5.5 TESTS AND INSPECTION

The quality of both the materials and construction of the Containment Structure was assured by a continuous program of testing and inspection.

Qualified field supervisory personnel and inspectors were assigned to the project to carry out the work in accordance with the specifications and drawings. Project design personnel made frequent visits to the job site to coordinate the construction with the design. Inspectors were experienced and thoroughly familiar with the type of work to be inspected, particularly in the field of prestressed concrete. The inspector was given complete access to the work to perform such examinations as were necessary to satisfy himself that the standards set forth in the applicable codes and specifications were met. Where material did not satisfy the standards, he had the authority to stop work until the necessary alterations were made. Appropriate inspection records were maintained.

5.5.1 PREOPERATIONAL TESTING AND INSPECTION

5.5.1.1 During Construction

Test, code, and cleanliness requirements accompanied each specification or purchase order for materials and equipment. Hydrostatic, leak, metallurgical, electrical, and other tests to be performed by the supplying manufacturers were enumerated in the specifications together with the requirements, if any, for test witnessing by Bechtel inspectors. Fabrication and cleanliness standards, including final cleaning and sealing, were described together with shipping procedures. Standards and tests were specified in accordance with applicable regulations, recognized technical society codes, and current industrial practices. Inspection was performed in the shops of vendors and subcontractors as necessary to verify compliance with the specifications.

The following codes and practices were used to establish standards of construction procedures:

ACI 301	-	Specification for Structural Concrete for Buildings
ACI 318	-	Building Code Requirements for Reinforced Concrete
ACI 306	-	Recommended Practice for Cold Weather Concreting
ACI 347	-	Recommended Practice for Concrete Formwork
ACI 605	-	Recommended Practice for Hot Weather Concreting
ACI 613	-	Recommended Practice for Selecting Proportions for Concrete
ACI 614	-	Recommended Practice for Measuring, Mixing, and Placing Concrete
ACI 315	-	Manual of Standard Practice for Detailing Reinforced Concrete Structures
Part UW	-	Requirements for Unfired Pressure Vessels Fabricated by Welding of Section VIII of the ASME, B&PV Code
AISC	-	Steel Manual, Code of Standard Practice
ACI	-	Manual of Concrete Inspection
PCI	-	Inspection Manual
AWS	-	Code for Welding in Building Construction (D 1.0-66 and D 2.0-66)

Dimensional tolerances for construction, unless stated otherwise, conform to AISC Code of Standard Practice for erection of steel, and to ACI 301-66 and ACI 318-63 for placing of concrete.

Concrete

Concrete work was accomplished basically in accordance with ACI 318-63, "Building Code Requirements for Reinforced Concrete" and ACI-301, "Specifications for Structural Concrete for Buildings." Other codes and specifications are listed above. Concrete is a dense, durable mixture of sound coarse aggregate, fine aggregate, cement, and water. Admixtures were added to improve the quality and workability of the plastic concrete during placement and to retard the set of the concrete. Maximum practical size aggregate, water reducing additives, and a low slump of 2 or 3" were used to minimize shrinkage and creep. Aggregates conformed to "Standard Specifications for Concrete Aggregate," ASTM Designation C33.

Acceptability of aggregates was based on the following ASTM tests. These tests were performed by a qualified commercial testing laboratory.

Test	
L. A. Abrasion	ASTM C131
Clay Lumps Natural Aggregate	ASTM C142
Material Finer No. 200 Sieve	ASTM C117
Mortar Making Properties	ASTM C87
Organic Impurities	ASTM C40
Potential Reactivity (Chemical)	ASTM C289
Sieve Analysis	ASTM C136
Soundness	ASTM C88
Specific Gravity and Absorption	ASTM C127
Specific Gravity and Absorption	ASTM C128
Petrographic	ASTM C295

Cement was Type II low alkali cement as specified in "Standard Specification for Portland Cement," ASTM Designation C150, and was tested to comply with ASTM C114. Fly ash was not used in the concrete for the Containment Structure, or in any other concrete on the project.

