizontal or hoop thrust in the dome in k/ft of shell
r	=	mean radius of dome in feet
$\varnothing_O$	=	the central angle measured from the top of the dome to the point under consideration
w	=	the dead load per unit surface area of shell in $k/ft.^2$
T	=	the vertical or meridinal thrust in the dome in k/ft of shell

3.1.2 DESIGN BASIS ACCIDENT PRESSURE LOAD

Membrane pressure loads in the vertical direction in the cylinder and either direction in the dome are determined by

$$P = \frac{pR}{2} \qquad (3.1.5)$$

For the horizontal or hoop direction in the cylinder

$$P = pR \qquad (3.1.6)$$

where:

P	=	pressure load in #/in of wall
p	=	internal design pressure in $\#/in^2$
R	=	mean radius in inches

3.1.3 DISCONTINUITY MOMENT AND SHEAR LOAD

The bending moments, shears and deflections induced in the cylindrical shell by the restraint provided by the base are found by considering a cylindrical shell with a uniform internal pressure. [(1)] Using the general equations for deflection and slope for a cylinder with end moment and shear, and substituting boundary conditions of $w = \delta$ and $\theta = 0$ at $x = 0$ (the built in end) where δ = the unrestrained growth of a cylinder under uniform internal pressure, one obtains formula for the moment and shear at the built-in end to cause zero deflection and rotation

$$Mo = P / 2\beta^2 \quad \text{and} \quad Q_O = -P/\beta \qquad (3.1.7)$$

where:

P	=	the internal pressure in #/in^2
β^4	=	$E_s h_s / 4a_c^2 D$ (3.1.8)
D	=	$E_c h_c^3 / 12(1-\mu)$ (flexural rigidity of the shell) (3.1.9)
h_s	=	area of horizontal steel and liner in the cylinder which acts as a spring constant (in^2 / in)
a_c	=	mean radius of the containment cylinder in inches
h_c	=	effective depth or thickness of the wall
μ	=	Poisson's ratio = 0 for cracked concrete
E_s	=	modulus of elasticity of steel = 29 x 10^6 psi
E_c	=	modulus of elasticity of concrete = 3.2 x 10^6 psi
M_o	=	moment at built in Section to cause 0 rotation
Q_o	=	shear at built in Section to cause 0 deflection

Substituting these values in the following expressions, values for bending moment, shear and deflection at any distance from the end can be found:

$$\Delta_x = w = \frac{-1}{2\beta^3 D} \left[\beta M_0 \gamma(\beta x) + Q_o \theta(\beta x)\right] \quad (3.1.10)$$

$$\theta_x = \frac{dw}{dx} = \frac{1}{2\beta^2 D} \left[2\beta M_0 \theta \quad (\beta x) + Q_o \phi(\beta x)\right] \quad (3.1.11)$$

$$M_x = D\frac{d^2 w}{dx^2} = \frac{-1}{2\beta D} \left[2\beta M_0 \phi(\beta x) + 2Q_o \delta(\beta x)\right] D \quad (3.1.12)$$

$$V_x = D\frac{d^3 w}{dx^3} = \frac{1}{D} \left[2\beta M_0 \delta(\beta x) - Q_o \gamma(\beta x)\right] D \quad (3.1.13)$$

where:

$$\phi(\beta x) = e^{-\beta x}(cos\,\beta x + Sin\,\beta x)$$
$$\gamma(\beta x) = e^{-\beta x}(cos\,\beta x + Sin\,\beta x)$$
$$\theta(\beta x) = e^{-\beta x} cos\,\beta x$$
$$\delta(\beta x) = e^{-\beta x} S\,in\,\beta x$$

Δ_x = the deflection of the shell at x
θ_x = the slope of the shell at x
M_x = the moment of the shell at x
V_x = the shear in the shell at x

From these values Figures 3.1 and 3.2 are plotted showing moment and shear v. height of wall in inches. Since no backfill is present shifts in moment and shear, due to backfill restraint, will not occur.

The problem of determining the discontinuity moment and shear at the springline is similar to that at the base. Discontinuity forces at the dome-cylinder junction are only a function of the relative deformation at this point, since

the rotations of the cylinder and the dome due to the internal pressure are zero and therefore present no discontinuity. The extension of the radius of the cylindrical shell due to the internal pressure is given by

$$\delta_c = \left(Pa_c^2 / E_s h_s^c\right)\left(1 - \mu/2\right) \quad (3.1.14)$$

and the unrestrained extension of the dome $\left(\delta_D\right)$ is given by

$$\delta_d = \left(Pa_d^2 / 2E_s h_s^d\right)\left(1 - \mu\right) \quad (3.1.15)$$

where

a_d = mean radius of the containment dome in inches

h_s^d = area of horizontal steel and liner of the dome which acts as a spring constant (in^2 / in)

Since the area of the hoop steel per foot in the dome is approximately one half that of the cylinder, the values of δ_c and δ_d are nearly equal and therefore the relative deformation is insignificant.

In calculating the discontinuity effects, the bending is of a local character so that an approximate solution can be obtained by assuming that the bending is of importance only in the zone of the dome close to the springline and that this zone can be treated as a portion of a long cylindrical shell. Equations of continuity for deflection and rotation are written such that the values of M_o and Q_o at the springline may be found. The distribution of the moment and shear into the dome and the cylinder are then found by substituting M_o and Q_o into equations 3.1.12 and 3.1.13. The resulting moments and shears are insignificant.

3.1.4 BASE MAT LOADS

The beam shears and moments in the base mat can be calculated by considering the loads shown in Figure 3.3 acting on a 1' –0 wide beam. The 1' –0 strip of mat to be considered is located at the point where the uplift from the overturning moment in the containment due to earth quake is maximum.

This gives the maximum moments and shears in the strip.

The loads considered as shown in Figure 3.3. are:

$$U_T = P + T_{EQ} + T_v - T_{DL} \text{ in k/ft} \qquad (3.1.16)$$

where:

P = design basis loss-of-coolant accident pressure effect load in the wall in k/ft of wall

T_{EQ} = the tensile load k/ft of wall developed by the earthquake overturning moment

T_v = the effective tensile load or reduction of dead load in k/ft of wall caused by response of the containment structure to vertical earthquake motion

T_{DL} = the dead load in the wall in k/ft

M = base discontinuity moment defined in Section 3.1.3

V'_u = base discontinuity shear defined in Section 3.1.3

D = the dead weight of the base mat on the outside of containment cylindrical wall centerline in k/ft

C = the reaction of the internal structural support columns which are based on the 3'–0 reinforced concrete fill mat; in all cases equal to 50K spaced every 23'–0

w = $12p + \frac{\rho z}{12}$; the effective uniform load acting on a 1' wide segment of the base slab per inch of segment length where

p = the containment internal pressure in kips/in^2

ρ = the density of reinforced concrete in #/ft^3 = 150#/ft^3

z = the total depth of section including the 3' –0 fill slab.

The crane wall reaction in k/ft is determined by

$$R = D_c + D_o + P_c \quad (3.1.17)$$

where:

D_c = $\rho t_1 \quad H$; or the dead weight of the crane wall in k/ft

t_1 = the thickness of the crane wall = 3.0 ft.

H = the height of the crane wall = 50.0 ft.

D_o = $\pi R_1^2 t_2 \rho / 2\pi R_2$ or the approximate dead weight of the operating floor in k/ft

R_1 = the outside radius of the operating floor = 53' –0

R_2 = the mean radius of the crane wall

= 51' –6

P_c = 12 pt_1 or the pressure load acting on the top of the crane wall with t_k given in inches

t_2 = the thickness of the operating floor = 2' –0

Moments and shears are calculated by writing equations for moment and shear in terms of x as the origin, with x increasing toward the center of the containment building and x measured in inches.

The formulas are as follows:

For $0 \le x \le 201$

$$V_x = U_T - D - 2C^* - wx \qquad (3.1.18)$$

* $-2C$ when $x \ge 201$

$-c$ when $x < 201$

with V_x assumed constant and equal to the value of V_x at 201 inches for the region under the crane wall $201 \le x \le 237$.

For $x \ge 237$

$$V_x = U_T - D - C - w(201) - R - C\,w(x - 237) \qquad (3.1.19)$$

or

$$V_x = U_T - 2C - D - R - wx + 36w \qquad (3.1.20)$$

where:

V_x = uplift shear at any point x (inches) in k/ft

Equation 3.1.20 is applicable until $V_x \le 0$.

The design moment in the base slab is determined for $0 \le x \le 201$

$$M_x = M + V'_u e + D(x + 19.5) + \frac{wx^2}{2} + C(x - 27) - U_T x \qquad (3.1.21)$$

With M_x assumed constant and equal to the value of M_x at 201 inches for the region under the crane wall $201 \le x \le 237$. 5A-24

For $x \geq 237$

$$M_x = M + V'_u e + D(x + 19.5) + w(201)(x - 105.5) + C(x-27)$$

$$+ C(x-201) + R(x-219) + \frac{w(x-237)^2}{2} - U_T x \qquad (3.1.22)$$

or

$$M_x = M_u + V'_u e + D(x + 19.5) + x(1/2\, x^2 - 36x + 6850) + 2Cx - 228C$$

$$+ R(x-219) - U_T x \qquad (3.1.23)$$

where:

e = the effective depth of the 9' –0 base mat divided by 2 and

M_x = the base moment at any point x (inches) in in-k/ft

At the point where $V_x \leq 0$ flexural beam action is no longer considered since uplift is 0 and the mat acts as a flat circular plate supported on a rigid non-yielding foundation.

Again it should be noted that these maximum values for shear and moment occur at only one point on the base slab circumference where the uplift from the horizontal earthquake is maximum and decreases to zero 90° from this point; therefore, it is considered that the calculations shown are conservative.

A gradient with an operating temperature of 120°F inside the containment and a 50°F temperature at the mat-rock interface was considered and the stresses determined are negligible. Accident temperatures have no appreciable effect on the base slab.

3.1.5 SEISMIC LOAD

Horizontal Earthquake

The loads on the containment structure caused by the earthquake are determined by Dynamic Analysis of the structure. The Dynamic Analysis is made on an idealized structure of lumped masses and weightless elastic columns acting as spring restraints. The model representation is essentially that of a cantilever beam. Since the containment is founded on rock, no translation or rotation of the structure as a rigid body is considered.

The analysis is 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.

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

$$(k)\Delta = \omega^2 (M)\Delta \qquad (3.1.24)$$

(k)	=	Matrix of stiffness coefficients including the combined effects of shear and flexure.
(M)	=	Matrix of concentrated masses. Each mass may have up to six degrees of freedom.
Δ	=	Matrix of mode shapes
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…N, where N is the number of degrees of freedom assumed in the idealized structure.

The response of each mode of vibration to the earthquake ground motion is computed by the response spectrum technique as follows:

The participation of each mode, P_n is computed from:

$$P_n = \sum_{m=1}^{N} \Delta_{mn}^{x} M_m \Big/ \sum_{m=1}^{N} \Delta_{mn}^{2} M_m \tag{3.1.25}$$

Where Δ_{mn} is the deflection of mass point m in mode n.

Δ_{mn}^{x} is the component of Δ_{mn} in the direction of the earthquake.

The relative deflection of each mass is determined from

$$Y_{mn} = \Delta_{mn} \, x \, P_n S_{an} \Big/ \omega_n^2 \tag{3.1.26}$$

Where S_{an} = the spectral acceleration of a single degree of freedom system with a frequency ω_n and damping coefficient, a.

The shear at any section of the cylinder is determined by

$$V_s = RMS\left(V_{im} = \Sigma F_{rim}\right)$$

where:

V_{im} = the seismic shear at point i for mode m

F_{rim} = the horizontal inertial force at r nodes above elevation i for mode m

V_s = the root mean square of V_1 for each mode

Figures 3.4 and 3.5 show the base shear and moment distribution up the wall.

The shear flow is determined by consideration of a hollow ring with a total thickness of 2t.

$$S_f = V_s Q/I \tag{3.1.28}$$

where:

S_f = shear flow in the wall

V_s = shear at the elevation under investigation as determined by (Eqt. 3.1.27)

$$Q = 2\int_{o}^{\pi/2} ydA$$

where:

y = distance from element under consideration to the neutral axis of the circular tube cross section of R sin θ

R = radius of containment in inches

θ = angle from neutral axis to the element under consideration in radians

dA = the area of the element under consideration of Rtdθ

t = the thickness of the containment shell in inches

I = moment of inertia of section about neutral axis in in.^{4}

Vertical Earthquake:

The frequency of the containment structure in the vertical direction is determined as described in the dynamic analysis for horizontal earthquake loads.

