APPENDIX B - CONSTRUCTION MATERIAL STANDARDS AND QUALITY CONTROL PROCEDURES

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B.0 CONSTRUCTION MATERIAL STANDARDS AND QUALITY CONTROL PROCEDURES

B.1 CONCRETE STANDARDS

B.1.1 General

All concrete work done conformed to the requirements as cited from the codes, standards, and recommended practices as listed in Table 3.8-2 with the exceptions and additional requirements indicated in this Section B.1. For the restoration of the containment opening following steam generator replacement, current versions of the cited standards and recommended practices listed in the following sections were used. If the referenced standards or recommended practices were no longer in use, appropriate replacement standards or recommended practices were used.

B.1.2 Material Requirements and Quality Control

B.1.2.1 Cement

Portland Cement, Type II, was used and conforms to all applicable requirements of "Specification for Portland Cement" (ASTM C150). Portland Cement, Type I, conformed to all the standard chemical requirements and standard physical requirements listed in Tables 1 and 2 respectively of ASTM C150. Type I cement was used on a limited basis in Category I structures other than the containment.

Qualification Tests preliminary to mix design were performed on every source of cement for conformance with ASTM C150.

The cement supplier furnished certification with each shipment of cement to the project site for the following ASTM tests:

a. ASTM C114, "Chemical Analysis of Hydraulic Cement," including actual Na_2O content and requirements for tricalcium silicate and tricalcium aluminate as specified in Table 1A of ASTM C150,

b. ASTM C109, "Test for Compressive Strength of Hydraulic Cement Mortars" (results were forwarded within 30 days after delivery),

c. ASTM C204, "Tests for Fineness of Portland Cement by Air Permeability Apparatus," and

d. ASTM C266, "Tests for Time of Setting of Hydraulic Cement by Gilmore Needles," or C191, "Tests for Time of Setting of Hydraulic Cement by Vicat Needle."

Control testing was performed for the following ASTM tests, based on a frequency of every 1200 tons:

a. ASTM C114,

b. ASTM C266 or C191,

c. ASTM C151, "Test for Autoclave Expansion of Portland Cement," and

d. ASTM C204.

All cement was stored in accordance with the applicable requirements of Section 2.5.1 of ACI 301, "Specification for Structural Concrete for Buildings."

B.1.2.2 Aggregates

Fine and coarse aggregates conformed to "Standard Specification for Concrete Aggregates" (ASTM C33) and to the following.

a. Size Numbers 57 or 67 were used for grading of coarse aggregates (ASTM C33).

b. Coarse aggregate contained less than 15% (by weight) flat and elongated particles as determined by CRD-C119, "Method of Test for Flat and Elongated Particles in Coarse Aggregate."

Samples of aggregate were obtained in accordance with ASTM D75, "Sampling Aggregates," and the following qualification tests, preliminary to mix design, were performed on each source and type of aggregate proposed for use:

a. ASTM C136, "Sieve or Screen Analysis of Fine and Coarse Aggregates,"

b. ASTM C117, "Materials Finer Than No. 200 Sieve in Mineral Aggregates by Washing,"

c. ASTM C40, "Organic Impurities in Sands for Concrete,"

d. ASTM C87, "Effect of Organic Impurities in Fine Aggregate on Strength of Mortar,"

e. ASTM C88, "Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate,"

f. ASTM C142, "Clay Lumps and Friable Particles in Aggregates,"

g. ASTM C123, "Lightweight Pieces in Aggregate,"

h. ASTM C131, "Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine,"

i. ASTM C235, "Scratch Hardness of Coarse Aggregate Particles,"

j. ASTM C127, "Specific Gravity and Absorption of Coarse Aggregate,"

k. ASTM C128, "Specific Gravity and Absorption of Fine Aggregate,"

l. ASTM C29, "Unit Weight of Aggregate,"

m. ASTM D1411, "Water-Soluble Chlorides Present as Admixes in Graded Aggregate Road Mixes,"

n. ASTM C289, "Potential Reactivity of Aggregates (Chemical Method),"

o. ASTM C295, "Petrographic Examination of Aggregates for Concrete," and

p. CRD-C119.

The following control tests were performed during periods of casting of concrete to ascertain conformance with ASTM C33, "Specifications for Concrete Aggregates," at the frequencies indicated:

a. ASTM C117 and C29 - daily;

b. ASTM C136 and C40 (C87 if C40 failed) - daily;

c. ASTM C566, "Total Moisture Content of Aggregate by Drying" - twice daily;

d. CRD-C119, C142, C123, C235, C127 and C128 are performed monthly during production; and

e. ASTM C131 or C535, "Resistance to Abrasion of Large Size Coarse Aggregate by Use of the Los Angeles Machine," C289, and C88 every 6 months.