Water used in concrete was clean and free from deleterious amounts of acid, alkali, salts, oil, sediment, or organic matter. Water used in concrete mixing was sampled and analyzed by a qualified testing laboratory to assure conformance with specification.

The water-reducing agent, Placewell LS, was selected as the one providing shrinkage similar to that prescribed by ASTM C494, "Specifications for Chemical Admixtures for Concrete." Admixtures containing chlorides were not used.

Concrete mixes were designed in accordance with ACI 613, using materials qualified and accepted for this work. Only mixes meeting the design requirements specified for Containment Structure concrete were used. Trial mixes were tested in accordance with applicable ASTM Codes as indicated below:

Test	
Making and curing cylinder in Laboratory	ASTM C192
Air Content	ASTM C231

Slump	ASTM C143
Compressive Strength Tests	ASTM C39

The concrete had a design compressive strength of 5000 psi at 28 days for the containment wall and dome, and 4000 psi at 28 days for the containment base slab.

Concrete strength, slump, and temperature tests were performed. The purpose of the tests was to ascertain conformance to specifications. The basis for the inspection procedures was the ACI Manual of Concrete Inspection with modifications as set forth in construction specifications for this application.

Test cylinders were cast from the mix selected for construction and the following concrete properties were determined:

Uniaxial creep	ASTM C512
Modulus of Elasticity and Poisson's Ratio	ASTM C469
Autogenous Shrinkage	ASTM C342
Thermal Diffusivity	ASTM C34 and CRD-C36-63
Thermal Coefficient of Expansion	ASTM C342 and CRD-C124-62
Compressive Strength	ASTM C39

An independent laboratory tested the concrete mixes. To maintain the quality of the mix used in the structure, the workability and other characteristics of the mixes were ascertained before placement. A small concrete-control laboratory was set up close to the batch plant. A batch plant inspector was assigned, and testing, as shown below, was performed. Field control was accomplished basically in accordance with the ACI Manual of Concrete Inspection as reported by Committee 611.

Aggregate testing was carried out as follows:

a. Sand Sample for Gradation (ASTM C33 Fine Agg)
b. Organic Test on Sand (ASTM C40)
c. 3/4" Sample for Gradation (ASTM C33 Size No. 67)
d. 1-1/2" Sample for Gradation (ASTM C33 Size No. 4)
e. Check for Proportion of Flat and Elongated Particles

Concrete samples were taken from the mix according to ASTM C172, "Sampling Fresh Concrete." From these samples, cylinders for compression testing were made in accordance with ASTM C31, "Tentative Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Field."

Samples were taken at the point of truck discharge. In addition, a minimum of five cylinders were taken at the pipe discharge for each 1000 c.y. for each class of concrete placed in Seismic Category I structures.

Slump, air content, and temperature measurements were taken when cylinders were cast. Slump tests were performed in accordance with ASTM C143, "Standard Method of Test for Slump of Portland Cement Concrete." Air content tests were performed in accordance with ASTM C231, "Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method." Compressive strength tests were made in accordance with ASTM C39, "Method of Test for Compressive Strength of Molded Concrete Cylinders." Evaluation of compression tests was in accordance with ACI 214-65.

The inspection and testing of cement, in addition to the tests required by the cement manufacturers, included the following:

Chemical Analysis	ASTM C114
Fineness of Portland Cement	ASTM C115
Autoclave Expansion	ASTM C151
Time of Set	ASTM C191
Compressive Strength	ASTM C109
Tensile Strength	ASTM C190

The purpose of the above tests was to ascertain conformance with ASTM Specification C150. In addition, tests ASTM C191 and ASTM C109 were repeated periodically during construction to check storage environmental effects on cement characteristics. These tests supplemented visual inspection of material storage procedures.