Using this frequency of , 12.0 cps and the given value response spectral acceleration curve with 5% critical damping a coefficient of spectral acceleration of 0.11g (1.OE') is obtained for the design basis earthquake For the operational basis earthquake with 2% critical damping a coefficient of spectral acceleration of 0.065 is obtained. Multiplying this coefficient by the total mass of the structure yields the vertical earthquake reaction in k/ft of wall. The model in the vertical direction assumes a single degree of freedom response.

$$T_{V_i} = k M_i / 2\pi R \qquad (3.1.29)$$

where:

k = coefficient of seismic acceleration in the vertical direction: (0.111 for 1.OE'), (0.0813g for 1.25E)

M_i = mass of containment shell above point i in kips/g

R = radius of containment in feet

Uplift from the Horizontal Earthquake:

The horizontal inertial forces on the containment structure produce overturning movements which in turn produce tension on one side of the containment and compression on the other side in the direction of the earthquake. These forces per foot of wall section are computed by dividing the overturning moment on the section, considering the containment a cantilever beam, by the moment of inertia of the containment as a hollow cylinder. Since the concrete shell is assumed cracked and in tension under the loss-of-coolant accident pressure condition, only the area of the containment vertical rebar and liner are considered in determining the moment of inertia.

The seismic overturning moment above a point i about point i is determined:

$$M_i = \text{RMS}\ (M_{im} = F_{irm}\ h_{ir}) \qquad (3.1.30)$$

where:

M_{im} = the seismic overturning moment above a point i about point i for mode m

h_{ir} = the distance from the location of forces F_{irm} to the point i

F_{irm} = the horizontal inertial forces on the r segments above point i for mode m

M_i = the root mean square of M_{im} for each node

The moment of inertia is computed by

$$I = \pi t_1 r^3 \text{ (A hollow circular ring)} \qquad (3.1.31)$$

where:

t_1 = equivalent thickness of vertical reinforcing steel, including liner in sq. in. per inch of wall

r = mean radius of containment in inches

and $$T_{EQ} = M_i C t_1 / I \qquad (3.1.32)$$

where:

T_{EQ} = vertical force in k/in induced in the containment wall by the seismic overturning moment

C = distance from neutral axis to outermost fiber of containment cross section.

Torsional effects from an earthquake are negligible due to the symmetry of the containment structure and therefore are not considered.

3.1.6 TEMPERATURE EFFECT LOAD

An increase in internal temperature caused by a loss-of-coolant accident has been considered. The maximum temperatures, which do not occur at the same time as the maximum pressures, related to the design (P), 1.25P and 1.5P cases are 247°F, 285°F and 306°F respectively. This increase in temperature causes compressive forces in the restrained liner which in turn induces tensile stresses into the rebar. The equivalent force induced in the containment wall is determined:

$$F_c = A_L \varepsilon_{TL} E_S \qquad (3.1.33)$$

where:

F_c = the equivalent tensile load induced in concrete containment shell by the attempted expansion of the liner

ε_{TL} = final compressive strain in the liner after pressure and temperature conditions and elastic relaxation of the concrete shell have been considered

E_S = modulus of elasticity for the liner steel

A_L = area of liner steel in in^2/ft

In addition to the liner temperature effect on the containment shell the effect of operating thermal gradients through the wall have been considered in analysis of the containment as shown in Section 3.2.5.

The effect of accident thermal gradients has been investigated and found to penetrate less than 10 percent of the containment wall thickness during the maximum temperature-pressure transient following a loss-of-coolant accident. For this reason, the accident temperature transient thermal gradient effect has not been considered in design analysis.

3.1.7 WIND LOAD

The wind load will be determined by considering a conservative wind pressure of 30 psi for ground level up as stipulated in the state building and construction code for the State of New York.

The forces due to the wind loading are given by

$$V_i = P_1 A_i \qquad (3.1.34)$$

where:

V_i = the wind shear at point i

P_1 = the wind pressure of 30 psf

A_i = the projection, perpendicular to the direction of the wind, of the area of containment above the point i

and

$$M_i = P_1 A_i L \qquad (3.1.35)$$

where:

M_1 = overturning moment about point i determined from the wind load

L = the moment arm from the centroid of the projected area above point i to point i

In all cases the magnitude of the design wind loads are less than the seismic loads as shown in Table 4.1; therefore no stresses are calculated.

3.1.8 TORNADO WIND AND MISSILE LOADS

Tornado loads consist of extreme wind including associated pressure difference and missiles. They are assumed to occur independent of any other extreme load condition.

The wind load is considered for three tornado conditions. One includes a tangential velocity of 300 mph and a translational velocity of 60 mph. This load superposition (Case I, Fig. 3.9) depicts a tornado condition where the funnel coincides with the center of the containment. Load pressure distribution patterns that will result due to various locations of the funnel are considered. The structure will be designed for a triangular (Case II, Fig. 3.9) and a rectangular (Case III, Fig. 3.9) wind distribution of 360 mph.

Case I

For Case I, a torsional effect is induced into the containment structure. This torsional effect results from the tangential wind striking the containment building at an angled α from the normal (See Fig. 3.10). The torsional force is due to the component of the wind tangential to the surface of the containment building and is equal to

$$F_t(\text{lbs.}) = A C_D q \quad Sin\alpha \qquad (3.1.36)$$

where:

A = surface area of the containment (FT^2)

C_D = 0.45[2] (coefficient of drag)

q = 0.002558 V^2 [2] in pounds per square foot

where V = the wind velocity in miles per hour = 300 mph

α = 45°

This assumption is conservative in that the actual tangential force would be the result of skin friction and the effects would be negligible. The shear force F_t which is a maximum at the juncture of the walls and base slab and varies to zero at the top of the dome is distributed over the containment circumference to obtain a maximum shear force per foot.

The average shear force from the translational velocity of 60 mph is equal to

$$F^{(lbs)} = C_D q A^{(2)} \quad (3.1.37)$$

where:

C_D = .45[5] (coefficient of drag)

q = 0.002558 V^2 [2] in pounds per sq. ft.

where V = wind velocity in miles per hr. = 60 mph

A = projected area of the containment normal to the wind direction (FT^2)

The maximum shear equals twice the average shear from above since the shape factor for a hollow circular ring is equal to two. This maximum shear force which occurs at the juncture of the walls and base slab and varies to zero at the top of the dome is distributed over the containment circumference to obtain a maximum shear force per foot.

The total shear per ft. for Case I is equal to 18^k/FT + $.583^k$/FT = 18.583^k/FT. This is less than the smallest earthquake shear of 46.5^k/FT. The seismic steel is designed to resist an earthquake causing 61.5^k/FT which is 3.3 times greater than the tornado shear.

Case II

For Case II, a torsional effect is induced into the containment structure by the tangential wind which is assumed to strike the containment in such a way that one-half of the containment surface is affected by a frictional force F_t.

F_t is calculated by equation 3.1.36

where:

A = one-half the surface area of the containment and V = 360 mph.

The average shear force from the translational velocity of 360 mph is calculated by Eqt. (3.1.37). The average shear force is equivalent to one-half the force from Eqt. 3.1.37 since a triangular load distribution is assumed rather than the rectangular distribution assumed for the 60 mph wind in Case I. The maximum shear force equals twice the average shear from above.

The torsional and translational wind forces which are greatest at the juncture of the walls and base slab and vary to zero at the top of the dome are distributed over the containment circumference to obtain a maximum shear force per foot.

The total shear per ft. for Case II is equal to 12.85^k/FT + 10.4^k/FT = 23.25^k/FT which has a factor of safety of 2.65 with the maximum earthquake shear force for which the seismic steel is designed.

Case III

Case III, considers a 300 mph tangential wind traveling with a forward velocity of 60 mph for a total load of 360 mph with a rectangular distribution. The average shear force from the translational velocity of 360 mph is calculated by Eqt. (3.1.37). The maximum shear force equals twice the average shear from above.

The maximum translational wind force which is greatest at the juncture of the walls and base slab and varies to zero at the top of the dome is distributed over the containment circumference to obtain a maximum shear force per foot.

The total shear per foot for Case III is equal to 21.2^k/FT which has a factor of safety of 2.9 with the maximum earthquake shear force for which the seismic steel is designed.

Since the maximum base shear for Case II is smaller than the base shear from both earthquakes, the seismic steel, which is sized for the earthquake producing the largest base shear, provides an adequate mechanism for resisting all tornado shear loads. Since the tornado acts independently of other severe loads, it is not necessary to do a stress analysis for these smaller loads.

Overturning Moment from Wind Load

The maximum overturning moment is produced by the 360 mph wind with a rectangular distribution in Case III. The overturning moment is calculated from Eqt. 3.1.35.

where:

$$P_i = q\, C_D{}^{(5)} \qquad (3.1.38)$$

q and C_D are as defined in Eqt. (3.1.37) and equal .45 and 330 psf respectively.

The maximum M_i occurs at the wall base mat juncture and varies to zero at the top of the dome. The maximum overturning moment equals 6.15 x 10^9 #-in which is less than the overturning moment for the smallest earthquake (17.2 x 10^9 #-in).

Missile Loads

The containment structure is designed to resist the following missiles:

1. 4" x 12" wood plank @300 mph
2. 4000# auto at 50 mph less than 25'-0 above the ground

Only one missile is considered acting at any time simultaneously with the 360 mph wind load and 3 psi negative pressure if it is conservative to consider the 3 psi negative pressure. The capability of the containment shell to withstand missile impact was calculated by the procedures presented in Reference 5.

The results of this analysis indicate a percentage depth of penetration equal to $\left(\frac{\text{Pent.}}{3.5'}\right)$ and $\left(\frac{\text{Pent.}}{4.5'}\right)$ for the plank and automobile respectively.

3 psi Negative Pressure

The 3 psi negative pressure is not a design consideration when acting independently or in combination with the wind and/or missile. The containment is designed for a maximum no loss of function factored load pressure of 70.5 psi. In combination with the missile or external wind load the negative uniform pressure is assumed to act radially hence does not contribute to the rigid body failure modes of containment.

Vertical Missile Loads

Vertical missile loads are not a factor in the containment design. Since the height of the containment above grade is more than 25'-0 the auto is not a factor.

A wood plank falling at 90 mph, in the unlikely event that it reaches heights greater than the containment, would produce very small loads in comparison to the horizontal auto missile and therefore is not a design consideration.

3.1.9 LOAD COMBINATIONS

The loads discussed above were combined to design the containment structure as given in Section 2.1.12.

3.2.0 GENERAL STRESS/STRAIN FORMULA

3.2.1 DEAD LOAD STRESS

$\sigma_{T_i} = T_{DLi} / A_{s_i}$ when overall effect is tension (3.2.1)

$\sigma_{c_i} = T_{DLi} / A_{c_i}$ when overall effect is compression (3.2.2)

where:

A_{s_i} = area of vertical steel including liner, per foot of wall

A_{c_i} = area of concrete per foot of wall

T_{DLi} = dead load as defined in Section 3.1.1

3.2.2 DESIGN BASIS ACCIDENT PRESSURE LOAD STRESS

$\sigma = P / A_s$ (3.2.3)

where:

A_s = area of vertical steel or hoops, including liner, per foot of wall

P = pressure induced membrane force per foot of wall.

3.2.3 DISCONTINUITY MOMENT AND SHEAR LOAD STRESS

The stress induced in the containment shell wall from the discontinuity moment is calculated by considering formula (16-1) of the ACI 318-63 Code "Ultimate Strength Design."

$$M = A_{s_1} \; f_s \left(d - a/2\right) \qquad (3.2.4)$$

$$f_s = M \big/ A_{s_1} \; \left(d - a/2\right) \qquad (3.2.5)$$

where:

$$a = A_{s_1} f_y \big/ .85\, f'_c\; b \qquad (3.2.6)$$

and

A_{s_i} = area of steel on the tension side of the containment wall in in^2/ft

f_s = stress in the steel in k/in^2

f_y = yield strength of the steel in k/in^2

f'_c = 3000 psi 28 day design compressive stress of concrete in k/in^2

b = width of cross section: in all cases assumed equal to 12"

d = effective depth of cross section in inches = 45"

M = resisting moment in inch-kips per foot. The basis for this number is Figure 3.1. This is less that the ultimate moment since $f_s < f_y$.

The stress in the stirrups is computed from Equation (17-6) of the ACI 318-63 Code – Ultimate Strength Design.

$$A_v = V's \big/ F_s d \left(Sin\,\alpha + Cos\,\alpha\right) \qquad (3.2.7)$$

$$f_s = V's \big/ A_v d \left(Sin\,\alpha + Cos\,\alpha\right) \qquad (3.2.8)$$

where:

- A_v = total area of web reinforcement in tension within a distance, s measured in a direction parallel to the longitudinal reinforcement in in^2.
- V' = total shear to be carried by web reinforcement in kips
- s = spacing of stirrups or bent bars in a direction parallel to the longitudinal reinforcement in inches
- f_s = stress in the stirrups in k/in^2
- d = effective depth of cross section in inches = 45"
- α = angle between inclined web bars and longitudinal axis of member = 45°

3.2.4 BASE MAT STRESS

Stress from the moment is calculated by considering formula (16-1) of the ACI-318-63 code ultimate strength design as shown in Eqs. 3.2.4, 3.2.5 and 3.2.6.

where:

- A_s = area of steel on the tension face of the containment base slab in in^2/ft
- f_s = stress in the steel in k/in^2
- f_c = 3000 psi 28 day design compressive stress of concrete in k/in^2
- b = width of cross section – in all cases assumed equal to 12"
- d = effective depth of cross section in inches = 100"
- M = resisting moment in inch – kips per foot

Stress from the uplift shear is computed from Eqt. (17-6) of the ACI-318-63 code as shown in Eqts. 3.2.7 and 3.2.8.

where:

$$V' = V - V_c \qquad (3.2.9)$$

where:

v = total shear

$V_c = v_c^{bd}$ (3.2.10)

and

v_c = the allowable concrete shear stress or $2\varnothing\sqrt{f'_c} = 93k/in^2$

ϕ = capacity reduction factor = .85

f_s = stress in the stirrups in k/in^2

α = angle between inclined web bars and longitudinal axis member = 45°

b = width of the section = 12 inches

d = effective depth of the cross section = 100"

Additional web reinforcement was also provided on the basis of a minimum spacing of s equal to 0.75d.

