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5.1 CONTAINMENT STRUCTURE

Learning Objectives:

1. State the purposes of the containment building.

2. State the purposes of the shield building.

3. Briefly describe the physical arrangement of the containment and shield buildings.

5.1.1 Introduction

The containment building, a Seismic Category I structure, is a freestanding cylindrical steel containment vessel with elliptical upper and lower heads. It is surrounded by the Seismic Category I shield building.

The containment building is comprised of the containment vessel and the structures contained within the containment vessel. The containment building is designed to house the reactor coolant system and other related systems and provides a high degree of leak tightness. The containment building is an integral part of the overall containment system with the functions of containing the release of airborne radioactivity following postulated design-basis accidents and providing shielding for the reactor core and the reactor coolant system during normal operations.

The containment vessel is an integral part of the passive containment cooling system (PCS). The containment vessel and the passive containment cooling system are designed to remove sufficient energy from the containment to prevent the containment from exceeding its design pressure following postulated design-basis accidents.

The shield building is the Seismic Category I structure that surrounds the containment vessel. During normal operations, a primary function of the shield building is to provide shielding for the containment vessel and the radioactive systems and components located in the containment building. The shield building, in conjunction with the internal structures of the containment building, provides the required shielding for the reactor coolant system and the other radioactive systems and components housed in the containment.

Another function of the shield building is to protect the containment building from external events. The shield building protects the containment vessel and the reactor coolant system from the effects of tornadoes and tornado-produced missiles.

During accident conditions, the shield building provides the required shielding for radioactive airborne materials that may be dispersed in the containment as well as radioactive particles in the water distributed throughout the containment. In addition, the shield building is an integral part of the passive containment cooling system.

5.1.2 Containment Vessel

5.1.2.1 Vessel Description

The containment vessel is an ASME metal containment. It serves both to limit releases in the event of an accident and to provide the safety-related ultimate heat sink.

The portion of the vessel above elevation 132 ft, 3 in. is surrounded by the shield building but is exposed to ambient conditions as part of the passive containment cooling flow path. A flexible watertight and airtight seal is provided at elevation 132 ft, 3 in. between the containment vessel and the shield building. The portion of the vessel below elevation 132 ft, 3 in. is fully enclosed within the shield building.

The containment vessel is a free-standing, cylindrical steel vessel with ellipsoidal upper and lower heads. The containment vessel has the following design characteristics:

- Diameter: 130 ft
- Height: 215 ft, 4 in.
- Design code: ASME III, Div. 1
- Material: SA738 Grade B
- Design pressure: 59 psig
- Design temperature: 300°F
- Design external pressure: 1.7 psid

The wall thickness of most of the cylinder is 1.75 in. The wall thickness of the lowest course of the cylindrical shell is increased to 1.875 in. to provide margin in the event of corrosion in the embedment transition region. The thickness of the heads is 1.625 in. Each head is ellipsoidal with a major diameter of 130 ft and a height of 37 ft, 7.5 in.

The containment vessel includes the shell, hoop stiffeners and crane girder, equipment hatches, personnel airlocks, penetration assemblies, and miscellaneous appurtenances and attachments.

The polar crane is designed for handling the reactor vessel head during normal refueling. The crane girder and wheel assemblies are designed to support a special trolley to be installed in the event of steam generator replacement.

The containment vessel supports most of the containment air baffle. The air baffle is arranged to permit inspection of the exterior surface of the containment vessel. Flow distribution weirs are welded to the dome as part of the water distribution system of the passive containment cooling system, described in section 5.2.

The principal system located within the containment building is the reactor coolant system that consists of two main coolant loops, a reactor vessel, two steam generators, four canned motor reactor coolant pumps, and a pressurizer. Each reactor coolant loop is surrounded by structural walls of the containment internal structures. These structural walls are a minimum of 2-ft, 6-in. thick and enclose the reactor vessel, steam generators, reactor coolant pumps, and the pressurizer.

The main steam and feedwater lines are routed from the steam generators to a horizontal run below the operating deck. The steam and feedwater lines penetrate the north side of the containment vessel and are routed through the main steam isolation valve area in the auxiliary building to the turbine island.

The passive core cooling system is also located in the containment building. The primary components of the passive core cooling system are two core makeup tanks, two accumulators, the refueling water storage tank, the passive residual heat removal heat exchanger, and two spargers. The first three stages of the automatic depressurization valves are located above the pressurizer and consist of a two-tier valve module.