Initial Containment Prestressing After Construction

See Appendix 5E for a discussion on the stressing and restressing of new replacement vertical tendons and original construction tendons, respectively, between 2001 and 2002 on both Units.

Testing and inspection of all prestressing materials and special installation equipment is described in Appendix 5B. Full-time supervision of the prestressing operation was provided. The BBRV post-tensioning system furnished by the Prescon Corporation was used.

Each tendon consists of 90 1/4"-diameter wires conforming with ASTM A421-65T, and 2 anchor heads and 2 sets of shims conforming with ASTM A6-66. The tendon sheathing system consists of spirally-wound carbon steel tubing connecting to a trumplate (bearing plate and trumpet) at each end. The bearing plates were fabricated from steel plate conforming with ASTM A6-66 and the trumpets from AISI C1010-C1020 material.

Tendons were delivered to the site coated with a rust preventive and specially covered. Each tendon came precut to exact length, with one end unfinished and the other end shop button-headed and threaded through the stressing washer.

Tendons were fabricated by the Prescon Corporation at their Mauldin, South Carolina, plant and shipped to the Calvert Cliffs job site. During combing and twisting operation, the hoop and dome tendons were banded every 8' to 10' with steel banding and twisted one complete 360° turn per each 40' of tendon length by an automatic twister. During tendon fabrication, a wire sampling method was used to ensure that all wires met minimum tensile strength specifications. The wires were shipped in coils, each weighing 800 to 1200 lbs. Two samples per coil were used for wire-sampling inspection to compare their actual breaking strength with minimum wire breaking strength. A 3' minimum wire sample was taken from the start end of each coil and placed in an appropriate storage tube in the wire sample cart for delivery to the tensile testing machine. After the sample broke, a reading was taken from the maximum load pointer and recorded on a wire inspection record under the minimum breaking strength column. If the sample failed, a second supporting inspection was conducted. Wire strength acceptance was based on the final results of two out of three samples if the first sample failed. If the actual breaking strength was greater than the minimum breaking strength, the wire was recorded as being acceptable. This wire sampling operation verified the initial strength of the wires.

One unit of tendon stressing equipment consisted of a 500-ton ram, a jack base (which is bolted on the ram), a pull rod, a nut, 2 hydraulic hoses, and a hydraulic pump with 440 Volt electric power. The jack base was designed to rotate with ease by inserting a rod into one of the eight holes in the base and turning it. This simplified the dome or hoop stressing operation that required many orientations for the jack base. During tendon stressing, the pull rod could rotate a maximum of 90° due to the twist applied to the hoop and dome tendons during fabrication. This pull rod could freely rotate while stressing the tendon without exerting any twisting moments on the anchor.

It is conceivable, however, that the torque remaining after the tendon had seated, would produce insignificant stress in the anchor. The primary bearing and shear stresses (due to twisting), produced during post-tensioning and which were transferred to the concrete, were well below allowable design value. Only the dome and hoop tendons were twisted when fabricated to give helical shape to the wires and equalize their lengths. (See Appendix 5E for a discussion on new vertical tendons installed between 2001 and 2002. These new vertical tendons were twisted when fabricated.) The average maximum eccentricity, (1/2" over the total tendon length) that may exist due to erection inaccuracies, in our judgment, produced no significant increase in compressive stress in the anchor material or concrete.