Bond stresses in the stirrups are computed by considering the formula

$$\mu = A_v f_s / \varepsilon_o L \quad (3.2.11)$$

where:

μ = the bond stress in k/in^2

ε_o = sum of perimeters of all effective bars crossing the section on the tension side

L = the anchorage length above or below the mid height of the mat. No credit is taken for additional anchorage provided by the bend in the bar.

The allowable bond stress for tension bars with deformations conforming to ASTMA-408 and other than top bars is

$$\mu_A = (.8) \quad \sqrt[6]{f'_c} \quad (3.2.12)$$

where:

μ_A = the allowable bond stress in k/in^2

.8 is the factor allowed by the ACI-318-63 ultimate strength design code for anchorage bond

A finite element analysis was performed on the Unit No. 2 base mat utilizing loads for the three basic loading conditions specified in the Containment Design Report. Since earthquake loads are smaller for Unit No. 3 than for Unit No. 2, due to differences in percent critical damping for the design basis earthquake and the fact that a modal analysis is performed on Unit No. 3, the results of the Unit No. 2 analysis can conservatively be used for Unit No. 3. Maximum hoop moment caused by lack of symmetry of the seismic loading was found to be 454 in.-k/in. This compares with a capacity of 690 in.-k/in. for the in place hoop reinforcing. In all cases tornado loads are smaller than earthquake loads, therefore, no tornado analysis is required.

3.2.5 SEISMIC LOAD STRESS

Horizontal or Vertical Earthquake Effects

$$\sigma = \frac{Load}{A_s} \quad = \quad \text{(For structure in membrane tension)} \qquad (3.2.13)$$

$$\sigma = \frac{Load}{A_c} \quad = \quad \text{(For structure in membrane compression)} \qquad (3.2.14)$$

where:

A_s = area of vertical reinforcing steel, per foot of shell

A_c = area of concrete per foot of shell

Load = force per foot of shell resulting from dead load response to vertical earthquake acceleration or overturning moment induced by horizontal earthquake acceleration.

The basic assumptions considered in the seismic analysis are:

1) Maximum stress in the seismic reinforcing occurs under the action of seismic shear at 90° points from the direction of seismic motion.

2) The liner does not participate in resisting seismic shear.

3) The stress limitations on intersection bars under the combination of pressure plus earthquake shear in one bar may reach 95% of yield and the opposing bar may relieve stress to 0 ksi. Under this consideration only half of the seismic diagonal steel is considered active in resisting earthquake shear at any given instant.

4) The concrete in the containment does not participate in resisting membrane seismic shear.

Thus, the stress can be calculated by considering the shear flow in the wall being resisted by diagonal bars in a hollow ring.

$$A_{s_s} = 1.414 S_f / 2 f_s \quad (3.2.15)$$

$$f_s = 1.414 S_f / 2 A_{s_s} \quad (3.2.16)$$

where:

A_{s_s} = area of diagonal steel per foot, in one direction, measured along a horizontal plane

f_s = stress in the steel in k/in^2

S_f = the shear flow as determined from Eq. 3.1.27

The 1.414 take the 45° angle of inclination of the diagonal bars into account.

3.2.6 TEMPERATURE EFFECT STRESSES

As discussed in Section 3.1.6 temperature considerations must involve both temperature gradient and the interaction effects of the liner on the containment shell. The following development for interaction takes both of these phenomena into account.

Temperature effects as shown in Figure 3.6 are combined with dead load, pressure, and earthquake uplifts in the following manner.

Due to the redistribution of stresses in the rebar, the reinforcing steel is considered to carry an equal amount of tension which must balance the compression in the liner to satisfy $\Sigma F_x = 0$

To satisfy equilibrium conditions:

$$F_{Liner} = F_{Wall} \qquad (3.2.17)$$

$$A_L \, {}^{\varepsilon}TL \, E = -A_s \, {}^{\varepsilon}TL' \, E$$

$$A_L \left[\frac{{}^{\varepsilon}TL_x + {}^{\mu\varepsilon}TL_y}{1-\mu^2} \right] E = -A_s \, {}^{\varepsilon}TL' \, E \qquad (3.2.18)$$

$$ {}^{\varepsilon}TL'_x = \frac{A_L}{A_S} \left[\frac{{}^{\varepsilon}TL_x + {}^{\mu\varepsilon}TL_y}{1-\mu^2} \right]$$

The 2nd condition which must be satisfied is the deformation compatibility

$${}^{\varepsilon}TLx + {}^{\varepsilon}\Delta T = {}^{\varepsilon}T + {}^{\varepsilon}TL'$$

$${}^{\varepsilon}TLx + {}^{\varepsilon}\Delta T = {}^{\varepsilon}T - \frac{A_L}{A_S} \left[\frac{{}^{\varepsilon}TLx + {}^{\mu\varepsilon}TLy}{1-\mu^2} \right] \qquad (3.2.19)$$

Let $\varepsilon_x = \varepsilon_T - {}^{\varepsilon}\Delta_T$

$$^{\varepsilon}TLx\left[1+\frac{A_L}{A_s\left(1-\mu^2\right)}\right] = {}^{\varepsilon}x - \frac{A_L}{A_s}\left[\frac{\mu\varepsilon TLy}{1-\mu^2}\right]$$

$$^{\varepsilon}TLx = \frac{^{\varepsilon}x}{1+\dfrac{A_L}{A_S\left(1-\mu^2\right)}} - \frac{\mu\varepsilon TLy}{\dfrac{A_s}{A_L}\left(1-\mu^2\right)+1} \tag{3.2.20}$$

Let $\mu = .25$

$$\varepsilon_{TLx} = \frac{\varepsilon_x}{1 + 1.067\frac{A_L}{A_S}} - \frac{.25\varepsilon_{TLy}}{.9375\frac{A_S}{A_L} + 1} \qquad (3.2.21)$$

$$\varepsilon_{TLy} = \frac{\varepsilon_y}{1 + 1.067\frac{A_L}{A_S}} - \frac{.25\varepsilon_{TLy}}{.9375\frac{A_S}{A_L} + 1} \qquad (3.2.22)$$

to solve Eq. 3.2.18 for the strain in the rebar induced by liner compression solve Eq. 3.2.21 and 3.2.22 simultaneously and insert values for ε_{TLx} and ε_{TLy} into Eq. 3.2.18.

The definitions of the terms used in the above derivations are:

ε_T = strain in the rebar induced by the dead load, pressure and uplift from horizontal and vertical earthquakes.

ε_{TL} = Final strain in liner causing stress or the restrained portion of the potential strain of the liner due to the temperature increase (X or Y direction)

$\varepsilon_{TL'}$ = strain in rebar from stress induced by liner compression. (X or Y direction)

μ = Poissons Ratio = .25

A_L = Area of liner in in^2/ft

A_s = Area of rebar in in^2/ft

E = the modulus of elasticity of steel when the section is in tension $\left(\varepsilon_T + \varepsilon_{TL'} \geq 0\right)$ and modulus of elasticity of concrete when the section is in compression $\left(\varepsilon_T + \varepsilon_{TL'} \leq 0\right)$.

All preceding developments are for the section in tension since this will yield the maximum rebar stress.

$^{\varepsilon}\Delta T$ = the strain in the liner if unrestrained growth were allowed or $\alpha\Delta T$

where:

α = coefficient of thermal expansion in inch/inch/degree F = 6.5×10^{-6}

ΔT = the difference in temperature between the accident temperature felt by the liner and the temperature of the neutral surface (or the point through the wall where no thermal stress exists because of a thermal gradient through the wall).

The gradient is assumed linear with the inside temperature equal to the operating temperature of 120°F and the outside surface temperature of 0°F.

ΔT can be considered in two steps

ΔT gradient = 120° - ^{T}neutral surface

ΔT interaction – ^{T}Max - 120°

This shows the contribution of both the gradient and interaction effects.

The effect of accident temperatures on thermal gradients has not been considered since analysis has shown only 10 percent of the wall located on the inner face of the containment sees any change of thermal gradient during the pressure phase of the accident. In actuality the stresses induced by thermal gradients in the concrete shell are secondary in nature and are largely relieved by the shell cracking under design accident pressure load conditions. For conservatism, however, the operating temperature gradient was included in the stress analysis.

The location and temperature at the neutral surface as shown in Figure 3.7 is found by equating tension on the outside of the neutral surface to compression on the inside

assuming the concrete carries no tension. This development of thermal stresses in the rebar is based on the method presented in ACI chimney code [4].

The total compressive force is equal to

$$\tfrac{1}{2}\alpha k^2 t T_x E_c + \alpha k T_x \frac{E_s A_L}{b} + \alpha\left(k - Z_q\right)\frac{T_x E_s A_s}{b} + \alpha\left(k - Z_8\right)\frac{T_x E_s A_s}{b} \qquad (3.2.23)$$

and the total tensile force is equal to

$$\alpha \frac{T_x E_s A_s}{b}\left(Z_7 + Z_6 - 2k\right) \qquad (3.2.24)$$

When equating total tension to total compression the result is the following

$$k^2 + \frac{2k\, nt_L}{t} + \sum_{l}^{i} \frac{2n A_s}{bt} \qquad \left(k - Z_i\right) = 0 \qquad (3.2.25)$$

where:

i = number of layers of reinf. type

k = distance from the liner to the neutral surface divided by the total thickness of the wall

b = rebar spacing in inches

n = $\frac{E_s}{E_c}$

t = total wall thickness

t_L = liner thickness in inches

Z = distance from the liner to the rebar under consideration divided by the total thickness of the wall.

α = coefficient of thermal expansion in inch/inch/degree

F = 6.5×10^{-6}

The temperature at the neutral surface = $(1 - k)\,\Delta T_1$ (3.2.26)

where:

$\Delta T_1 = 120° - 0° = 120°$

to get the final stress in the rebar due to temperature, pressure, earthquake and dead load.

$$\sigma = \left({}^{\varepsilon}t + {}^{\varepsilon}TL'\right)E_s \qquad (3.2.27)$$

3.2.7 TORNADO WIND AND MISSILE STRESSES

Tornado- caused base shears, overturning moments, and internal pressures are all less than design loads used for the containment and, therefore, stresses are not computed for these loads.

The local stresses caused by tornado generated missiles (4000# auto at 50 mph) can be quite large depending on the area of the containment assumed engaged by the missile and mechanisms considered for absorbing the kinetic energy of the missile. Gross shear and overturning effects have been considered in Section 3.1.18. Local structural integrity of the shell is assured by application of emperically derived penetration formulas(5) to determine structural adequacy.

3.3.0 DETAILED ANALYSIS OF CONTAINMENT AT REPRESENTATIVE LOCATIONS

In order to perform a specific comparison between actual stress-strain levels and limiting behavior criteria several representative points on the containment shell to include the base, cylinder and dome are selected for analysis.

The selected points are shown in Figure 3.8 and described in Section 3.3. and through 3.3.8. Detailed tabulation of design loads for the eight points listed are found in Section 3.3.9 with the resultant stresses and allowable stress criteria presented in Section 3.3.10. The detailed determination of the loads and stresses shown in Sections 3.3.9 and 3.3.10 are based on the equations given in Sections 3.1 and 3.2. The actual calculations are in the files of United Engineers and Constructors, Inc., Philadelphia, Pennsylvania.

3.3.1 POINT 1

Point 1 is located in the base mat at a point adjacent to the outside face of the crane wall in a region of negligible uplift, where the mat begins to act as a flat circular plate supported on a rigid non-yielding foundation, and high positive moment, point 1 is located at coordinates
H = 53 ft., V = 43 ft.

3.3.2 POINT 2

Point 2 is located in the base mat near the containment wall in a region of high uplift and negative moment adjacent to the knuckle of the liner. Point 2 is located at coordinates
H = 67 ft. and V = 43 ft.

3.3.3 POINT 3

Point 3 is located in the cylindrical portion of the containment shell in a region of very high negative discontinuity moment at a point adjacent to the knuckle at the cylinder-base mat junction which is insulated against any thermal effects. It is located at coordinates
H = 67.5 ft. and V = 45.7 ft.

3.3.4 POINT 4

Point 4 is located in the cylindrical portion of the containment shell in a region of relatively high positive discontinuity moment adjacent to the cut off point for liner insulation at coordinates H = 67.5 ft. and V = 64 ft.

3.3.5 POINT 5

Point 5 is located in the cylindrical portion of the containment shell, about half way between the base mat and the springline, in a region of membrane stresses only at coordinates H = 67.5 ft. and V = 117 ft.

3.3.6 POINT 6

Point 6 is located in the cylindrical portion of the containment shell at a point just below the springline. It is an area of membrane stress only since the discontinuity effects at the springline are insignificant because the deflection of the dome and cylinder are essentially equal due to the changing steel areas. It is located at coordinates H = 67.5 ft. and V = 191.0 ft.