The chemical and volume control system equipment module is located in the containment below the maintenance floor level. This module represents the high pressure purification loop of the chemical and volume control system.

Two containment recirculation cooling units are located adjacent to the steam generator compartments. Each unit consists of two vane axial fans, cooling coils, and the associated exit ducts and inlet plenum. The four recirculation fans are connected to the common exit plenum (ring header). Several vertical ducts branch off from the ring header to provide cooling flow to the lower compartments in the containment, while other vertical ducts are directed upward to provide cooling flow to the upper regions of the containment vessel.

5.1.2.2 Containment Vessel Support

The bottom head is embedded in concrete, with concrete up to elevation 100 ft on the outside and to the maintenance floor at elevation 107 ft, 2 in. on the inside. The containment vessel is assumed as an independent, free-standing structure above elevation 100 ft.

Vertical and lateral loads on the containment vessel and internal structures are transferred to the basemat below the vessel by shear studs, friction, and bearing. The shear studs are not required for design-basis loads. They provide additional margin for earthquakes beyond the safe shutdown earthquake.

Seals are provided at the top of the concrete on the inside and outside of the vessel to prevent moisture between the vessel and concrete.

5.1.2.3 Coatings and Concrete Embedment

Inorganic zinc is the basic coating applied to the interior of the containment vessel. Below the operating floor, most of the inorganic zinc coating is top coated with epoxy where enhanced decontamination is desired. The epoxy top coat on the containment vessel extends above the operating floor up to a wainscot height of seven feet above the operating floor. Carbon steel and structural modules within the containment are coated with self-priming high solids epoxy (SPHSE).

Concrete surfaces inside containment are coated primarily to prevent concrete from dusting, to protect it from chemical attack, and to enhance decontamination. Exposed concrete surfaces inside containment are coated with an epoxy sealer to help bind the concrete surface together and to reduce dust that can become contaminated and airborne. Concrete floors inside containment are coated with a self-leveling epoxy or an SPHSE floor coating. Exposed concrete walls inside containment are coated to a minimum height of seven feet with an epoxy or SPHSE applied over an epoxy surfacer that has been struck flush.

The exterior of the containment vessel is coated with the same inorganic zinc as is used on the inside of the vessel. The inorganic zinc coating enhances heat transfer by providing good heat conduction and by enhancing surface wetting of the exterior surface of the containment vessel. The inorganic zinc also provides corrosion protection.

The portions of the containment vessel which are fully embedded in concrete are not coated. The exterior of the vessel is embedded up to elevation 100 ft, and concrete is placed against the inside of the vessel up to elevation 107 ft, 2 in. Above those elevations the inside and outside surfaces of the containment vessel are accessible for inspection of the coating. Embedding the steel vessel in concrete protects the steel from corrosion. Seals are provided at the surfaces of the concrete inside and outside the vessel so that moisture is not trapped next to the steel vessel just below the top of the concrete. The seal on the inside accommodates radial growth of the vessel due to pressurization and heatup.

5.1.3 Shield Building

5.1.3.1 Building Description

The shield building is the Seismic Category I structure that surrounds the containment building, with an annulus between the buildings. The shield building shares a common basemat with the containment building and the auxiliary building.

The following items represent the significant features of the shield building and the annulus area:

- Shield building cylindrical structure
- Shield building roof structure
- Connections between reinforced concrete and steel/concrete composite modules
- Tension ring at the interface between the roof and the shield building cylinder
- Knuckle region at the interface between the roof and the outer wall of the passive containment cooling system water storage tank (PCCWST)
- Compression ring below the inner wall of the PCCWST
- Lower annulus area
- Middle annulus area
- Upper annulus area

- Passive containment cooling system air inlets at the top of the shield building cylinder
- Passive containment cooling system air inlet plenum
- Passive containment cooling system water storage tank
- Passive containment cooling system air diffuser
- Passive containment cooling system air baffle

The cylindrical section of the shield building serves as shielding and a missile barrier and is a key component of the passive containment cooling system. It structurally supports the roof and is a major structural member for the entire nuclear island. Floor slabs and structural walls of the auxiliary building are structurally connected to the cylindrical section of the shield building.