The tendon installation prestressing procedure was carried out as follows:

a. To assure a clear passage for the tendons, a "sheathing rabbit" was run through the sheathing prior to, during, and following placement of the concrete.
b. Tendons were uncoiled and pulled through the sheathing unfinished end first.
c. The unfinished end of the tendons was pulled out with enough length exposed so that field attachment of the stressing washer and button-heading could be performed. To allow this operation, trumpets on the opposite end have a larger diameter to permit pulling in the shop finished ends with their stressing washers.
d. The stressing washers were attached and the tendon wires button-headed.
e. The shop finished end of the tendon was pulled back and the stressing jack attached.
f. The post-tensioning was done by jacking to the permissible overstressing force to compensate for friction and placing the shims (as required) to lengths corresponding to the calculated elongation. Proper tendon stress was achieved by comparing both jack pressure and tendon elongation against previously calculated values. The vertical tendons were prestressed from either one or both ends, while the horizontal and dome tendons were prestressed from both ends.
g. The grease caps were bolted onto anchorages at both ends and made ready for pumping the tendon sheathing filler material. See Appendix 5E for a discussion on new vertical tendon grease caps installed between 2000 and 2002 on both Units.

h. The tendon sheaths and grease caps were filled with sheathing filler and sealed. The sheathing filler material had limitations specified for deleterious water soluble salts.

During installation of the Unit 1, post-tensioning system two vertical and three horizontal tendons were not installed. These missing tendons are addressed in Section 3.1.4 of the Final Prestressing Report for Unit 1, November 1973. Similarly, one horizontal tendon was abandoned during construction of Unit 2 containment, and is addressed in Section 3.1.4 of the Prestressing Report for Unit 2, June 1977.

Reinforcing Steel

Reinforcing steel in the base slab of the Containment Structure and around penetrations in the cylinder was of the deformed billet steel bars conforming to ASTM Designation A615-68, Grade 60. This steel had a minimum elongation of 7% in an 8" specimen. Deformed billet steel bars conforming to ASTM A615, Grade 40 or Grade 60, were used in the cylinder wall and the domed roof to control shrinkage and tensile cracks. The Grade 40 steel had a minimum yield strength of 40,000 psi and a minimum tensile strength of 70,000 psi; the Grade 60 steel had a minimum yield strength of 60,000 psi and a minimum tensile strength of 90,000 psi.

Mill test reports were obtained from the reinforcing steel and "Cadweld" suppliers for each heat of steel to show proof that the reinforcing steel and mechanical splice sleeves had the specified composition, strength, and ductility.

Welding of reinforcing steel, if required, was performed by qualified welders in accordance with AWS D12.1, "Recommended Practice for Welding Reinforcing Steel, Metal Inserts, and Connections in Reinforced Concrete Construction." For the filling of blockouts in the Auxiliary Building, reinforcing steel was welded using an angle splice as shown in Figure 5-16. The design criteria and quality control is described in Section 5B.1.

Reinforcing steel had not been welded at anytime in the Containment Structure. Number 14S and 18S reinforcing steel was spliced by the Cadweld Process. The design criteria and quality control for Cadweld is described in Section 5B.3.

All reinforcing steel was user-tested in accordance with ASTM specifications. Tests include one tension and one bend test per heat for each diameter bar except that no bend tests were performed on #14 and #18 bars. High strength bars were clearly identified prior to shipment to prevent any possibility of mix-up with lower strength reinforcing bars.

Visual inspection of fabricated reinforcement was performed to ascertain dimensional conformance with specifications and drawings. Visual inspection of in-place reinforcement was performed by a placing inspector to assure dimensional and location conformance with drawings and specifications.

Liner Plate

The Containment Structure is lined with a welded steel plate 1/4" thick conforming to ASTM A36 to ensure low leakage. This steel had a minimum yield strength of 36,000 psi and a minimum elongation in an 8" specimen of 20%. Structural steel shapes, bars, and backing strips used in fabrication of the liner also conformed to ASTM A36.

The A-36 material was chosen on the basis that it has sufficient strength as well as ductility to resist the expected stresses from design basis loading and at the same time preserve the required leak tightness of the containment. In addition, A-36 steel is readily weldable by all of the commercially available arc and gas welding processes.

The crane bracket together with the thickened liner plate was a shop fabricated assembly, and all welds have been spot radiographed and magnetic particle inspected. These welds were not considered working welds, since all applied loads were transferred to the concrete and not the liner plate.