3.3.7 POINT 7

Point 7 is located in the dome portion of the containment shell at a point just above the springline. It is an area of membrane stress only since the discontinuity effects at the springline are insignificant because the deflection of the dome and cylinder are essentially equal due to the changing steel areas. Point 7 is located at coordinates H = 67.5 and V = 191.0 + ft.

3.3.8 POINT 8

Point 8 is located in the dome portion of the containment shell at a point approximately defined by a 30° arc from the springline in a region of membrane stresses only. The seismic bars are terminated at this point and seismic shear is resisted by hoop and meridional rebar. Point 8 is located at coordinates H = 57.8 ft. and V = 225.8 ft.

3.3.9 SUMMARY OF CONTAINMENT DESIGN LOADINGS

In this Section are presented two tables relative to the design Points 1 through 8 shown in Figure 3.8. In Table 3.1 is shown the material and section properties relative to the eight

design points selected while Table 3.2 shows the resultant loads for the points selected which were developed from the equations given in Section 3.1 for the load factors and combinations presented in Section 2.1.12.

3.3.10 SUMMARY OF CONTAINMENT DESIGN STRESSES COMPARED TO CRITICAL STRESS LEVELS

In Table 3.3 is presented the stress resultants for the loads given for selected points in Table 3.2 Section 3.3.9. The Table also presents a comparison between resultant stress and allowable stress levels.

3.4.0 EQUIPMENT HATCH & PERSONNEL LOCK— BOSS DESIGN

3.4.1 INTRODUCTION

There are two large openings in the Indian Point – Unit No. 3 Containment Structure. The Personnel Lock is located in the South East quadrant with a center line elevation of 83' –6 and an opening size of 8' –6 diameter. The Equipment Hatch is located in the North East quadrant of the Containment with a center line elevation of 101' –6 and opening size of 16' –0 diameter. Both of these openings along with their thickened reinforced concrete bosses are located a sufficient distance above the fixed base mat at El. 43' –0 that all moments and shears created at this discontinuity have substantially dissipated in the hatch area.

Both hatch and lock are constructed of ASTM 516 GR 60 (formerly A201 GRB) steel normalized to meet the requirements of ASTM A300. The material has been impact tested to meet the requirements of Section N331 of Section III of the ASME Boiler and Unfired Pressure Vessel Code.

All reinforcing steel in the cylindrical wall and the heavily reinforced hatch areas is high – strength deformed billet steel bars conforming to ASTM Designation A432-65 “Specification For Deformed Billet Steel Bars For Concrete Reinforcement With 60,000 psi Minimum Yield Strength.” This steel has a minimum tensile strength of 90,000 psi and a minimum elongation of 7% in an 8-in. specimen.

Bars No. 14S and 18S are spliced by the Cadweld process only. The splices used to join these bars are designed to develop at least 125% of the minimum yield point stress of the bar.

The plate steel liner inside the cylindrical wall including the hatch areas is carbon steel conforming to ASTM Designation A442-65 Grade 60 “Standard Specification for Carbon Steel Plates With Improved Transition Properties.” This steel has a minimum yield strength of 32,000 psi and a minimum tensile strength of 60,000 psi with an elongation of 22% in an 8-in. gauge length at failure. The liner material is tested to assure an NDT temperature more than 30°F lower than the minimum operating temperature of the liner material. Impact testing was done in accordance with Section N331 of Section III of the ASME Boiler and Pressure Vessel Code.

Internal forces and stresses in the concrete containment shell were determined for the factored load combinations listed in Section 3.4.3.1 of the Containment Design Report for Unit #2 (Docket 50-247). In verifying the adequacy of resistance to these factored loads, capacity reduction factors recommended in ACI 318-63 Building Code Requirements for Reinforced Concrete were applied where applicable.

Under loadings which include incident pressure and temperature, some local yielding of the liner may occur; however, this has no adverse strength implications for the containment wall. Moreover, the ductility of the liner fastening studs is sufficient to tolerate local inelastic buckling without stud failure.

Under load combinations a, b, and c on Page 5A-11 dropping the thermal effects, and with the liner contribution to strength disregarded, calculated rebar stresses do not exceed $\varnothing f_y$ (where $\varnothing$ is the capacity reduction factor). Under load combination a involving a factor not greater than 1.0 on reactor incident, and with the liner stress (and temperature) accounted for, calculated rebar stresses do not exceed $\varnothing f_y$. Under factored load combinations b and c involving a factor greater than

1.0 on reactor incident, and with the liner (and temperature loads) accounted for, a limited amount of local rebar yielding is permitted. These criteria guarantee not only assured resistance to the active loads but also minimize any local inelastic strains which may be associated with stress redistribution due to local rebar yielding.

The hatch and lock are anchored into reinforced concrete bosses by means of stud anchors. Along the Equipment Hatch there are 16 rows of 5/8" ∅ x approximately 15" long studs to extend beyond the first row or hoop rebar with 100 per row around the hatch for a total of 1600 studs. Along the Personnel Lock there are 9 rows of 5/8" ∅ x approximately 15" long studs to extend beyond the first row of hoop rebar with 44 per row around the lock for a total of 396 studs. In the areas adjacent to the penetrations, the liner is thickened to 3/4" and is anchored into the concrete by hooked L – anchors of 1/2" ∅ x 9" long (minimum including 2" hook).

The reinforced concrete bosses are thickened to 7'-6 at the Equipment Hatch and 5'-6 at the Personnel Lock. The bosses have flat outside faces and a smooth transition to the dimensions of the wall beyond the effects of the discontinuities (see Figure 3.11).

The hatch and lock have been designed to withstand the internal Containment pressure plus operating and earthquake loads associated with the design accident in accordance with Section III Subsection B of the ASME Boiler & Pressure Vessel Code – Nuclear Vessels. The anchors have been designed to transmit these loads back into the reinforced concrete boss.

Both the Equipment Hatch and Personnel Lock penetrate the concrete shell. In the case of the 16' ∅ Equipment Hatch, a personnel lock is mounted in the head of the hatch and transmits all pressure loads thru the barrel to the concrete when the inside door is closed. Should the personnel door be left open on this lock, the temperature and pressure loads are transmitted to the lock but not into the concrete due to the space between the lock and hatch. Where the 8'-6" Personnel Lock is mounted in the concrete, the temperature and pressure loads inside the lock are transmitted to the concrete if the inside door is left open. (See Figure 3.12.)

3.4.2 DESCRIPTION OF OPENING REINFORCEMENT

The thickened boss has been heavily reinforced in addition to the dense reinforcing which already exists in the 4'-6 thick Containment cylinder wall. The hoop, vertical and seismic wall reinforcing are bent around the openings to provide continuity of reinforcing and assure flow of membrane forces around the openings. All splices will be by the Cadweld process only. The splices are designed to assure that they will develop at least 125% of the minimum yield point stress of the rebar. Several secondary bars have been terminated by means of mechanical anchorage. At the continuous bar bends, hooked bars are provided to prohibit any local crushing of the concrete. In addition the radius of the bar bends is such that crushing of the concrete will not occur. Due to bending the main bars around the large openings, a void in reinforcing is created on the horizontal and vertical center lines. To prevent any cracking and spalling of concrete and to resist membrane tensions, these voids are filled with added rebar which are terminated by hooks at each end.

To accommodate stress concentrations and discontinuity effects of the opening hoop reinforcing is provided around the opening.

In addition to the membrane forces a moment on the ring is produced by the shear load from the pressure on the door of the hatch tending to cause the ring to rotate inside out. Since the ring is restrained from warping, bending moments occur in the cross section of the ring which are resisted by the additional hoops in the reinforced boss. The hoops are designed to resist the tensile loads in addition to bending mentioned above. Since the ring tends to rotate inside out and detach itself from the Containment shell about its outer boundary, a tensile load is induced on the inside surface of the ring and containment. This is resisted by the main vertical and horizontal reinforcing in the Containment cylinder continuous wall.

Since there is an eccentricity between the center of the wall and the center of the thickened ring, moments causing tension on the inside face of the ring develop. These moments are resisted in tension by the main vertical and horizontal bars which are continuous around the opening. In addition these bars assist in resisting membrane tensile loads.

In addition to the main vertical and horizontal reinforcing in the Containment cylinder wall, the two-way seismic reinforcing in the wall is continuous around the opening, thus increasing the steel area available to carry discontinuity forces and moments.

Transverse shears radial to the center of the containment and in plane shears are resisted by #8 stirrups placed radially to the opening at 6" centers around the opening. Popout shears along the circumference of the opening caused by edge reactions from the pressure against the barrel head are resisted by 2-#9 bars @12" around the opening placed through the cross section perpendicular to the reference plane. These bars are spaced at d/3 to insure that at least one bar will cross a potential diagonal crack through the cross section. One end of the bar will be hooked in order to develop adequate anchorage from the point of crack formation to the end of the bars. In addition to the above mentioned stirrups; concrete, extra stirrups at the voids created by the main horizontal and vertical rebar bending around the opening and inclined horizontal and vertical rebar are also available to resist shear loads. See Figures 3.11 and 3.13.

3.4.3 DESIGN OF OPENINGS

The design of the Unit #3 Equipment Hatch and Personnel Lock is identical to that used in Unit #2 Hatches.

The resultant stresses in the containment shell are modified slightly due to the movement of the containment shell seismic reinforcement toward the outer face to facilitate placement and the 6 percent reduction in total containment reinforcement resulting from the reduced seismic load based on 5 percent rather than 2 percent damping.

The methods used in the design of the equipment hatch and personnel lock were verified by a finite element analysis, the details of which are presented in Section 3.4 of the Containment Design Report of the FSAR for Unit #2.

References

(1) Timoshenko, S. P., Woinowsky-Krieger, S., Theory of Plates and Shells, 2nd Ed., McGraw Hill Book Co., New York, 1959.

(2) Nuclear Reactors and Earthquakes, TID 7024, Division of Technical Information, USAEC August, 1963.

(3) Blume, J., Newmark, N., et al., Design of Multistory Reinforced Concrete Buildings for Earthquake Motion, Portland Cement Association, 1961.

(4) American Concrete Institute, "Specification for the Design and Construction of Reinforced Concrete Chimneys (ACI 505-54)," ACI Manual of Concrete Practice, Part 2, 1967.

(5) Trexel, C.A., Tests and Design of Bombproof Structures of Reinforced Concrete, Navy Department, U.S. Government Printing Office, Washington, 1961.

4.0 CONTAINMENT COMPONENT DESIGN

4.1.0 CONTAINMENT SUMPS

There are three containment sumps that cause projections of the bottom of the containment base mat. The largest is the containment reactor sump which is a key shaped reinforced concrete pit located in the center of the base slab (Figure 4.1). This sump, which is 52.5 feet long and 25'-6" deep, encloses the bottom section of the reactor vessel and the in-core instrumentation leads. The side walls and floor of the sump are 4.5 feet thick supporting the ¼" steel liner. An additional 2 feet of concrete is poured over the liner.

Since the reactor sump walls and floor are poured directly against the rock foundation, rigid support conditions have been considered in the design at the sump structural elements to withstand load. Also, since this sump is located in the central portion of the base slab which is poured directly on the rigid rock foundation, negligible bending shears and moments exist in the base slab at the sump location under all load conditions. The reinforcing steel in the sump includes an extension of the reinforcement with the standard detailing procedures specified in ACI-315 being followed. Temperature steel is included in the sump to meet the requirements of ACI-318.

The next largest sump encloses the intakes for the recirculating pumps and consists of a rectangularly shaped reinforced concrete pit 18 feet by 12 feet in plan and 12 feet deep. The side walls and floor of this sump are 9 feet thick supporting the sump liner with an additional 3 feet covering the pit liner floor and 1 foot covering the liner enclosing the sides of the sump (Figs. 4.2, 4.3, 4.4, and 4.5). As in the case of the reactor sump, the walls and floor of this sump are supported by the rigid rock foundation and the sump is located in a region of negligible bending stresses in the base mat. The walls and floor of the sump are considered structurally as part of the base mat.

The smallest sump encloses the containment sump intake and measures 7.5 feet by 7.5 feet by 5.75 feet deep. It has side walls and floor 7.25 feet thick with a 1 foot covering on the liner. As in the case of the recirculating water sump, the walls of the sump are considered as part of the base mat and are located in a region of negligible bending moment and shear.

The three sumps and in particular the concrete cover over the sump liners, also serve as excellent shear keys in transferring seismic or thermal shear loading from the containment internal structure to the base mat. While it is anticipated most of the shear load would be transmitted by friction between the containment base liner and the containment mat the concrete cover area of the sumps acting alone is capable of transmitting full seismic shear load for a 0.15 earthquake at an average shearing stress of 120 psi.

4.2.0 CONTAINMENT BASE MAT

The containment base mat is a reinforced concrete slab 146 ft. in diameter and 9 ft thick (Figure 4.6). The base slab is designed as a flat circular plate supported on a rigid non-yielding foundation. For loads applied uniformly around the slab, the analysis considers a one foot wide beam fixed at a point where the vertical shear is equal to zero. This is the point where the downward pressure on the mat and the dead weight overcome the uplift at the containment wall base mat juncture from pressure and earthquake loadings.