The upper annulus of the shield building is the volume of the annulus between elevation 132 ft, 3 in. and the bottom of the air diffuser. The middle annulus area, the volume of annulus between elevation 100 ft and elevation 132 ft, 3 in., contains the majority of the containment vessel penetrations. The area below elevation 100 ft is the lower annulus of the shield building. There is a concrete floor slab in the annulus at elevation 132 ft, 3 in., which is incorporated with the stiffener attached to the containment vessel.

A watertight and airtight seal is provided between the upper and middle annulus areas to provide an environmental barrier. The seal spans the space between the concrete floor slab at elevation 132 ft, 3 in. and the shield building. This environmental barrier is provided to protect against the following:

- In the event of an accident or spurious actuation, the passive containment cooling system drains the system water storage tank. The water, which runs down the outside of the containment vessel, is prevented from draining into the middle annulus area by the watertight seal. Drains are provided to direct the passive containment cooling system runoff water out of the shield building.

- The passive containment cooling system is designed to perform with the upper annulus permanently open to the environment to permit sufficient air flow through the shield building in the event of an accident. The watertight seal protects the middle annulus area from ambient environmental conditions.

The seal is designated as nonsafety-related and nonseismic; it is not relied upon to mitigate design-basis events. The seal accommodates containment temperature and pressure excursions that result in inward or outward containment shell movement.

The shield building roof is a reinforced concrete conical shell supporting the passive containment cooling system water storage tank and air diffuser. Air intakes are located at the top of the cylindrical portion of the shield building. The conical roof supports the passive containment cooling system water storage tank, which is constructed with a stainless steel liner attached to reinforced concrete walls. The air diffuser in the center of the roof discharges containment cooling air directly upwards.

The passive containment cooling system air baffle is located in the upper annulus area. One portion of the air baffle is attached to the containment vessel, and the other portion is attached to the shield building roof. The function of the passive containment cooling system air baffle is to provide a pathway for natural circulation of cooling air in the event that a design-basis accident results in a large release of energy into the containment. In this event the outer surface of the containment vessel transfers heat to the air between the baffle and the containment shell. This heated, lower density air flows up between the air baffle and the outside of the containment vessel to the air diffuser, and higher density air is drawn into the shield building through the air inlets at the top cylindrical portion of the shield building.

5.1.3.2 Structural Details

The shield building involves concrete-filled steel plate (SC) construction as well as reinforced concrete (RC) structure. The SC portion of the shield building wall is anchored to the RC portion by mechanical connections. These RC-to-SC connections are also used in other regions of the shield building, including:

- The auxiliary building RC roof connection to the shield building SC wall,
- The auxiliary building RC wall connection to the shield building SC wall, and
- The tension ring connection to the shield building RC roof.

The connections provide for the direct transfer of forces from the RC reinforcing steel to the SC liner plates.

The cylindrical shield wall has an outside radius of 72.5 feet and a thickness of 36 inches. Beginning a few feet below the auxiliary building roof line, the cylindrical wall section is a reinforced concrete structure. The section that is not protected by the auxiliary building is a steel/concrete composite structure. The steel plate is connected to the reinforced concrete basemat and walls by mechanical connectors as described above. The overall SC wall thickness of 36 inches is the same as that of the RC wall below. The concrete for the SC portion is standard concrete with a compressive strength of 6000 psi. The SC portion is constructed with steel surface plates, which act as concrete reinforcement. Three-quarter-in. tie bars are welded to the steel faceplates to develop the composite behavior of the steel faceplates and the concrete. Shear studs are welded to the inside surface of the steel plate. The tie bar spacing is reduced in the higher stress regions.

The tension ring is located at the interface between the shield building steel/concrete composite air-inlet structure and the shield building reinforced concrete roof. The top of the tension ring interfaces with the RC roof slab. The tension ring supports the roof girders that are located under the RC roof slab. The bottom of the tension ring is attached to the air-inlets structure. The bottom of the air-inlets structure is attached to the top of the cylindrical SC wall of the shield building. The connection of the tension ring to the roof is described above.

The primary function of the tension ring is to resist the thrust from the shield building roof. The air-inlets structure is located directly below the tension ring and includes the air openings that provide for natural circulation of cooling air. Though its steel plates are connected to the concrete infill by studs and tie bars, the tension ring is conservatively considered as a hollow steel box girder. The concrete infill is credited only for stability of the steel plates. The tension ring is designed to have high stiffness and to remain elastic under required load combinations.