The liner plate was designed to function only as a leaktight membrane. It does not serve as a structural member to resist the tension loads from internally applied pressure which may result from any credible accident.

Structural integrity of the containment is maintained by the prestressed, post-tensioned concrete. Since the principal applied stress to the liner plate membrane is in compression and no significant applied tension stresses were expected from internal pressure loading, there was no need to apply special NDTT requirements to the liner plate material. On the other hand, all material for containment parts which must resist applied internal pressure stresses, such as penetrations, was impact tested in accordance with the requirements of ASME, B&PV Code, Section III, Nuclear Vessels, Paragraph N-1211.

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

Mill test reports were obtained for the liner plate material. The plate was visually checked for thickness, possible laminations, and pitting.

Steel plate was tested at the mill in full conformance to the applicable ASTM Specifications. Certified mill test reports were supplied for review and approval by the design group in the project engineer's office.

There was impact testing done on the liner plate material. The purpose of impact testing is to provide protection against brittle failure. The possibility of a brittle fracture of the liner plate is precluded because at the design accident pressure condition, there will be no significant tensile stress anywhere in the liner plate since the principal applied stress is compression. This is true whether there is instantaneous release of pressure or there is some time lag in temperature load application.

Welding inspection conformed to the quality control inspection procedure described in detail by Appendix 5B.

All of the welding was visually examined by a technician responsible for welding quality control. The basis for visual quality of welds was as follows:

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

Butt welds were of multipass construction, slightly convex, of uniform height, and had full penetrations.

Fillet welds were of the specified size, with full throat and legs of uniform length.

All welding covered by concrete or otherwise inaccessible after construction was vacuum box soap bubble tested. In this test a leak detector solution was applied to the weld. A vacuum box containing a window was then placed over the area to be tested, and was evacuated to produce at least a 5 psi pressure differential. Leaks were indicated by the appearance of bubbles which were observed through the window in the vacuum box. Welds which were inaccessible for soap bubble testing due to physical limitations or configurations were liquid penetrant inspected.

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

Radiographic techniques were in accordance with ASME, B&PV Code, Section VIII, Paragraph UW-51. At least one 12" spot radiograph was taken in the first 10' of welding completed in the flat, vertical, horizontal, and overhead positions by each welder. Thereafter, approximately 10% of the welding was spot examined on a random basis using 12" film.

Dye penetrant and magnetic particle inspections were also used as an aid to quality control. The field welding inspectors used dye penetrant or magnetic particle inspection to closely examine welds judged to be of questionable quality of the basis of the initial visual inspection. Also, dye penetrant inspection was used to confirm the complete removal of all defects from areas which had been prepared for repair welding. Dye penetrant or magnetic particle inspection of liner plate welds were in accordance with ASME, B&PV Code, Section VIII.

The welds for each section of base slab liner plate were vacuum box soap bubble tested immediately upon installation. After successfully passing this leakage test, they were covered with test channels and the particular welds associated with that section of liner plate were pressure tested. Any repairs were carried out utilizing the same high standards and control exercised in the initial construction.

A testing pipe was provided for each continuous segment of the bottom liner plate leak chase channels (equivalent to containment weld channels). The tops of the pipes were above the cover slab and were sealed with caps. These pipes were initially used to test the leak tightness of the bottom liner and can also be used at a later date, if so required.

5.5.1.2 Structural Test at Completion of Initial Construction

The purpose of instrumenting and testing prestressed concrete Containment Structure is to provide a means for comparing the actual response of the structure to the loads induced both during post-tensioning and pressure testing with the predictions of the design calculations. If the response is as predicted, the design techniques are assumed to have been verified.

The Containment Structure was pressurized to 115% of design pressure for one hour following completion of construction to establish the structural integrity of the building. The structural integrity test was conducted in accordance with a written procedure. Personnel access limitations included in the written procedures designated areas of limited access during specific periods of the test.