4.2.1 SHEAR REINFORCEMENT DESIGN OF SLAB

The limiting loading condition for shear is defined by the 1.25P factored load equation which results in the base mat loads as shown in Figure 4.7. The external shear load per foot of 1 foot wide section of the mat is determined from Eqs. 3.1.18 and 3.1.20.

The maximum shear stress permitted on an unreinforced web subjected to combined shear and bending is given by (ACI-318; Eq. 17-2)

$$v_c = \varnothing\left(1.9\sqrt{f'_c} + 2500\frac{P_w V d}{M}\right) \qquad (4.2.1)$$

where:

v_c = shear stress carried by concrete

$\varnothing$ = capacity reduction factor for shear (0.85)

p_w = reinforcement ration (As/bd)

V = total shear at section

M = bending moment at section

d = depth of section from compression fact to centroid of tensile steel (100 in)

Solving Eqs. 4.2.1 and 4.2.3 for the loads defined in Figure 4.7 the distance x determined as the cut off point for shear reinforcement is 16.0 ft. or just inside of the crane wall.

The shear load V used for the design of shear reinforcement is determined at a distance d from the edge of the slab. This value for the loading given in Figure 4.7 is 183 k/ft. The shear load which is assumed carried by other than shear reinforcement is determined as shown in Eq. 3.2.10 equal to 108 k/ft.

V_c = vbd = 108 k/ft

where:

v = $2\varnothing\sqrt{fc'}$ (ACI-318, section 1701); $\varnothing = 0.85$

d = effective depth of base mat slab (100 in.)

b = width of wedge shaped section at x = d = 100 in.

The required area of shear reinforcement per foot is determined by Eqs. 3.2.9 and 3.2.7 as shown in Figure 4.8.

4.2.2 MOMENT REINFORCEMENT DESIGN OF SLAB

As in the case for shear, moment was calculated by writing equations for moment in terms of x using the center of the containment wall-base slab juncture as the origin with x increasing toward the center of the containment building. For the 1.5P limiting case the discontinuity moment is 1210 k. ft/ft, the discontinuity shear is 157 k/ft as shown in Figure 4.9. The expressions for the moment as a function of x are shown in Equations 3.1.21 and 3.2.23.

The loading diagram in the mat is shown in Figure 4.9. The equation for moment as a function of x is set equal to zero and the distance x at which the condition of tension in the top of the mat would discontinue is found to be 6.5 feet. The expression for shear is also set equal to zero and the distance x at which the maximum positive moment (1208 k. ft) occurs is found to be 20.6 feet.

The moment steel provided for the maximum negative moment of 1210 k ft/ft which occurs along the perimeter of the slab is also assumed to carry one half of the discontinuity shear of 157 k/ft as an axial load which results in a direct stress of 18.4 psi. The section is designed according to Part IV-B Structural Analysis and Proportioning of Members – Ultimate Strength Design of the ACI-318-63 Code as shown in Section 3.2.3 of this report.

The value of fy used is reduced to 41.6 KSI since 18.4 KSI is taken by the discontinuity shear and the ultimate moment is found to be 1,250 K ft/ft which is greater than the maximum applied negative moment value of 1210 K ft/ft.

For all combinations of pressure, dead load and earthquake loadings which tend to cause uplift in the base slab, the dead weight of the crane wall greatly reduces uplift. This forms a rigid central region in the base slab which is supported on an essentially rigid non-yielding foundation. The model used to analyze this condition is a circular and solid flat plate with a central rigid portion subjected to an external moment (Figure 4.10). The maximum radial stress at the inner edge is given by [1].

$$\sigma_R = \beta \frac{M_{EXT}}{a\,t^2} \qquad (4.2.2)$$

where:

M_{EXT} = external overturning moment

β = parameter which depends on ratio of a to the radius of the central rigid portion of the slab.

a = radius of the circular slab (875 in)

t = thickness of the slab

The radial stress due to an internal moment is:

$$\sigma R = \frac{M_{INT} C}{I} = \frac{6 M_{INT}}{t^2} \qquad (4.2.3)$$

where:

M_{INT} = internal moment in base slab

C = distance from neutral axis to outer fiber of section

I = moment of inertia of section

By equating Eqs. 2.11 and 2.12, the expression for internal moment as a function of the external overturning moment is:

$$M_{INT} = \frac{\beta M_{EXT}}{6a} \qquad (4.2.4)$$

The external overturning moment ^{M}EXT is that due to the seismic shear forces. The maximum positive moment acting on the slab base occurs for the 1.25 P factored load case at the crane wall. The uplift pressure is added to the internal moment due to the seismic overturning moment.

Temperature steel was also added in the base mat to meet the requirements of article 807 of the ACI 318 Code. In the circumferential direction reinforcement is placed in the top and bottom of the base slab. In the central region of the base slab for a radius of 28 feet the temperature steel is placed in an orthogonal grid pattern.

4.3.0 CONTAINMENT CYLINDER WALLS

The analysis of the cylinder was accomplished by the superposition of membrane forces resulting from gravity, internal design basic accident, temperature and pressure and overturning due to earthquake using the factored load equation presented in Section 2.1.12. The cylindrical walls are reinforced circumferentially with steel hoops and vertically with straight bars.

For the vertical axial load in the cylinder the 1.25 P loading condition governs the design. The axial force in the cylinder due to the pressure loading on the dome is given by Eq. 3.1.5.

The uplift force in the cylinder due to the horizontal earthquake is given by Eqs. 3.1.29 and 3.1.32. The dead weight force in the cylinder is obtained by taking the total weight of the dome as the force acting at the top of the cylinder and the total weight of the dome and cylinder as the force acting at the base. The uplift force in the cylinder due to the pressure loading on the dome and the uplift due to the horizontal earthquake are combined with the dead weight load in the cylinder. The resultant load diagram varies from an uplift force of 330 k/ft at the base of the cylinder to 276 k/ft at the springline.

For the hoop direction, the 1.5P case controls since the dead weight and earthquake effects are zero. The force in the hoop direction is given by Eq. 3.1.6.

The seismic loads were determined as described in Section 3.1.5. To provide for the seismic steel, diagonal bars are placed in the cylinder walls in both directions at an angle of 45°.* Seismic steel reinforcement is as shown in Figures 4.11 and 4.12.

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* The design of the diagonal steel is such that its horizontal component is equal to the maximum value of the shear flow which is equal to twice the average shear on the cross-section. Since the diagonals are assumed to act in diagonal tension only, half of the total area of the 45° diagonal seismic bars as assumed active to resist seismic shear effects at any given instant.

4.4.0 CONTAINMENT DOME

The thickness of the dome is small in comparison with the radius of curvature (1/15) and there are no discontinuities such as sharp bends in the meridional curves, therefore the stresses due to dead weight, pressure, or earthquake, were calculated by considering a uniform distribution across the wall thickness. All membrane tensile stresses are assumed taken by the steel reinforcement and none by the concrete unless they are compressive stresses since the concrete is assumed to have no tensile strength.

The membrane analysis of the hemispherical dome has been performed by the superposition of forces resulting from gravity and accident pressure. The dead weight forces in the dome are computed by using the procedure outlined in the Portland Cement Association Bulletin ST55, "Design of Circular Domes." The total vertical dead load acting downward for a given central angle from the apex is given by Eq. 3.1.4.

The meridional thrust (T) is given by Eq. 3.1.3 and the circumferential thrust (H) is given by Eq. 3.1.2.

The membrane force due to the internal design pressure is equal throughout the dome and is given by Eq. 3.1.5.

Analysis has shown that the earthquake effects are small in the dome, therefore the critical design condition is the 1.5P factored load case. The membrane forces due to the 1.5 factored internal design pressure of 70.5 psi are added vectorily to the membrane forces due to 95 percent of dead weight and the total force per foot is divided by the allowable yield stress of the rebar (57 KSI) to determine the area of steel required. All of the combined direct stresses are developed in the reinforcing steel encased in the concrete.

The vertical steel in the cylindrical concrete wall is extended into the dome such that a continuity between the dome and cylinder is achieved. At an angle of 60° from the springline, the 18S bars come together to a 6 inch spacing. The bars are connected to splice plates by means of Cadwell mechanical splices such that for every two bars coming together there is one 18S bar extending beyond this point.

At an angle of 75° from the springline the bars again come together to a 6 inch spacing and are cadwelded to a splice plate to increase the spacing to 12 inches. Similarly, the 18S bars are connected to splice plates at an angle of 83° and 86.5° from the springline. At the apex of the dome 18S bars at a constant spacing of 12 inches connect the splice plates which are 3.5° from the center of the dome as shown on Figure 4.13.

To provide the required earthquake resistance the seismic steel in the cylinder is extended into the dome to a point which is 30° above the springline as shown in Figure 4.14.

Above 30° from the springline the membrane steel in the dome is sufficient to carry the seismic shear . The maximum stress in the rebar due to an earthquake is determined by resolution of the principal tensile stress into components parallel the rebar. In addition, the dome liner has sufficient capacity to carry seismic loads under operation or accident conditions.

4.5.0 CONTAINMENT LINER

4.5.1 PURPOSE OF LINER

The purpose of the steel liner, which is attached to the inside face of the concrete shell, is to ensure a high degree of leak tightness in the event of an accident resulting in the loss of reactor coolant and potential release of radioactive material. The liner is attached to the concrete by means of stud anchors so that it forms an integral part of the entire composite structure under all loadings.

4.5.2 DESIGN LOAD CRITERIA

The loads considered in the design of the containment structure, which can create stresses within the component parts such as the liner, are enumerated in Section 2.1.0. The resultant limiting loads in the liner from these specified load combinations for the typical points specified in Section 3.3.0 are shown in Table 4.1

4.5.3 STRESS CRITERIA

The design stress criteria for the liner is based on the philosophy that no gross deformation beyond the elastic limit occurs for all primary membrane loading conditions defined previously.

In this reinforced concrete structure, the design limits for tension member (i.e., the capacity required for the design loads) are based upon ASTM specified minimum allowable stresses for reinforcing steel.

This reinforcement has also been designed so that it is not subject to average stresses beyond the yield point across any section due to the factored loads.

4.5.3.1 Additional Safety Provisions Regarding Stresses

As an additional safety factor, the allowable stress under any given load is reduced from the values referred to above by a capacity reduction factor, denoted as "$\varnothing$." This reduction provides for the possibility that small adverse variations in material strength, workmanship, dimensions, control and degree of supervision, while individually within required tolerances and the limits of good practice, occasionally may combine to result in undercapacity.

The values of "$\varnothing$" used for the liner is 0.95.

Thus, for principal compression and tension, the liner stresses are maintained below 0.95 specified minimum yield at normal operating temperature, i.e., 0.95 x 32,000 = 30,400 psi. For shear, the liner stresses are maintained below 0.6 specified minimum yield at normal temperature. (The actual shear stresses are well below this limit.) The actual proportioning of seismic shear between the liner and the concrete shell is dependent upon the relative stiffness of the two elements. Conservatively assuming only the relative stiffness of the steel reinforcement in the concrete shell versus the stiffness of the liner approximately 30 percent of the seismic shear could be transmitted into the liner.

The limiting case governing the contribution of shear stress to direct stress in the liner to determine the maximum principal compressive stress shows the liner capable of carrying 40 percent of the seismic shear before principal yield compression would be reached. The liner plate material is ASTM A-442, Grade 60.

For the Structural Proof Test, primary membrane stresses are maintained within elastic limits.

4.5.4 MISSILE PROTECTION

High pressure reactor coolant system equipment which could be the source of missiles is suitably shielded from impacting on the liner either by the concrete shield wall enclosing the reactor coolant loops and pressurizer or by the concrete operating floor to block any passage of missiles to the containment walls. A structure is provided for the control rod drive mechanism to block any missiles generated from fracture of the mechanisms.

4.5.5 DESIGN AND STRESS ANALYSIS

The reactor containment is a reinforced concrete shell in the form of a vertical right cylinder with a hemispherical dome and a generally flat base, supported on rock. The inside surface of the structural concrete is lined with steel plate anchored in the concrete shell.

Anchorage of the liner to the concrete shell is effected as shown on Figure 4.15 and described below.

Attachment of the dome liner to the concrete is made by a combination of structural steel tee sections welded to the exterior face of the dome plate in two directions at approximately five foot intervals and Nelson Studs which are provided between the tees. The liner for the cylindrical portion of the concrete shell is anchored by means of Nelson Studs welded to the plate at 14 inches vertical spacing and 24 inches horizontal spacing on the 3/8 inch thick plate and 28 inches by 24 inches on the ½ inch thick plate.

The first course of studs is approximately 18 inches above the base slab. Results of the analysis performed for the base slab preclude the need for anchorage of the bottom horizontal liner plate to the concrete base.

The basic design concept for the liner utilizing stud anchorage ductility assures that the studs fail due to shear, tension or bending stress without the stud connection causing failure or tearing of the liner plate.

The design has also taken into consideration the possibility of daily stress reversals due to ambient temperature changes for the life of the plant. Fatigue limit of the studs, verified by extensive testing of the fatigue life of plates with stud shear connectors will exceed the design requirements. Moreover, to accommodate possible fatigue failure in the plate-to-stud weldment, the depth of weld to the liner plate is controlled to avoid impairment of liner integrity.