If an aggregate sample failed any of these tests, two additional samples were taken immediately and the test for which the original sample did not meet specification requirements was repeated on each. If both samples met requirements, the material was accepted. If one or both of the retests failed, production was halted and Sargent & Lundy was notified, and determined the necessary action required.

Samples for tests were in accordance with ASTM D75, Paragraph 3.3.3, with the following modification: the gradation tests for each source and type of aggregate proposed for use that day were performed on samples collected and blended into one combined sample from four locations in that portion of the stockpile intended for use that day.

Control, handling and storage of aggregates, were in accordance with Section 2.5.2 of ACI 301.

The fine and coarse aggregates used in the concrete mix for restoration of the steam generator replacement project (SGRP) containment opening conformed to ASTM C33. The maximum size of coarse aggregates was 3/8 inch. The qualification tests, prior to mix design, were performed in accordance with the above listed standards (Note: ASTM C235 standard has been withdrawn). In addition, ASTM C1218, "Standard Test Method for Water-Soluble Chloride in Mortar and Concrete," and ASTM C586, "Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregate (Rock Cylinder Method)," tests were also performed.

B.1.2.3 Heavy Weight Aggregate

Heavy weight aggregate conformed to ASTM C637, "Aggregates for Radiation-Shielding Concrete," Sections 5 and 6, except that at the Byron Station a larger percentage of material finer than sieves No. 100 and No. 200 was allowed, based on Section 4.1 of ASTM C637 and actual placing tests. Heavy weight aggregates also conform to the following.

Test Frequency: One complete set of qualification tests of each type of aggregate and one complete test at the time aggregate was delivered at the project site were performed. Sampling was performed in accordance with Paragraph 7.1 of ASTM C637.

B.1.2.4 Fly Ash

Fly ash conformed to the Class C and F mandatory requirements of ASTM C618, "Standard Specifications for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete," except that in Table 1, "Chemical Requirements," the loss on ignition was a maximum of 6%.

Qualification tests preliminary to mix design were performed on every source of fly ash for conformance with the above specification.

Certified material test reports were furnished by the fly ash supplier who certified that delivered fly ash had been tested and did meet the mandatory requirements of ASTM C618, as modified above. This certification included the test results and was supplied with delivery of fly ash for mix designs and with each 2000 tons delivered to the project.

Storage of fly ash was as specified in Section 2.5.1 of ACI 301.

B.1.2.4.1 Fly Ash In Process Testing

ANSI N45.2.5 Table B requires in-process testing of fly ash per ASTM C618 with a frequency of every 200 tons. Fly ash was not used in Braidwood Station concrete, except for the restoration of the containment following steam generator replacement. It was used on a limited basis at Byron Station. In-process testing at Byron Station was performed by the fly ash supplier and by Commonwealth Edison's testing laboratory. Fly ash was tested and certified by the supplier for conformance with ASTM C618 at a frequency of every 2000 tons. The following tests were performed every 2000 tons by the supplier:

a. Loss on ignition,

b. Sulfur trioxide (SO_3),

c. Amount retained on No. 325 sieve,

d. Sum of the oxides (SiO_2 + Al_2O_3 + Fe_2O_3),

e. Moisture content,

f. Pozzolanic activity with cement,

g. Pozzolanic activity with lime,

h. Water requirement,

i. Soundness, and

j. Specific gravity.

The Applicant's testing laboratory tested the fly ash at a frequency of every 200 tons for the following tests:

a. Loss on ignition,

b. Sulfur trioxide (SO_3), and

c. Amount retained on No. 325 sieve.

In-process concrete control testing by the Applicant's testing laboratory at a frequency of 200 tons include chemical and physical tests for which correlation with concrete properties has been established. Any test result that cannot be correlated with concrete properties serves no useful concrete quality control function.

Prequalification tests were performed for every source of fly ash for full compliance with ASTM C618. Once fly ash from a power plant using a specific coal is qualified by ASTM C618, testing for loss on ignition, sulfur trioxide, and the amount retained on No. 325 sieve performed every 200 tons are sufficient to ensure the uniformity of the fly ash.

Uniformity of fly ash can be correlated to concrete quality. When fly ash was used, it was added in the proportion of 20% by weight of cement. Fly ash was not used as a substitute for cement.

B.1.2.5 Admixtures

Air-entraining admixtures conformed to "Specification for Air-Entraining Admixture for Concrete" (ASTM C260), including "Optional Uniformity Requirements" in Section 5. Air-entraining admixtures containing more than 1% chloride ions were not used.