The test objectives were:

a. To provide direct verification that the structural integrity as a whole is equal to or greater than that necessary to sustain the forces imposed by (a) the structural test at 115% of the design pressure and (b) the post tensioning sequence.

b. The in-place tendons (the major strength elements) have a strength of at least 80% of guaranteed ultimate tensile strength and that the concrete has the strength needed to sustain a strain range from high initial average concrete compression when unpressurized to low average concrete compression when pressurized.

A quality assurance program was instituted as described in Appendix 5B. In addition, each individual tendon was tensioned in place to 80% of the guaranteed ultimate tensile strength and then anchored at a lower load that is still in excess of those predicted to exist at test pressure levels. During pressurization of the structure, the structure's response was observed at selected pressure levels with the highest being 115% the design pressure. An indication that the structure is capable of withstanding internal pressure resulted from these tests. The strain measuring program is described earlier. Individual test values which fall outside the predicted ranges will not be considered as necessarily indicative of a lack of adequate structural integrity.

The Calvert Cliffs Units were very similar to the Turkey Point, Oconee, Point Beach, and Palisades structures, differing only in being somewhat larger in diameter. The design and construction are the same. The structures for both Turkey Point and Palisades are completely instrumented. The Turkey Point instruments provide approximately 400 strain measurements at 55 locations throughout the structure and liner. In addition, about 25 optical measurements of structural deformation are made. The Palisades instrumentation is comparable. This amount of data will permit a detailed comparison between design calculations and observed response. The basic structural design and the accuracy of the calculation procedures used by Bechtel was, therefore, verified by these tests. This verification was applicable to the Calvert Cliffs design calculations.

Since the detailed confirmation of the design techniques is available, instrumentation of the Calvert Cliffs structure is not required and no additional confirmation of design techniques is necessary. For these reasons, no provisions for strain gauge instrumentation of the structural members of the Calvert Cliffs Containment Structure are made.

Prior to reactor fuel loading and operation, the integrity of the Containment Structure was demonstrated by a pressure proof test. The post-tensioning and pressure tests permitted verification that the structural response due to the induced loads is consistent with the predicted behavior. This was accomplished by measuring deflection of Containment Structure using taut wires.

The measurement technique required stretching taut wires across the Containment Structure at appropriate elevations and azimuths and around the equipment hatch openings. These displacements were correlated with measurements made on Turkey Point, Oconee, and Point Beach I Containment Structures for verification of structural behavior.

In analyzing the structures to obtain the calculated displacement, the most probable values of material constants were used rather than the highly conservative design values. For example, values of the elastic modulus for concrete were predicted to provide an estimate of its most probable value at the time of the test.

The use of only two meridians for taking measurements during pressure testing is justified as follows:

a. It represents the true cross-section of the cylindrical shell where uniform wall thickness and buttress (thickened wall) sections exist. Other discontinuity areas, such as the equipment hatch, are individually checked for strain measurements.
b. Analytical methods are based on an assumption that the structure is axisymmetric and the material properties assumed for calculation purposes are idealized for derivation of the theories of elasticity. The basic method of analysis is Bechtel's Finite Element Program, CE 316-4 as explained in Section 5.1.3.1. This analysis furnished the predicted strain for this test, assuming the actual structure was perfectly cylindrical with no discontinuities such as buttresses or penetrations and that there were no deviations from axisymmetry of applied forces.
c. The correctness of the predicted strains versus measured strain will not significantly differ by increasing the number of measurements at more than two meridians because the basic assumptions as mentioned in b would be identical.
d. Tests of Containment Structures with similar configuration have demonstrated that the predicted and measured strain values are in good agreement. The applied test procedure and selected points for strain measurements were identical for all tests.

Nevertheless, the Calvert Cliffs Nuclear Power Plant test procedure included additional points to the extent possible to obtain measurements as described in AEC Safety Guide 18, Structural Acceptance Test for Concrete Primary Reactor Containments.