In general, the stresses in the liner have been determined assuming deformation compatibility with the containment concrete. The exception to this assumption is the base of the cylindrical wall at the juncture with the base slab. The shear capacity of the studs in the vicinity of the juncture points is less than 10 per cent of the shear capacity required to transfer total discontinuity bending stresses into the liner. For this reason stresses induced in the liner by bending of the concrete shell have been neglected.

The design of the liner takes into consideration buckling of the plate under loading. In order to determine the critical buckling stress, the plate is assumed to be hinged along EFGH as shown in Figure 4.16. This assumption corresponds to buckling mode type III as identified in reference 2. The critical buckling stress for the case of equal bi-axial compression of the assumed hinged plate EFGH is 38.1 ksi. The maximum calculated stresses as shown in Table 4.2 and F are -30.4 ksi vertically and –25.0 ksi horizontally and from a Mohr's circle consideration, the normal stress on the assumed hinged plate is –29.0 ksi and the shear stress 2.34 ksi. The shear stresses on the assumed hinged plate is of such low magnitude that no reduction of normal critical buckling stress results.

Since the maximum applied stress of 29.0 ksi is less than the critical buckling stress of 38.1 ksi, the plate will not buckle.

It will be assumed that during the 115% pressure test of the containment at 54 psig, the liner will contribute to the net overall cross-sectional strength of the structure to resist membrane forces. Since the liner will be anchored to the shell by Nelson Studs at appropriate intervals, elastic stability will be assured and the liner will not be loaded beyond a 95% yield. Results of the calculations for the overpressure test indicate maximum stresses of 30.3 ksi in the liner which are within the allowance of 95% of yield.

The liner will make only a small contribution to the structural capability of the total containment under an accident loading condition. It will tend to expand faster than the concrete at increased temperature and therefore will be stressed first in tension due to pressure build up, and then in compression as a result of temperature rise. Insulation material will be applied to the lower 20 on the inside of the liner cylinder to maintain stresses within the design criteria and to ensure elastic stability.

The maximum liner stresses, computed for this condition, is 30.4 ksi, which is within the design criteria.

The stress values at different points in the liner due to the three loading conditions (a), (b) and (c) on the containment structure, described in Section 2.1.12, are summarized in Table 4.2. The results indicate that the calculated maximum liner stresses are in conformance with the criteria. In determining the final stress state both Poisson ratio effects and elastic deformation of the concrete are considered. In all cases, the seismic loads exceed tornado induced loads hence stresses for load case (d) has not been included.

Columns 3 through 9 of Table 4.2 show the stresses resulting from individual load components of the factored load equations. In column 10 is found total resultant liner stress considering the containment wall rigid, that is neglecting the deformation of the liner due to elastic straining of the concrete shell, and no Poisson ratio effects. The stresses corrected for the interaction between liner and concrete shell are presented in column 11 and final liner stress intensities including Poisson ratio effects are shown in column 12.

4.6.0 PENETRATIONS

In general, a penetration consists of a sleeve embedded in the concrete wall and welded to the containment liner. Piping penetrations pass through on embedded sleeve and the ends of the resulting annulus are closed off, either by welded end plates, bolted flanges or a combination of these.* Provision is made for differential expansion and misalignment between pipe or cartridge, and sleeve. The cartridges, however, have no expansion provisions as they are only connected at one end.

Penetrations are designed with double seals so as to permit continuous pressurization during plant operation to prevent outleakage in the event of a loss-of-coolant accident. In addition, small steel channels are welded over all joints in the containment vessel liner to form chambers which also permit continuous pressurization to demonstrate the integrity of the penetration-to-liner weld joint. Pressurizing connections are provided to continuously demonstrate the integrity of the penetration assemblies. Pressure in the penetrations and liner joint channels is maintained at a minimum pressure greater than the calculated peak accident pressure. This is accomplished by the Containment Penetration Pressurization System. This system also allows introduction of Freon or a similar tracer gas for leak detection as may be required should consumption of pressurizing air be excessive. These provisions, in addition to the Isolation Valve Seal Water System, effectively block all containment leakage paths.

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* Electrical penetrations and the equipment hatch pass through an embedded sleeve but the ends are not closed off outside the containment building.

4.6.1 TYPES

4.6.1.1 Electrical Penetrations

"Cartridge" type penetrations are used for all electrical conductors passing through the containment. The penetrations are provided with a pressure connection to allow continuous pressurization. Ceramic type seals are used to provide a pressure barrier for the conductors. Typical electrical penetrations are shown in Figure 4.17.

4.6.1.2 Piping Penetrations

Double barrier piping penetrations are provided for all piping passing through the containment. The pipe is centered in the embedded sleeve which is welded to the liner. End plates are welded to the pipe at both ends of the sleeve. Several pipes may pass through the same embedded sleeve to minimize the number of penetrations required. In this case, each pipe is welded to both end plates. A connection to the penetration sleeve is provided to allow continuous pressurization of the compartment formed between the piping and the embedded sleeve. In the case of piping carrying hot fluid, the pipe is insulated and cooling is provided to maintain the concrete temperature adjoining the embedded sleeve at or below 150°F. Typical piping penetrations are shown in Figure 4.18.

4.6.1.3 Equipment and Personnel Access Hatches

An equipment hatch is provided which is fabricated from welded steel and furnished with a double-gasketed flange and bolted dished door. The hatch barrel is embedded in the containment wall and welded to the liner. Provision is made to continuously pressurize the space between the double gaskets of the door flanges and the weld seam channels at the liner joint, hatch flanges and dished door. Pressure is relieved from the double gasket spaces prior to opening the joints. The personnel hatch is a double door, mechanically latched, welded steel assembly. A quick-acting type, equalizing valve connects the personnel hatch with the interior of the containment vessel for the purposes of equalizing pressure in the two systems when entering or to prevent both being open simultaneously and to ensure that one door is completely closed before the opposite door can be opened.

Remote indicating light and annunciator situated in the control room indicate the door position status. An emergency lighting and communication system operating from an external emergency supply is provided in the lock interior. Emergency access to either the inner door, from the containment interior; or to the outer door, from outside is possible by the use of special door unlatching tools.

4.6.1.4 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 pit. The penetration consists of a 20 inch stainless steel pipe installed inside a 24 inch pipe. The inner pipe acts as the transfer tube and is fitted with a pressurized double-gasketed blind flange in the refueling canal and a standard gate valve in the spent fuel pit. The arrangement prevents leakage through the transfer tube in the event of an accident. The outer pipe is welded to the containment liner and provision is made, by use of special seal ring, for pressurizing all welds essential to the integrity of the penetration during plant operation. Bellows expansion joints are provided on the pipes to compensate for any differential movement between the two pipes or other structures. The fuel transfer penetration is shown in Figure 4.19.

4.6.1.5 Containment Supply and Exhaust Purge Ducts

The ventilation system purge ducts are each equipped with two quick-acting tight-sealing valves (one inside and one outside of the containment) to be used for isolation purposes. The valves are manually remotely opened for containment purging but are automatically closed upon a signal of high containment pressure or high containment radiation level. The space between the valves is pressurized above design pressure while the valves are normally closed during plant operation.

4.6.1.6 Sump Penetrations

The piping penetration in the containment sump area is welded directly to the base liner. The weld to the liner is shrouded by a test channel which is used to demonstrate the integrity of the liner.

4.6.1.7 Dome Penetration

An opening is located n the dome at the top of the vessel. This opening is for construction ventilation and will be permanently closed at the conclusion of the construction work.

4.6.1.8 Temporary Construction Openings

There are no temporary construction openings.

All personnel locks and any portion of the equipment access door extending beyond the concrete shall conform in all respects to the requirements of ASME Section VIII Nuclear Vessels Code. The weldments of liner to penetration sleeve are of sufficient strength to accommodate stress concentrations and adhere strictly to ASME Code Section VIII requirements for both type and strength. Liner reinforcements are designed to support penetrations in the appropriate portion of the liner plate during shop testing, shipping and field erection.

The adequacy of penetrations in retaining strength and ductility while preventing leakage is ensured by the following measures:

1. The materials for all components are selected primarily because of their high ductility.

2. By design, all penetrations can withstand all stresses imposed on the as a result of normal plant operation and the hypothetical loss-of-coolant accident. Specifically, the joint between the penetration sleeve and the building liner plate is reinforced with a thickened plate. The sleeve is anchored to the concrete by means of stud anchors welded to a steel ring which is, in turn, welded to the sleeve. The penetration end plates through which the pipes or electric cable pass are designed to withstand the penetration's internal air pressure during normal operation and also containment internal pressure during the hypothetical loss-of-coolant accident.

3. Load transfer around penetrations is based on maintaining continuity of main reinforcing bars which is accomplished by bending of reinforcing to ensure the transfer of tensions, bending moments and shares. At the equipment access opening, a reinforced concrete boss is provided to carry stresses around the opening and to resist bending and torsional moments created by the load transfer. Again, main reinforcement is bent to maintain continuity of stress to ensure load transfer.

4. The line is basically not a load-carrying member and because of its integral relationship with the reinforced concrete is subjected to the strains which the reinforced concrete imposes upon it. Therefore, the criterion at penetrations is one of consistent deformations rather than transfer of load. Nevertheless, the liner is reinforced at each penetration according to the rules set forth in the ASME Unfired Pressure Vessel Code, Section VIII UG-36. An additional conservatism is that the reinforcing requirements set forth in the ASME Code are based on unequal bi-axial stresses, whereas the liner principal stresses, being dependent on reinforcing bar strains, are essentially equal. For the penetrations the maximum stress at the opening is essentially the same as the average nominal stress of the liner.

5. The weldments of liner to penetration sleeve are of sufficient strength to accommodate the stress raisers around the openings. These welds shall adhere strictly to ASME Section VIII requirements for both type and strength. In addition, each weld has a channel placed over it (for pressurization and ultimate leak testing) which adds strength and stiffness to the welded area and assists in reducing stress in the weld and liner plate.

4.6.2.1 Penetration Loading

The penetration sleeves and end plates are designed to accommodate all loads imposed on them. These loads include the following:

1. Internal pressure
2. Concentrated loads imposed by the sleeve anchors to the concrete as the anchors strain in conjunction with wall movement under both operating and accident conditions.
3. Thermal effects due to both gradient and thermal reactions of the particular item passing through the sleeve.
4. Shear, bending and compression due to accident end pressures.
5. Shear and bending due to seismic movements of the particular item passing through the penetration.

The sleeve and expansion joint are designed to remain within the stress limitations imposed by ASME Code Section VIII.

In addition, pipes which penetrate the containment building wall and which are subject to machinery originated vibratory loadings, such as the reactor coolant pumps, will have their supports spaced in such a manner that the natural frequency of the piping system immediately adjacent to the penetrations will be greater than the dominant frequencies of the pump. Pipe line

vibration will be checked during preliminary plant operation; and where necessary vibration dampers will be fitted. This checking and fitting will effectively eliminate vibrating loads as a design consideration.

4.6.2.2 Design Computations

Stresses in the penetration sleeves and the liner to which they are attached is determined by compatibility of deformation between the liner and the sleeve. The radial deformation in a plate subject to biaxial stresses is determined by performing an integration of the tangential strains around the periphery of the hole.

$$\sigma_\theta = S - 2S \cos 2_\theta + \left[S - 2S \cos(2\theta - T)\right] \qquad (4.6.1)$$

Where:

σ_θ = tangential stress at the boundary of the hole defined at the angle θ from the horizontal axis

S = horizontal stress in the liner

S' = vertical stress in the liner

The displacements are determined

$$\delta D = \frac{1}{E}\int_o^\pi \left(\mathrm{S} - 2\mathrm{S} \cos 2\theta + \left[\mathrm{S}' - 2\mathrm{S}' \cos(2\theta - \pi)\right]\right) \; r \sin\theta d\theta \qquad (4.6.2)$$

$$\delta D = \frac{r}{E}\int_o^\pi S \sin\theta d\theta - 2S\int_o^\pi \cos 2\,\theta \sin\theta d\theta + \mathrm{S}'\int_o^\pi \sin\theta d\theta - 2\mathrm{S}'\int_o^\pi \cos(2\delta - \pi) \sin\theta d\theta \qquad (4.6.3)$$

$$\begin{aligned} \int \cos(2\theta - \pi) \sin\theta d\theta &= -\int \cos 2\theta \sin \theta d\theta \\ &= -\int \left(1 - 2\mathrm{Sin}^2\theta\right)(\mathrm{Sin}\,\theta)\, d\theta \\ &= -\int \left(\mathrm{Sin}\,\theta - 2\mathrm{Sin}^3\theta\right) d\theta \\ &= -\left[(-\cos\theta) - 2\left(\frac{\mathrm{Sin}^2\theta \cos\theta}{3} + \frac{2}{3}\int \sin\theta d\theta\right)\right] \\ &= -\left(-\cos\theta + {}^2\!/_3 \sin^2\theta \cos\theta + \frac{4}{3}\cos\theta\right)\Big] \end{aligned} \qquad (4.6.4)$$

$$\int cos(2\theta-\pi)\,sin\,\theta d\theta = \frac{-cos\,\theta}{3} - \frac{2}{3}sin^2\,\theta cos\,\theta$$

$$\delta = \frac{r}{E}\left[-S\,cos\,\theta - 2S\left(\frac{cos\,\theta + \;\; 2}{3 \qquad\quad 3}sin^2\,\theta cos\,\theta\right) - S'\,cos\,\theta - 2S'\left(\frac{-cos\,\theta}{3} - \frac{2}{3}sin^2\,\theta cos\,\theta\right)\right]_{o}^{\pi} \quad (4.6.5)$$

$$\delta = \frac{r}{E}\left[\left(S + \frac{2}{3}S + S' - \frac{2}{3}S'\right) - \left(-S - \frac{2}{3}S - S' + 2/3S'\right)\right]$$

$$\delta = \frac{r}{E}\left[2S + \frac{4}{3}S + 2S' - \frac{4}{3}S'\right]$$

$$\delta = \frac{r}{E}\left[\frac{10}{3}S + \frac{2}{3}S'\right]$$

$$\delta = \frac{2}{3}\frac{r}{E}[5S + S'] \qquad \text{(For Stresses in the Same Direction)} \qquad (4.6.6)$$

$$\delta = \frac{2}{3}\frac{r}{E}(5S - S') \qquad \text{(For Stresses in Opposite Directions)} \qquad (4.6.7)$$