The air entrained admixture supplier furnished certified material test reports which state that the admixture was tested in accordance with ASTM C260 and satisfied both of these above additional requirements. This certification included the manufacturer's statements as described in Sections 4.1, 4.2, and 4.3 of ASTM C260, and also included the results of the following tests performed on a composite sample from each shipment:

a. infrared spectrophotometry,

b. pH value,

c. solid content,

d. chloride ion content, and

e. specific gravity.

Chemical admixtures conformed to "Specification for Chemical Admixtures for Concrete" (ASTM C494). Type A, water-reducing admixtures were permitted, subject to the following requirements:

a. The material was either a hydroxylated carboxylic acid base or a modified salt thereof, or a hydroxylated polymer base.

b. The material was not prepared by the addition of any chloride ions. The supplier certified that the admixture did not contain from all sources more than 1%, by weight, of chloride ions.

c. The supplier furnished certified test results of specific gravity, viscosity, infrared spectrophotometry, pH value and solids content of the material used for the project, establishing the equivalence of materials from the different lots or different portions of the same lot in accordance with Article 4.4 of ASTM C494.

Storage of admixtures was as specified in Section 2.5.5 of ACI 301.

The following admixtures were used in the concrete mix for restoration of the containment opening following steam generator replacement:

a. Air-entraining admixture conforming to ASTM C260 with chloride ions not exceeding 1% (by weight).

b. Water-reducing admixture conforming to ASTM C494, Type A, with chloride ions not exceeding 1% (by weight).

c. High-range, water-reducing admixture conforming to ASTM C494, Type F, with chloride ions not exceeding 1% (by weight).

B.1.2.6 Water and Ice

Mixing water and ice were clean and the maximum content of chloride ion in mixing water did not exceed 500 ppm.

Qualification tests preliminary to mix design were performed to ensure compliance with the requirements specified.

Control testing was performed using the following ASTM tests:

a. ASTM D512, "Chloride Ion in Industrial Water and Industrial Waste Water" - monthly, and

b. ASTM C109, "Compressive Strength of Hydraulic Cement Mortars," C191 and C151 - every 3 months.

B.1.2.6.1 Water and Ice, Chloride Ion Content

ANSI N45.2.5 has no requirement for the chloride ion content in water and ice. ASME Boiler and Pressure Vessel Code, Section III, Division 2, subparagraph CC-2223.1 limits the chloride ion content in water to 250 ppm.

Subsection B.1.2.6 states that the maximum ion content did not exceed 500 ppm. At Byron Station, the maximum chloride ion content in the mixing water does not exceed 250 ppm. At Braidwood Station, the maximum chloride ion content in the mixing water did not exceed 347 ppm with an average content of 300 ppm.

A chloride ion content of 500 ppm is a conservative limit when compared with the limits allowed in ACI 201.2R-77 and in the proposed revision to ACI 301-72. Limiting the chloride content in water is an indirect and easy method to limit the total soluble chloride content in the concrete. In ACI 201.2R-77, it is stated that some forms of chloride are readily soluble and hence, are likely to induce corrosion in the reinforcement. Other chlorides are not likely to induce corrosion. However, the test for soluble chloride is time consuming and difficult to control. ACI 201 committee recommends testing for total chlorides and, when less than recommended maximum, states that the test for soluble chlorides is not required.

In Section 4.5.4 of ACI 201.2R-77 the maximum chloride content in concrete is limited in terms of cement content, concrete exposure and type of construction. The average total chloride content per cubic yard of concrete at Braidwood Station exceeds Byron Station. The total chloride in water, cement and admixtures at Braidwood Station equals 0.025% of the weight of cement. Of this, approximately 59% is provided by the water, 28% by the cement, and 12% by the admixture.

When the limits for soluble chloride in ACI 201 and the proposed revision to ACI 301 are compared with 0.025%, it shows that this content is 2.4 times less than that allowed for prestressed concrete, four times less than that allowed for reinforced concrete in a moist environment exposed to chloride, and six times less than that allowed for reinforced concrete in a moist environment but not exposed to chloride, respectively.

At the Byron/Braidwood Stations, whatever water is in contact with both prestressed and reinforced concrete is neither sea water nor the brackish water present on bridge decks and highways due to winter deicing salt. Therefore, the chloride induced corrosion of embedded metals in this concrete is highly unlikely.