From the previous experience and analytical assumptions, it was expected that agreement would have been between test results and analytical predictions in the following range:

Cylinder at equator	15%
Dome	15%
Bottom slab	25%
Bottom slab - Wall junction	25%

Dome - Wall junction	20%
Around opening	30%
Localized stress concentration	100%

If the measured strains had fallen noticeably beyond the above-mentioned ranges of error, a review and investigation would have been made to determine the cause of such discrepancies.

5.5.1.3 Initial Leakage Test

At the time of the initial leakage test, the design leak-rate was 0.20% by weight of the contained atmosphere in 24 hrs at 50 psig. It has been demonstrated that, with good quality during erection, this is a reasonable requirement. The purpose of these tests is to ensure that leakage through the Containment Structure and associated systems is held below the design leakage rate (Reference 1).

Initial leak-rate tests of the Containment Structure and its penetrations were conducted at pressures of 50 and 100% of the calculated peak pressure, maintaining each pressure for a sufficient length of time to establish the leak-rate. Values of Containment Structure ambient dry bulb temperature and relative humidity were recorded during the test period for correction of data as required.

The preservice leak-rate test equipment consisted of bottled air or nitrogen, pressure regulator and pressure, temperature and flow indicator. Each part's measuring range and accuracy were as follows:

a. Pressure Regulator

   Range: 2000 psig to 50 psig

b. Pressure Indicator

   Pressure gauge: Readout unit, calibration accuracy of 0.015% of reading, readout 100,000 counts = full scale

   Range: 0 psia to 100 psia

   Minimum graduation: 0.1 psia

   Accuracy: 0.1% of full scale

   Repeatability: 0.03% of full scale

   Sensitivity: 0.01% of full scale

c. Temperature Indicator

   Range: 0°F to 125°F

   Accuracy: 0.5°F

   Readability: 0.5°F

d. Flow Indicator (Rotameter)

   Range (dual scale): 87-875 cc/min
   23-230 cc/min

   (air at 70°F and 50 psig)

   Accuracy: ± 2% of maximum flow

The test established the capability of the Containment Structure to contain the pressure for which it was designed at a leak-rate not exceeding that specified in the license application. These data were plotted to establish initial relationships between internal pressure, leak-rate, external pressure, temperature, relative humidity.

5.5.2 POST-OPERATIONAL SURVEILLANCE

5.5.2.1 Leakage Monitoring

The reactor containment and other equipment subjected to containment test conditions are designed to allow periodic leakage rate testing at containment design pressure in compliance with AEC General Design Criteria 52, published in the Federal Register on February 20, 1971. Frequency of the periodic leakage rate test is explained in the Containment Leakage Rate Testing Program.

Periodic leakage-rate tests of the Containment Structure will be conducted to verify its continued leak-tight integrity. The post-operational leakage-rate tests are conducted at an internal pressure between 96% of the peak containment accident pressure and 100% of the containment design pressure. The acceptable leakage rate for the test pressure used is given in the Technical Specifications and in the Containment Leakage Rate Testing Program.

The temporary hatch cover plate on the emergency personnel lock shall be seal-tested prior to use during movement of irradiated fuel within the containment.

Periodically, in accordance with the Containment Leakage Rate Testing Program, a visual inspection of the exposed accessible interior and exterior surfaces of the containment, including the liner plate will be conducted to assure that no corrosion or other visually apparent deterioration has occurred.

The basic steps in conducting leakage-rate tests include the following:

a. Measurements of absolute pressure, temperature and moisture content within the Containment Structure.
b. Verification of the integrated leakage-rate measurement system by the use of precise measurements of a flow causing a change in the weight of air in the containment that is approximately equal to the measured or permissible 24-hr leak.
c. Maintaining pressure between 47.4 and 50 psig for the length of time required by the integrated leakage rate test procedures.
d. Controlling containment temperature between 50°F and 120°F.
e. Obtaining measurement accuracy tolerances within 95% confidence limits, such that the calculated leakage-rate plus the accuracy tolerance is less than the permissible leakage-rate at the appropriate test conditions.