The composite deformation determined in the plate and the sleeve and the resultant stress in the liner and sleeve is determined:

$$^{\Delta}UN = {}^{\Delta}P \;\; \text{(restrained)} \;\; + {}^{\Delta}S \qquad (4.6.8)$$

$$^{\Delta}UN = \frac{S_1}{E}(1-v)R + \frac{S_1(t)R^2\lambda}{2Et_s}$$

$$^{\Delta}UN = \frac{S_1}{E}\left[R(1-v) + \frac{^{t}pR^2\lambda}{2 \quad t_s}\right]$$

$$S_1 = \frac{\Delta UN^{E}}{R\left[(1-v)+\left(\frac{t_p R\lambda}{2t_s}\right)\right]} \qquad (4.6.9)$$

$$S_s = \frac{S_1 t_p R\lambda}{2t_s} \qquad (4.6.10)$$

$$S_S = \frac{\Delta UN^{E}\, t_p R \lambda}{R\left[(1-\upsilon)+\left(\frac{t_p R\lambda}{2t_s}\right)\right]} \quad 2t_s$$

where:

$$\lambda = 4\sqrt{\frac{3(1-v^2)}{R^2 t_s^{\,2}}}$$

ΔUN = unrestrained deflection

Δp = deflection of liner plate

Δs = deflection of sleeve

S_1 = stress in liner

R = radius of penetration

υ = poissons ration

t_p = thickness of liner plate

t_s = thickness of sleeve

E = modulus of elasticity

A summary of liner and penetration stresses is shown in Table 4.3. The assumptions assumed in design are as follows:

1. The liner alone was designed for stress concentration effects while the cracked concrete was ignored.

2. The unrestrained growth is based on maximum growth from a stress concentration consideration.

3. The main stream and mechanical penetrations have been considered in a non-insulated zone when they are just inside the insulated zone. The compression in the hoop direction will be greatly reduced or perhaps go into tension, thus reducing the stresses.

4. The allowable stress in the sleeve = 56,700 psi except for the stainless steel fuel transfer penetration = 49,500 psi. These values come from Table N-421 and Figure N-414 of the ASME Nuclear Vessel Code Section III.

In addition, thermal loads have been investigated for their effect on the shell adjacent to the penetration sleeve and found to be insignificant (38 psi bearing stress on the concrete is the maximum stress on the concrete shell).

4.7.0 CONTAINMENT CYLINDER, BASE AND DOME AT POINTS OF DISCONTINUITY

Discontinuity stresses occur at changes in section or direction of the containment shell. The juncture of the cylinder to the dome is a point of discontinuity since, under the internal pressure and temperature design conditions, the cylinder will tend to increase in diameter somewhat differently than the dome. To compute the unrestrained dimensional changes, the dome and cylinder have been considered as steel membranes equivalent to the area of reinforcing steel in the hoop direction. As shown in Section 3.1.3, the unrestrained radial deformation of the dome and cylinder are nearly equal therefore the discontinuity moments and shears are insignificant and there is no steel required at the dome to cylinder juncture due to the discontinuity effects.

The juncture of the cylindrical wall and the base mat is also a point of discontinuity. In determining the discontinuity moments and shears, the base mat was considered as offering complete fixity, therefore the only discontinuity is that due to the unrestrained radial expansion of the cylinder. As for the dome to cylinder juncture, the unrestrained radial expansion of the cylinder has been computed by considering the cylinder to be a steel membrane equivalent to the area of reinforcing steel in the hoop direction. The method of analysis for the discontinuity moment and shear and its distribution into the cylindrical walls is given in Section 3.1.3.

The maximum discontinuity moment at the base occurring under the 1.5P factored load condition is 1210 K.FT/FT and the maximum discontinuity shear is 157/K/FT. The limiting discontinuity moments and shears are distributed as shown in Figures 2.2., 2.3 and 2.4 of this report. The placement of steel to carry discontinuity shears and moments is shown in Figures 4.20 and 4.21.

The required area of shear reinforcing as determined from Eq. 17-6 of the ACI Code is given in Eq. 3.2.7. The allowable value of f_y used as the basis for f_y in Eq. 3.2.7 is reduced from 60 KSI to 47 KSI since part of the stress is assumed taken by the axial force due to uplift. The point where the minimum web reinforcement required is less than the .15 percent of the area b_s the provisions of ACI-318 Code Article 1706b apply.

The allowable shear which may be taken by the concrete alone is found from Article 1701 e) of the ACI Code and is given by:

$$v_c = 3.5 ø \quad f_c \ (1 + 0.002N/A_g)$$

where:

v_c = allowable shear stress carried by the concrete
f_c = concrete design compressive strength
N = load normal to the cross section where N is negative for tensile loads
A_g = gross area of cross section

References

(1) Roark, R. J., Formulas for Stress and Strain, 4th Ed. McGraw Hill Book Co., New York, 1965.

(2) Diable Canyon Unit No. 1, Pacific Gas and Electric Company, Docket No. 50-275, Supplement No. 4, Section III.

5. CONTAINMENT MATERIAL PROPERTIES, FABRICATION AND ERECTION PROCEDURES

5.1 CONCRETE

Concrete used in the containment structure was designed to have minimum compressive strengths in 28 days of 3000 psi and 4000 psi. The concrete mixes were designed to produce strengths of fifteen percent above the minimum design strengths as determined by the average strengths of three laboratory tests of the specified design mixes including satisfactory plasticity qualities.

The minimum cement factor specified was 5 sks/cu. yd. for 3000# Class and 6 ¼ sks/cu. yd for 4000# Class. The maximum slump permitted was limited to 5 inches, except in localized regions of extreme congestion where 7 inch slump was permitted. Concrete was prepared in ready mix equipment conforming to ASTM Specifications C94.

5.1.1 CEMENT

The cement used was Portland Cement Type II conforming to ASTM designation C-150. Cement used in the ready mix batch process was stored in weather-proof bins so as to prevent deterioration or contamination.

5.1.2 WATER

Concrete mix water was supplied from the drinking water supply of the city of Verplank, New York, and as such is clean, clear and free of significant impurity.

5.1.3 AGGREGATES

Fine aggregate consisted of sand conforming to the requirements of ASTM Specification C-33.

Typical properties of the sand are as follows:

SIEVE ANALYSIS

Sieve Sizes	% Passing by wt.	ASTM C-33 Specifications
3/8"	100	100
#4	97.8	95-100
#8	84.9	80-100
#16	61.8	50-85
#30	42.7	25-60
#50	18.1	10-30
#100	3.3	2-10
Fineness Modulus	2.91	
Specific Gravity (SSD)	2.67	
Absorption %	0.7	
Clay Lumps %	Negative	1.0 Max.
Coal & Lignite %	Negative	0.5 Max.
Material Finer than No. 200 Sieve %	0.6	3.0 Max.
Organic Impurities	Standard	Standard
Soundness 5 Cycles, % Loss	10.9	
Unit wt. (dry-rodded) lbs/ft^3	104.3	

Coarse aggregate consisted of crushed gravel conforming to the requirements of ASTM Specification C-33. Typical properties of the crushed gravel are as follows;

COARSE AGGREGATE

30% — 40% Crushed Gravel

SIEVE ANALYSIS

Sieve Sizes	% Passing by wt.	ASTM C-33 Specifications
1 ½"	100.0	100
1"	97.2	95-100
3/4"	71.5	-
1/2"	30.9	25-60
3/8"	12.4	-
#4	0	0-10
Fineness Modulus	7.16	
Specific Gravity	2.67	
Absorption %	0.7	
Clay Lumps %	Negative	0.25 Max.
Soft Particles %	Negative	5.0 Max.
Unit wt. (dry-rodded) lbs/ft^3	102.2	
Magnesium Sulfate Soundness		
5 Cycles, % loss	14.8	18 Max.
Los Angeles Abrasion, % loss	41.7	50 Max.

5.1.4 ADMIXTURES

The admixtures used in the concrete mix design was a plasticizer "Placewell" manufactured by the Union Carbide Corporation. The plasticizer is provided to increase ease of concrete placement in highly congested areas. Air entraining admixture used was Aircon when specified in concrete design mix.

5.1.5 PLACEMENT AND CURING

Placing and Curing of concrete conform to the provisions of Chapter 6 of the ACI 318-63.

5.2. REINFORCING STEEL

Reinforcing steel used for the dome, cylindrical walls and base mat is high-strength deformed billet steel bars conforming to ASTM Designation A-615 “Specification for Deformed Billet Steel Bars for Concrete Reinforcement with 60,000 psi Minimum Yield Strength.” 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-in. specimen. The design limit for a tension member (i.e., the capacity required for the design load) was based upon the yield stress of the reinforcing steel. No steel reinforcement experiences average strains beyond the yield point at the factored load except in local areas when subjected to temperature at accident conditions. The load capacity so determined has been reduced by a capacity reduction factor "ø" which provides for the possibility that small adverse variations in material strengths, workmanship, dimensions, and control, while individually within required tolerances and the limits of good practice, occasionally may combine to result in under capacity. For tension numbers, the factor "ø" was 0.95, 0.90 for flexure and 0.85 for diagonal tension, bond and anchorage.

5.2.1 CADWELD SPLICES

All reinforcing bar design to carry membrane tension or in the size range 14S and 18S where jointed by means of mechanical butt splices known as a Cadweld splice which is a standard commercial product manufactured by Erico Products Inc., Cleveland, Ohio. All splices used are designed to develop the specified minimum ultimate strength of the ASTM A-615 reinforcing bar or greater even though the specified requirement on splice strength was set at 125 percent of specified minimum yield (83.3 percent of minimum ultimate).

The mean value of the ultimate strength of splices made during any time period shall be equal (as a minimum) to 75,000 psi, plus the standard deviation in strength from the mean ultimate strength. In addition, the mean value of the ultimate strength and the standard

deviation shall show, by statistical analysis, that at least 99.0% of all of the splices will have an ultimate strength of 60,000 psi or greater.

Splices shall be monitored by the following procedure. Any splice which, in the judgment of the inspector, does not pass visual inspection shall be cut out and replaced.

a. Bar ends shall be approximately square. They may be torch-cut, sawed or sheared. The cut faces of both re-bar, when inserted into the sleeve, shall be entirely within the specified limits for the size of the bar.

b. Bar ends shall be cleaned of dirt, oil, moisture, concrete, or heavy rust, to a degree of cleanliness as represented by heating the end of the bar uniformly to a surface temperature of 200°F to 300°F, power wire brushing to bare metal, reheating to the same temperature range, and hand wire brushing to remove any resulting dust and/or loose material.

c. The re-bars shall be assembled with their sleeve immediately after cleaning and properly aligned.

d. Preheating is not generally required; however, if the air temperature is below 40°F and/or the humidity is above 80%, the bar ends and sleeve shall be preheated to 100°F in order to remove moisture.

e. If it is necessary to remove a portion of the longitudinal rib on the re-bar in order to fit it into the splicing sleeve, the metal shall be removed by grinding only. In no case shall the entire rib be removed nor shall there be any under-cutting of the rib into the stock material of the re-bar.

Containment wall splices are staggered as specified on the UE & C drawings.

5.3 FORMWORK

Concrete form work was erected to conform to the shape, lines and dimensions of the concrete elements as called for on the drawing and sufficiently tight to prevent leakage of mortar.

For all permanently exposed surfaces of concrete the form facing was constructed of new unscarred plywood, re-used plywood in good condition or metal pans. Forms were removed in such a manner and at such a time as to insure the complete safety of the structure. No areas of the containment concrete structure are in contact with backfill.