Additionally, the ASME Boiler and Pressure Vessel Code Summer 1980 Addenda, Section III, Division 2, subparagraphs CC-2224.1 and CC-2231.2 were reviewed for conformance. Both Byron and Braidwood Stations conform to these requirements for chloride content in concrete and admixture. For Braidwood Station, the chloride content of the cement paste (cement, admixtures, and water) portion of the concrete is 170 ppm by weight. The chloride content at Byron Station is less.

B.1.3 Concrete Properties and Mix Design

Concrete mix design conformed to ACI 211.1, "Recommended Practice for Selecting Proportions for Normal Weight Concrete," and to ACI 304 Title No. 68-33, "Placing Concrete by Pumping Methods," including Chapter 9 of ACI 304.

Mix properties:

a. Slump - Concrete was proportioned to have a slump of 3 inches ±1 inch at 70°F as determined by ASTM C143, "Slump of Portland Cement Concrete."

b. Air content - Air content conformed to the following requirements as determined by ASTM C231, "Air Content of Freshly Mixed Concrete by the Pressure Mixture":

Nominal maximum size of aggregate, in.	Total air content, %, by volume
3/4	6 ± 1
1	5 ± 1

c. Specified compressive strength: Structural concrete strengths and one fill concrete strength were furnished as follows:

   1. 5500 psi at 91 days,

   2. 3500 psi at 91 days, and

   3. 2000 psi at 28 days (fill concrete).

Fly ash content when used equaled 20% of the weight of cement.

Concrete for restoration of the SGRP containment opening was proportioned to have the following properties:

a. Compressive strength: 5500 psi at 7 days,

b. Slump: 5 inches to 8 inches, and

c. Air content: 6.5 ± 1.5 percent.

B.1.3.1 Trial Mixtures

Trial mixtures having proportions and consistencies suitable for the work were made using at least three different water-cement ratios which produced a range of strengths encompassing those required for the work. All materials including the water were those used at the project site.

For each water-cement ratio, at least three compression test cylinders for each test age were made and cured in accordance with "Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Laboratory" (ASTM C192). They were tested for strength at 7, 28, and 91 days, in accordance with "Method of Test for Compressive Strength of Cylindrical Concrete Specimens" (ASTM C39). From the results of these tests, curves were plotted showing the relationship between water-cement ratios and compressive strength.

Mix design qualification of the concrete for restoration of the SGRP containment opening was performed using the trial batch method described in ACI 301. The mix was designed for a required average strength of 6900 psi (5500 psi plus 1400 psi) at 7 days based on the requirements of ACI 301. A minimum of two water/cementitious material ratios were tested to produce a range of strengths encompassing the required value.

B.1.3.2 Design Mixtures

Until the standard deviation was calculated for each of the mixtures used, the required average strength was determined by adding 1200 psi to the required compressive strengths of 5500 psi and 3500 psi at 91 days.

This required average strength was entered into water-cement ratio strength curves to determine the maximum water-cement ratio.

This water-cement ratio was used with the water requirement reported from trial mixtures for the aggregate size to calculate the minimum cement content.

Adjustments in absolute volume to maintain yield were made by adjusting aggregate amounts while maintaining the sand percentage of the original trial mixture.

B.1.3.3 Adjustment of Design Mixtures

After the accumulation of no less than 30 tests at 91 days of a mix design, these test results were evaluated by statistical methods in accordance with ACI 214 and the standard deviation was calculated. A new required average strength, f_{ave} req. was computed, using the higher of the values computed below:

$$f_{ave} \text{ req.} = f_c' + 1.343\ \sigma$$

$$f_{ave} \text{ req.} = f_c' - 500 + 2.326\ \sigma$$

where:

f_c' = specified compressive strength

σ = standard deviation.

With this new required average strength, the design mixtures procedure was repeated to obtain revised mix proportions using the curve for the water-cement ratio and compressive strength.

If, during the course of construction, statistical surveillance revealed that the required average strength was not achieved, an investigation was performed by Sargent & Lundy to investigate the cause and determine what corrective action was necessary.

The equations presented above for the adjustment of design mixes are the same as those in ACI 318-77 Commentary Section 4.3.1.

These equations are obtained when the proper values of the statistical parameter t, corresponding to the probable frequencies in ACI 318-77 Section 4.7, are used in Equations 4-1a and 4-1c of ACI 214-77 or in Equation 7 of ACI 214-65.

The values given in ACI 318-77 Section 4.3.1 for the required strength, are the results obtained from Equations 4-1a and 4-1c of ACI 214-77 when the higher of the standard deviation values are used.