The air-inlets structure is a 4.5-ft-thick SC structure with through-wall openings for air flow. The air-inlet openings consist of circular pipes oriented at a downward inclination of 38 degrees from the vertical. Steel plates on each face, aligned with the inner and outer flanges of the tension ring, serve as the primary reinforcement. The concrete infill is connected to the steel plates with tie bars and studs. The top of the air-inlets structure is welded to the underside of the tension ring. The bottom of the air-inlets structure is welded to the SC wall.

The shield building conical roof steel structure consists of 32 radial beams. Between each pair of radial beams are circumferential beams. Steel plate is welded to the top flanges of the beams; it forms the surface on which the concrete is placed. The steel structure forms a conical shell that spans the area from the compression ring to the tension ring.

The outside diameter of the PCCWST intersects with the shield building roof at the knuckle region. Beyond the extent of the PCCWST, the concrete roof slab thickness is 3 feet; at the bottom of the PCCWST, the concrete thickness is 2 feet. The wall of the PCCWST applies a load to the roof slab, and also provides stiffness and increases the strength of the roof in that region.

The inside-diameter wall of the PCCWST intersects with the roof slab at the compression ring. The compression ring provides the compression support for the conical roof dome. It consists of a composite structure with a curved steel beam section, which supports the concrete roof directly above it. The inside wall of the PCCWST is located above the concrete roof. Studs are placed on the top flange of the steel girder to allow the steel and concrete sections to act as a composite unit. The curved girder is designed to provide support for the steel structure during construction and during the initial placement of the concrete roof, before the concrete has hardened sufficiently.

The PCCWST sits on top of the shield building roof. It is supported by, and acts integrally with, the conical roof. The inside surface has a liner that functions to provide leak protection, but it is not required to provide structural strength to the structure. Leak chase channels are provided over the liner welds. The elevation of the water surface inside the tank provides sufficient freeboard to preclude water impact on the roof during a safe shutdown earthquake.

5.1.4 Containment Performance

The containment system is designed such that for all break sizes, up to and including the double-ended severance of a reactor coolant pipe or secondary side pipe, the containment peak pressure is below the design pressure (59 psig). A summary of the results is presented in Table 5.1-1.

This capability is maintained by the containment system, assuming the worst single failure affecting the operation of the passive containment cooling system. For primary system breaks, a loss of offsite power (LOOP) is assumed. For secondary system breaks, offsite power is assumed to be available when it maximizes the mass and energy released from the break.

The single failure postulated for the containment pressure/temperature calculations is the failure of one of the valves controlling the cooling water flow for the PCS. Failure of one of these valves would lead to cooling water flow being delivered to the containment vessel through two of three delivery headers. This results in reduced cooling flow for PCS operation. No other single failures are postulated in the containment analysis.

Subcompartments within containment are designed to withstand the transient differential pressures of a postulated pipe break. These subcompartments are vented so that differential pressures remain within structural limits.

5.1.5 Summary

The containment building, a Seismic Category I structure, is a freestanding cylindrical steel containment vessel. The vessel and the structures contained within the vessel house the reactor coolant system and other related systems. The containment vessel also contains the release of airborne radioactivity following postulated design-basis accidents, provides shielding for the reactor core and the reactor coolant system, and serves as an integral part of the passive containment cooling system. The containment vessel and the passive containment cooling system are designed to remove sufficient energy from the containment to prevent the containment from exceeding its design pressure following postulated design-basis accidents.

The shield building is the Seismic Category I structure that surrounds the containment vessel. The shield building provides shielding for the containment vessel and for the radioactive systems and components located in the containment building, protects the containment vessel and the reactor coolant system from the effects of tornadoes and tornado-produced missiles, and serves as an integral part of the passive containment cooling system.

Table 5.1-1 **SUMMARY OF CALCULATED PRESSURES AND TEMPERATURES**			
Break	**Peak Pressure (psig)**	**Available[1] Margin (psi)**	**Peak Temperature (°F)**
Double-ended hot leg guillotine	50.0	9.0	415.3
Double-ended cold leg guillotine	57.8	1.2	295.1
Full main steam line DER, 30% power, MSIV failure	57.0	2.0	374.1
Full main steam line DER, 101% power, MSIV failure	53.5	5.5	375.5

Note:
1. Design Pressure is 59 psig

Table 5.1-2 **INITIAL CONDITIONS**	
Internal Temperature (°F)	120
Pressure (psia)	15.7
Relative Humidity (%)	0
Net Free Volume (ft^3)	2.06E+06
External Temperature (°F)	115 dry bulb 86.1 wet bulb