Formulas used in computing the integrated leakage-rate are based on the formulas found in American National Standards Institute/American Nuclear Society 56.8 - 1994, “Containment System Leakage Testing Requirements.” The Type A (primary containment overall leakage), Type B (local leakage at penetrations), and Type C (isolation valves) tests for both pre-service and inservice are discussed in Sections 5.1.8, 5.2.3, and 5.5, the Technical Specifications and the Containment Leakage Rate Testing Program, which include acceptance criteria, corrective action to meet the acceptance criteria, test frequency and duration and requirements for reporting test results.

It was expected that the inservice leakage-rate test equipment will be similar to that for the preservice tests.

5.5.2.2 Surveillance of Structural Integrity

See Appendix 5E for additional surveillances associated with the long-term corrective action plan for addressing vertical tendon corrosion discovered in 1997.

The primary objective of the program for Inservice Inspection of the Containment Structure concrete, tendons, and liner during the lifetime of the plant is to ensure the strength and reliability of the post-tensioning steel and other major components such as stressing washers, shims, and bearing plates. The condition of the containments is monitored by a combination of physical testing and visual examinations performed on a regular schedule as called for by ASME Section XI, Subsections IWE/IWL (ASME XI) and 10 CFR 50.55a as it pertains to the Containment Structures.

During construction, 3 tendons of each type, hoop, dome, and vertical, were constructed with 93 wires in lieu of the standard 90 to provide designated surveillance tendons. However, the current ASME XI program requires that a random selection be made with the number examined specified as a percentage of the total population, with a minimum and maximum, of each type of tendon. This percentage varies with plant age and previous surveillance results. Thus, the original surveillance tendons are now a part of the general population. The Code also requires the designation of a common tendon of each type that is examined at each surveillance.

Under the Regulatory Guide 1.35 testing program that followed the initial tendon surveillance program, the Unit 2 Containment did not undergo tendon lift-off testing. The current ASME XI program now requires that both units undergo comparable inspections with an allowance to shift some examinations between units based on the similarity and timing of their construction. Thus, Unit 2 is now subject to the same tendon surveillance requirements as Unit 1. The selection criteria and examination frequencies as specified in ASME XI.

Because the tendons were initially strength-tested, the inservice inspection program is conducted to monitor the tendons for corrosion and to verify that the force applied by the tendons meets design assumptions. To achieve those goals, the random selection of tendons is visually examined and the corrosion protection grease is sampled. At alternating surveillances, the tendons are force checked via lift-off testing and one tendon of each type is detensioned and a wire is removed for tensile testing. Those tendons are restressed appropriately immediately after the wire is removed.

The lift-off values are compared to predicted values to determine whether the force required at the end-of-plant life will be met.

Any components or values not meeting the acceptance criteria of ASME XI requires scope expansion and/or engineering evaluation.

Visual examinations are conducted over the entire exterior of the containments in accordance with the ASME XI and 10 CFR 50.55a. These examinations are timed and designed to detect any degradation mechanism before it can affect the structural integrity.

Accessible portions of the interior steel liner are visually examined once per inservice inspection period. This examination is to detect any abnormality that could affect the leak tightness of the liner. When necessary, the visual examinations are supplemented with other methods.

Since the Unit 2 containment is a duplicate of Unit 1 design, tendon surveillance has been limited to visual inspection without dismantling load bearing components or the anchorage. End anchorages, adjacent concrete surfaces, and the liner plate are inspected.

5.5.3 REFERENCES

1. Bechtel Corporation, Testing Criteria for Integrated Leakage Rate Testing of Primary Containment Structures for Nuclear Power Plants, BN-TOP-1, Rev. 1, November 1, 1972