B.1.3.4 Grout

Grout of proportions similar to the mortar in concrete was determined as follows:

a. A trial mix was calculated. Quantities of fly ash, fine aggregate and admixtures were computed in the same ratio to cement as in the concrete.

b. The trial mixture was performed, and the quantity of water and air entraining admixture required was determined. If water required caused the water-cement ratio of the concrete to be exceeded, cement was added until the original water-cement ratio was restored. Compressive strength of the grout was tested in accordance with ASTM C109.

B.1.3.5 Additional Concrete Testing for Concrete Used in Containment

After the approval of the concrete mixtures, the following tests were performed:

a. Compressive strength at 7, 28, and 91 days (ASTM C39).

b. Static modulus of elasticity at 91 days (ASTM C469, "Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression").

c. Poisson's ratio at 91 days (ASTM C469).

d. Specific gravity at 91 days (ASTM C642, "Specific Gravity, Absorption, and Voids in Hardened Concrete").

e. Coefficient of thermal conductivity at 91 days (CRD-C44, "Calculation of Thermal Conductivity of Cement").

f. Coefficient of thermal expansion at 91 days (CRD-39, "Coefficient of Linear Thermal Expansion of Concrete").

g. Specific heat at 91 days (ASTM C351).

h. Shrinkage strains up to at least 180 days after 7 and 28 days of continuous moist curing, and then drying at 70 ± 2°F and 50% relative humidity (ASTM C157).

i. Creep strain of concrete in compression loaded after 28 and 91 days of continuous moist curing, to a sustained stress of approximately 2500 psi on test specimens drying at 70 ± 2°F and 50% relative humidity and on sealed test specimens (ASTM C512).

The following tests were performed after the concrete mix was approved for the restoration of the containment opening following steam generator replacement:

a. Compressive strength at 1, 7, and 28 days in accordance with ASTM C39. Static modulus of elasticity and Poisson's ratio at 7 and 28 days in accordance with ASTM C469.

b. Creep and shrinkage strain measurements for specimens maintained at 73 ± 3°F and 110 ± 3°F and loaded at the ages of 7 days and 28 days in accordance with ASTM C512.

However, the specific gravity (ASTM C 642), the coefficient of thermal expansion (CRD-C39), the coefficient of thermal conductivity (CRD-C44), and the specific heat (ASTM C351) were not tested to determine these parameters for the following reasons:

These parameters do not vary significantly for concrete mix designs. To demonstrate this, the value of specific heat, thermal conductivity, and coefficient of thermal expansion for the original mix designs are summarized below.

Parameter	Braidwood 28 days	Braidwood 1 year	Byron 28 days	Byron 1 year
Specific Heat (Btu/lb°F)	0.234	0.256	0.237	0.242
Thermal Conductivity (Btu/ft^2/hr°F/in)	14.7	15.1	14.6	14.2
Coefficient of Thermal Expansion	5.82	5.88	5.59	5.92

Based on the small surface area of the containment opening (approximately 600 ft^2) and the small volume of the replaced concrete (approximately 2100 ft^3) in comparison with the total surface area and volume of the containment, the effects of variation (if any) in the value of these parameters are insignificant.

The containment analysis used 150 lb/ft^3 for concrete density and 5.5E-06 for the coefficient of thermal expansion. These values are consistent with the original design and are industry standards.

B.1.3.6 Heavyweight Concrete

Heavyweight concrete mix conformed to Appendix 4 of ACI 211.1, "Recommended Practice for Selecting Proportions for Normal Weight Concrete."

B.1.4 Formwork

All formwork conformed to Chapter 4 of ACI 301 and as hereinafter specified.

Forms for all exposed surfaces conformed to Section 10.2.2, "Smooth Form Finish," of ACI 301.

"Exposed surfaces" as used, meant all formed concrete surfaces exposed to view on completion of work.

All exposed projecting corners of concrete work such as piers, columns, equipment foundations, switchyard foundations, and turbine foundations were beveled.

For exposed surfaces and exposed vertical corners of structures in contact with the ground, the smooth form finish and the vertical bevels were extended 1 foot 0 inch below finish grade.

B.1.5 Joints and Embedded Items

Joints and embedded items conformed to Chapter 6 of ACI 301 including the following:

a. For bonding methods in Sections 6.1.4.1 and 6.1.4.2 of ACI 301, specific approval by the purchaser or its representative was required.

b. Horizontal construction joints in containment walls are cleaned by cutting the concrete surface layer and exposing the aggregate without undercutting. Construction joints in Category I structures were grouted immediately before placement of concrete in accordance with provisions of Section 8.5.3, ACI 301, except that no grout is required on vertical surfaces of walls. Where keys were used, grouting of horizontal joints were not required.

c. Unformed construction joints were protected against loss of water required for curing by application, immediately after completion of construction by one of the following methods:

    1. Application of damp sand or moistened fabrics kept continuously moist until placement of concrete was recommended. Prior to resumption of placement, the curing materials were completely removed from the concrete surface, in accordance with provisions of Section 8.1 of ACI 301.