5.4 CONTAINMENT LINER

5.4.1 MATERIAL

The steel liner plate is carbon steel conforming to ASMT Designation A-442 “Standard Specification for Carbon Steel Plates with Improved Transition Properties,” Grade 60. This steel has a minimum yield strength of 32,000 psi and a minimum tensile strength of 60,000 psi with an elongation of 22 percent in an 8-in gauge length at failure. The liner is ¼-in. thick at the bottom, ½-in. thick in the first three courses except ¾-in. thick at penetrations and 3/8-in. thick for remaining portion of the cylindrical walls and ½-in. thick in the dome. The liner material was impact tested at a temperature 30°F lower than the minimum operating temperature of the liner material. For the liner steel the factor "ø" was 0.95 for tension and compression.

5.4.2 FABRICATION

The steel liner plate was fabricated from hot rolled plate in the Greeneville, Pennsylvania and New Castle, Delaware shop of the Chicago Bridge and Iron Co. The plate was shop fabricated into approximately 9' by 30' section and rolled to desired curvature. The Nelson stud anchors were welded to the containment liner shell after the plate was erected.

5.4.3 ERECTION

The difference between the minimum and maximum inside diameters at any cross section does not exceed 0.25 percent of the nominal diameter at the cross section under consideration. Maximum diameter 135'-2", minimum diameter 134'-10" below elevation +95. Above +95 tolerance does not exceed .50 percent of the nominal diameter of cross section under consideration. The liner was erected true and plumb not to exceed 1/500 of height at cross section under consideration with allowance for 2" buckling in the plates.

Particular care was taken in matching edges of cylindrical and hemispherical sections to insure that all joints were properly aligned. Maximum permissible offset of completed joints was 25 percent of nominal plate thickness.

5.5 LINER INSULATION

To protect the lower portion of the containment liner from severe temperature changes under accident conditions, the first 18 feet (approximately) of the liner is covered with insulation. The basic insulation selected is 7/8" thick urethane foam covered with a 1/2" thick gold bond fire shield gypsum board and a .019" thick stainless steel jacket and backed with asbestos paper cover on the unexposed side.

The insulation was designed to meet the following operational requirements:

1. Normal operating temperature - 120°F.
2. Under accident conditions rise in liner temperature not to exceed 80°F above ambient.
3. Insulation panels rated non-burning in accordance with ASTM procedure D-1692.

5.6 PENETRATIONS

In general, containment penetrations for pipe, electrical conduit, duct or access hatches consist of sleeves imbedded in the concrete section and welded to the containment liner. The weld to the liner is shrouded by a continuously pressurized channel which is used to assure the leak tightness of the penetration to liner weld joint. Differential expansion between sleeve and pipes passing through is accommodated by bellows type expansion joints between the outer end of the sleeve and the outer plate.

5.6.1 MATERIALS

The materials for penetrations, including the personnel and equipment access hatches together with mechanical and electrical penetrations, will be carbon steel, conform with the requirements of the ASME Nuclear Vessels Code and exhibit ductility and welding characteristics compatible with the main liner material. As required by the Nuclear Vessels Code, the penetration materials were Charpy V-notch impact tested to a minimum of 15 ft-lbs at 50°F.

The stainless steel bellows of the hot penetration expansion joints will be protected from damage in transit and during construction by sheet metal covers fastened in place at the fabricator's shop. These can be left in place permanently if there is no interference with nearby piping or equipment.

The specific materials used in penetrations may be found in Section 2.2.6.

5.6.2 DESIGN

Those portions of penetrations not backed up by concrete are designed to meet the requirements of ASME Code Section VIII. Those portions of penetrations backed up by concrete are designed considering strains and stresses compatible with the deformation

of the concrete wall sections and as such have the same governing design criteria as does the containment liner. As such, no primary load strains greater than the guaranteed yield point under factored loads are permitted. However, strains due to stress concentrations and other localized secondary load effects are limited to 0.5 percent strain.

5.6.3 FABRICATION

The qualifications of welding procedures and welders have been in accordance with Section IX, "Welding Qualifications" of the ASME Boiler and Pressure Vessel Code. The repair of defective welds has been in accordance with Para. UW-38 Section VIII "Unfired Pressure Vessels."

6. QUALITY CONTROL METHOD AND PREOPERATIONAL TEST PROCEDURES

6.1 QUALITY CONTROL ORGANIZATION AND CHAIN OF COMMAND

The responsibility for implementation of the on-site quality control program for WEDCO rests with the Manager – Site Quality Control who reports directly to the Reliability Manager who in turn reports directly to the WEDCO executive Vice President.

Reporting directly to the Manager-Site Quality Control at the project site are Quality Control Engineers assigned primarily to a specific discipline (e.g., Concrete, Structural, Mechanical, Electrical, and Piping/Welding), Quality Control Inspectors, Clerks, and subcontracted testing service personnel.

No one in this quality control chain of command is directly responsible for production or construction schedules.

WEDCO Site Quality Control and/or the subcontracted testing service personnel conduct the first level inspection and test of all construction of structural elements of the vapor containment building except for the field fabrication and erection of the containment liner and penetrations where the construction subcontractor to WEDCO has first level responsibility subject to audit and surveillance by the WEDCO Site Quality Control.

In all cases, all quality control activity is audited by the Prime Contractor, Westinghouse Electric Corp., the Owner, Consolidated Edison Co., and the owner's Surveillance Group, United States Testing Laboratories.

All necessary records and documentation are compiled and maintained by the WEDCO Site Quality Control.

6.2. SUMMARY OF MATERIAL TEST RESULTS

6.2.1 CONCRETE

Minimum design strengths of 3000 psi and 4000 psi are specified. To date no test cylinders strengths under 3000 psi or 4000 class 28 day strength have been determined. One set of six test cylinders to include three 7 day and three 28 day test cylinders have been tested per each 100 cubic yards placed. Approximately 10,000 cubic yards of 3000# Class and 2000 cubic yards of 4000# Class of concrete have been placed in the containment structure to date.

6.2.2 REINFORCING STEEL

Material mill test reports are required for each heat of steel received. Results of all tests show conformance with ASTM specification requirements. In addition to the mill test reports, random heats of no's 11, 14 and 18 bars are user tested. All tests have met minimum specified strength requirements.

6.2.3 STRUCTURAL STEEL

Various types of structural steel were furnished and erected. Structural steel was furnished to ASTM Specification in job lots substantiated by mill certification covering each job lot.

6.2.4 INSULATION

Letters of certification covering material requirements substantiated by test results are furnished by the manufacturer.

6.2.5 CONTAINMENT LINER

All heats of steel used in the fabrication of the liner plate are covered by mill test certificates showing chemical analysis, mechanical test results, and Charpy impact test results.

Each liner plate is marked or coded to a specific heat of steel. These heat numbers are recorded on the as-built drawings. Material control (heat number) continuity is maintained by subcontractor and checked by WEDCO.

The same method of heat identification, certification, and recordation is maintained for the penetration material as for the liner plate.

Weld rod control (only E 7018 rod used on liner plate) is maintained by subcontractor and audited by WEDCO Site Quality Control.

Dimensions of erected material are checked by the WEDCO engineers and recorded on marked-up drawings. Any dimension found out of tolerance is reported to the subcontractor, corrected and rechecked by the survey group. The correction procedure is approved by Engineering.

6.3 QUALITY CONTROL TESTS ON FABRICATED ELEMENTS

6.3.1 LINER, PENETRATIONS, LOCKS, AND EQUIPMENT HATCH

Nondestructive testing of these items consists of the following:

Coupon Testing – In locations on the liner where radiography is not possible, such as floor plates, and lower course of the shell where back-up plates are used, the subcontractor welds a 2" long overrun coupon which is broken off, marked for location and given to WEDCO for destructive examination or radiography.

a. Vacuum Box Test

Bottom liner plate welds and all liner plate seam welds in the cylindrical walls utilizing back-up plates are vacuum box tested with at least 5 psi pressure differential by the subcontractor. No leaks are permitted. (If any portion of a weld seam is inaccessible for vacuum box testings other forms of NDT will be applied.)

b. Strength Tests

After successful vacuum box testing or spot radiography all liner plate weld channels (bottom, cylinder, and dome) are welded on the seam weld and the channel welds tested by pressurizing the channel with air at 54 psig for 15 minutes. No leaks are permitted. Strength testing shall be by predetermined zones, and includes channels and gaskets of the personnel locks.

c. Leak Test

After strength tests of liner seam welds and channels, these welds and penetration sleeve weld channels, and personnel lock weld channels are leak tested by

pressurization to 47 psig with a 20% by weight Freon-Air mixture. The entire run of plate weld and the channel to plate welds are then traversed with a halogen leak detector.

The sensitivity of the leak detector is 1 x 10^{-9} standard cc per second. Any halogen indication indicates a leak requiring repair and retest. In addition, the zone of channels tested is held at test pressure for at least 2 hours, with no indication of drop in pressure.

The strength and leaks tests are also performed on the gaskets and seals on the lock penetrations by pressurizing the space between the gaskets and seals as above.

6.3.2 CADWELDS

All Cadwelds are visually inspected by WEDCO Site Quality Control or its Q.C. Sub-contractor site. Details of Cadwelding operations, operator qualification criteria, testing frequencies and criteria, inspection procedures and acceptance standards are included in the UE &C procedure - "Recommended Procedure for the Testing of Mechanical Type Splices for Concrete" reinforcing bars. Each splice shall be visually inspected in accordance with the following procedure:

a. Properly made splices will have filler metal visible at both ends of the sleeve and at the tap hole in the center of the sleeve.

b. Filler metal will not flow to the very edge of the sleeve due to the gasket action of the asbestos wicking used to seal in the molten filler metal. A recess less than 1/2" will not be cause for rejection.

c. As a result of the Cadweld process, a shrinkage bubble may be visible at the tap hole where the molten metal is introduced and shrinkage fissures and pinholes may be

visible at the top of splices. These casting flaws do not adversely affect the physical performance of the splice and, therefore, do not constitute cause for rejection.

Bars or splices which do not meet the requirements above shall be rejected and removed from the structure.

Before any Cadweld crew can be assigned to production work, they shall demonstrate their ability to produce splices meeting the specification requirements.

Each new crew shall be qualified using approved materials and procedures by making five splices of each type and tested to destruction.

Each Cadweld crew shall be qualified to do specific work only to the extent or having performed satisfactory qualification splices, for each category of crew can make only this type of splice. Any crew having prior qualification for the four types of splices (horizontal-straight, horizontal-reducing, vertical-straight, vertical-reducing) shall be deemed capable of making any type of splice required by the project.

Each crew shall be assigned an identification number and this number shall not be re-issued during the life of the project.

For purposes of this work a crew is defined as an operator who has been qualified in accordance with the above procedure and who shall be assigned a competent helper.

Cadweld splices shall be capable of developing tension at least 125 per cent of the specified yield strength of the reinforcing bar, in accordance with the requirements of ACI 318-63, Section 805-d.

Individual splices which do not meet 125% of yield shall be rejected.

6.3.3 STUD ANCHORS ON THE LINER

A procedure is set up whereby after qualification, the first stud welded each day by each welder is tested by cold bending the stud to an angle of 45°. This is repeated after the lunch break.

6.4 PREOPERATIONAL PERFORMANCE TESTING

6.4.1 STRUCTURAL INTEGRITY TEST

After completion of the vapor containment structure the building will be pressurized with air to 54 psig (115% of the design pressure of 47 psig). At pressure levels of 12, 21, 41, and 54 psig, gross deformations are determined and visual inspections are performed. Crack pattern and spacing measurements will be made to determine deformation behavior of the containment. These results will be correlated with the results obtained from the structural test behavior of Unit No. 2 as the test proceeds to ensure that structural behavior of Unit No. 3 is comparable to the successful testing of Unit No. 2.

Instrumentation will consist of invar wire extensometers inside the containment capable of measurement of movement of ± 0.01 in. and mechanical feeler gages used to measure crack width with ± 0.002 in. accuracy.

The range of strains and deformations expected vary from 0 to the following expected maximums:

	In.
Vertical elongation (top of mat to top of dome)	1.5
Increase in Diameter	2.0
Crack Width	1/16
Uniform Strain	.002 in/in.

In the quadrant of "boss" around the equipment hatch and personnel lock and in the 10' wide by 5' high areas of the base wall intersection, at the mid-height of the wall, and at the wall dome intersection, concrete surface will be sandblasted or acid etched and detailed measurements of crack width and spacing shall be recorded prior to pressurization at 54 psig, and immediately following depressurization.

6.4.2 CONTAINMENT INTEGRATED LEAK RATE TEST

Following the completion of the Structural Integrity Test (at 54 psig), the containment pressure will be lowered to 50% (min) of the calculated peak accident pressure for purposes of performing the reduced pressure Integrated Leak Rate Test. The 24-hour test will be conducted with the Weld Channel and Penetration Pressurization System depressurized and open to the inside of the containment building. The containment pressure will then be raised to 100% (min) of the calculated peak accident pressure and leakage again determined under the same conditions established during the 50% integrated leak test to correlate leakage rates for purposes of in-service testing.

In addition, a Sensitive Leak Rate Test will be performed to assess the capability of the Weld Channel and Penetration Pressurization System to limit building outleakage. This leak test will be conducted with the containment building at ambient conditions, and the Weld Channel and Penetration Pressurization System pressurized at a pressure greater than the calculated peak accident pressure. Leakage will be limited to less than equivalent 0.2% of the building free volume per day during accident conditions.