    2. Application of curing compound containing nonfugitive pigments. Prior to resumption of placement, this surface was completely cleaned by sand blasting, chipping, or jack hammering until no trace of pigment remained.

B.1.6 Bar Placement

Bar placement conformed to the design drawings and to the applicable requirements of Section 7.2 and 7.3 of ACI 318, to Chapter 8, "Placing Reinforcement Bars" of CRSI "Manual of Standard Practice," to Subarticles CC-4340, CC-4350, and CC-4360 in Section III, Division 2 of the ASME Boiler and Pressure Vessel Code, and to the following:

In lieu of Section 7.3.2.1 of ACI 318 and Paragraph 7, Chapter 8 of the CRSI Manual of Standard Practice, the following applied:

a. Clear distance to formed surfaces: For No. 3 through No. 11 bars: ± 1/4 inch for straight bars, ± 1/2 inch for bent bars.

b. For No. 14 and No. 18 bars: ± 1/2 inch for straight bars, ± 1 inch for bent bars.

c. The cover was not reduced by more than one-third of the specified cover, nor to less than 1-1/2 inch for No. 14 and No. 18 bars at interior surfaces.

d. Spacing tolerances between parallel bars: For No. 3 through No. 18 bars; ± 2 inches.

B.1.7 Bending or Straightening of Bars Partially Embedded in Set Concrete

Bending or straightening of bars partially embedded in set concrete was not permitted except in isolated cases where corrective action or a field change was required and specifically approved by Sargent & Lundy.

The bend diameter conformed to the requirements listed below.

The beginning of the bend was not closer to the existing concrete surface than the minimum diameter of bend.

Bars No. 3 through No. 5 were cold bent once. Preheating was required for subsequent straightening or bending. Bars No. 6 and larger were preheated for any bending.

MINIMUM DIAMETER OF BEND

Bar Size	Minimum Diameter of Bend
No. 3 through No. 8	6 bar diameters
No. 9, No. 10, No. 11	8 bar diameters
No. 14, No. 18	10 bar diameters

When required, preheating prior to bending or straightening was performed in accordance with the following:

a. Preheating was applied by methods which do not harm the bar material or cause damage to the concrete.

b. The preheat was applied to a length of bar at least equal to five bar diameters in each direction from the center of the portion to be bent or straightened, except that preheat was not extended below the surface of concrete. To avoid splitting the concrete, the temperature of the bar at the concrete interface did not exceed 500°F.

c. The preheat temperature was 1100°F to 1200°F.

d. The preheat temperature was maintained until bending or straightening was completed.

e. The preheat temperature was measured by temperature measurement crayons or contact pyrometer.

f. Precautions were taken to avoid rapid cooling of preheated bars. Water was never allowed to be used for cooling.

All bent and straightened bars were visually examined for cracks. Visual examination of preheated bars was performed after the bars reached ambient temperature.

Bars straightened after a first bend were checked for cracking using liquid penetrant method with the following sequence:

a. The first three straightened bars.

b. One out of the next and each subsequent unit of ten straightened bars.

c. All bars with subsequent straightening or bending and all bars that failed visual examination were checked using liquid penetrant method.

d. Concrete surface was visually examined for any damage due to the preheating, bending or straightening operations.

Bars exhibiting transverse cracks were properly replaced.

B.1.8 Batching, Mixing, Delivery, and Placement

Batching, mixing, and delivery equipment, including their operation, conformed to the requirements of ASTM C94, Articles 7, 8, and 9. To the extent applicable the placement complied with the requirements of the criteria for concrete placement in Category I Structures.

B.1.9 Witness and Inspections

Prior to production, the testing agency inspected batch plant, stationary and truck mixers to verify conformance with B.1.8 above. After the concrete batch plant and mixers were placed in production, the testing agency inspected the production facilities to verify that concrete was produced in accordance with Section 7.2 of ACI 301.

B.1.10 Concrete Placement

Air Content: The allowable limits of air content was as indicated in Table B.1-1, except as noted in Subsection B.1.3 for the restoration of the containment opening following steam generator replacement.

Slump: Concrete slump was within the allowable limits as indicated in Table B.1-2, except as noted in Subsection B.1.3 for the restoration of the containment opening following steam generator replacement.

Concrete Placing Temperature: Concrete placing temperature conformed to the criteria given in Table B.1-3.

Concrete placement conformed to the applicable requirements of Sections 8.1, 8.2, and 8.3 of ACI 301 and Chapter 6 of ACI 304 and the following:

a. All concrete was placed in a continuous and uninterrupted operation in such manner as to form a monolithic structure, the component parts of which were integrally bonded together. No concrete was deposited which had been segregated, contaminated by foreign materials, or considered nonplastic.

b. Concrete was considered plastic if either of the following requirements were met:

    1. If immediately before recommencing concrete placement a vibrator spud suspended vertically was applied to the concrete surface and it penetrated at least 6 inches into the concrete during 15 seconds of application, the concrete was considered plastic, if not, the concrete was considered nonplastic.

    2. If the temperature of the concrete in place and the time interval between placement of successive batches was within the following temperature and time limits:

Concrete Temperature	Time Limit
80°F	35 minutes
70°F	40 minutes
60°F	55 minutes
50°F	65 minutes

c. If concrete was found to be nonplastic, concrete was placed in accordance with requirements of Section 8.5.3 of ACI 301, except that no dampening was required before the application of grout.

d. All concrete was deposited in the forms after introduction of mixing water to cement and aggregates, within the following time limits:

Concrete Temperature	Time Limit
Below 60°F	2-1/2 hours
61°F to 70°F	2 hours
Above 70°F	1-1/2 hours

The above limitations were waived if the concrete was within the allowable limits for slump, provided it could be transported and placed without addition of water to the batch. Otherwise the concrete was rejected.

Concrete that was beyond the allowable limits for slump and air content but within the extreme limits as placed in the forms, was placed within a 1-1/2 hour time limit. Otherwise the concrete was rejected.

e. Hot weather concreting conformed to Section 12.3.2 of "Recommended Practice for Hot Weather Concreting," Section 12.3.2 of ACI 301, except as modified below:

1. Adequate provisions were made against plastic shrinkage cracking, as specified in Chapter 2 of ACI 305, "Recommended Practice for Hot Weather Concrete."

ANSI N45.2.5 Section 4.5.2 requires adherence to specified requirements for hot weather concreting practice as given in ACI 305.

ACI 305-72 Section 2.2.1 states that:

"For the more massive type of heavy construction, i.e., those whose dimensions are such that significant heat is generated through hydration of cement, a temperature of 60°F (16°C) or even lower would be desirable."

Table B.1-3 allows minimum concrete temperatures up to 70°F when air temperature is above 45°F and up to 75°F when air temperature is below 45°F.

The recommendation in ACI 305-72 applies to more massive structures than those found at Byron and Braidwood Stations. The containment mat foundation is the most massive concrete element and it is much less massive than concrete placements for dams. In addition, midwest hot weather concreting conditions are mild when compared with hot weather conditions in southern regions for which the recommendations in ACI 305 were intended.

ACI 305-77 Section 2.2.2 does not contain specific concrete temperature limits, but states that:

"It is impractical to recommend a maximum limiting temperature because circumstances vary widely. Accordingly, the committee can only point out the effects of higher temperatures in concrete and advise that at some temperature, probably between 75°F and 100°F there is a limit that will be found to be most favorable for best results in each hot weather operation, and such a limit should be determined for the work."

The limits in Table B.1-3 are determined to be conservative for the construction of nuclear power plants.

f. Cold Weather Concreting: Cold weather concreting conformed to the following provisions:

   1. Concrete was placed at a temperature within the allowable limits indicated in Table B.1-3 and in accordance with the minimum temperature for the time indicated in Table 1.4.2 of ACI 306, "Recommended Practice for Cold Weather Concreting," and upon removal of heat, the maximum temperature drop conformed to Table 1.4.1, Line 17 of ACI 306.

g. Where early strength was critical, as indicated by Sargent & Lundy, concrete was maintained at the minimum allowable temperatures indicated in Table B.1-3 for the period of time indicated in Table 5.1.7 of ACI 306.

h. If construction temperature records indicated the possibility of a portion of the concrete in place being exposed to freezing temperatures prior to elapse of curing times indicated in Table 1.4.2 of ACI 306, or during placement, an investigation with concrete test hammer, drilled cores, or soniscope was conducted.

Concrete placement for the containment opening restoration following steam generator replacement conformed to the applicable requirements of ACI 301 and 304R.

B.1.11 Concrete Control Tests

Concrete testing and sampling frequencies conformed to Tables B.1-4 and B.1-5. Allowable limits conformed to Tables B.1-1, B.1-2, and B.1-3.

Concrete samples were obtained at truck chutes, except samples from pumped concrete which were obtained at point of discharge from the pump. Samples were obtained in accordance with ASTM C172, except that when a sample was secured by diverting truck chute or pipe discharge into wheelbarrow, no compositing was required; and when central mixed concrete was delivered, the sample was taken from any portion of the truck discharge.

Each time sampling commenced, requirements for normal sampling as defined in Table B.1-4 were followed.

All normal samples were randomly selected.

When a concrete sample was taken from a truck as concrete was being discharged, discharge from the truck was immediately resumed while concrete was being tested.

If results from tests for slump, temperature, or air content were beyond the allowable limits, placement continued for the next five loads providing test results were not beyond the extreme limits and tightened sampling was instituted.

For tightened sampling, samples were taken from the next available truck whether or not its discharge had begun. Discharge from this truck was resumed immediately after the sample was taken. If test results were beyond the allowable limits, discharge from this truck was discontinued and a sample was taken from the next available truck. This may have continued until five consecutive loads outside the allowable limits had been tested at which time concrete placement was discontinued until corrections were made. If two consecutive samples were tested within the allowable limits, normal sampling was resumed.

The required test specimens from each sample were molded and cured in accordance with ASTM C31.

B.1.11.1 Fresh Concrete Testing

Table B of N45.2.5 requires that the first batch produced every day be tested for slump, air content, and temperature.

Table B.1-5 requires that the first batch of concrete used in the containment is tested for slump, air content, and temperature. For other safety-related structures, first batch testing is not required.

Testing the first batch is intended to control overnight variations in the moisture content of aggregate, variations in the concrete materials and errors in the concrete mix proportions. Since the batch plant bins and silos are usually kept full during concrete production, the materials used in the next day first batch are the materials already in the plant from the preceding day of production. Segregation, contamination, and degradation in properties of the aggregate used in the first batch of the next day are not different from those during the previous day. Therefore, testing of the first batch of concrete will not be of any significance in controlling the quality of concrete.

Experience has shown that some variations in slump, air content, and temperature may occur several batches after production is started. These variations are related to material transition from the materials left in the batch plant bins and silos overnight to those materials loaded after overnight materials are used in concrete production.

Concrete testing, sampling, and allowable limits for the restoration of the containment opening following steam generator replacement were as follows:

Concrete was sampled and tested in accordance with ASTM C94. Samples were taken at the point of placement. If the slump, air content, or temperature fell outside the limits specified, an additional test was made immediately on another portion of the sample. In the event of a second failure, the concrete was rejected. Tests were performed at the beginning, middle, and the end of the placement.

Allowable limits:

Slump:	Working Limit 5 inches to 7 inches; rejection limit 8 inches,
Air content:	5% (± 1.5%), and
Temperature:	between 45°F and 90°F.

Tests:

Slump:	ASTM C143,
Air content:	ASTM C173 or ASTM C231, and
Temperature:	ASTM C1064.

B.1.12 Evaluation and Acceptance of Fresh Concrete

Test results on fresh concrete were in accordance with the requirements in Tables B.1-1, B.1-2, and B.1-3.

Concrete which had set was not retempered but discarded.

Concrete was rejected for remixing or wasting if any or all the following conditions existed:

a. Time limitations after introduction of water to cement were exceeded.

b. Five consecutive trucks or batches remained on tightened inspection in Subsection B.1.11.

c. Temperature, slump, or air content was beyond the extreme limits, as listed in Tables B.1-1, B.1-2, and B.1-3.

B.1.13 Evaluation and Acceptance of Concrete Compression Results

The strength level of concrete was considered satisfactory if the following two criteria were satisfied when using the standard deviation from at least 30 consecutive strength tests representing similar concrete, and conditions of concrete being evaluated:

a. A probability of not more than 1 in 100 that an average of three consecutive strength tests was below specified strength.

b. A probability of not more than 1 in 100 that an individual strength test was more than 500 psi below the specified strength.

Methods in ACI 214 were used in concrete evaluation along with the above criteria.

The above criteria was considered satisfied if either:

a. The average of all sets of three consecutive strength test results at 91 days equaled or exceeded the specified compressive strength of the concrete and no individual strength test result fell below the specified compressive strength by more than 500 psi, or

b. The average compressive strength, f_{ave}req., conformed to the following two expressions:

$$f_{ave}\text{req.} \geq f_c' + 1.343\ \sigma$$

$$f_{ave}\text{req.} \geq f_c' - 500 + 2.326\ \sigma$$

where:

f_c' = specified compressive strength

σ = standard deviation.

B.1.13.1 <u>In-Process Concrete Compressive Testing</u>

ANSI N45.2.5 Table B requires that two cylinders for 28-day strength tests be taken every 100 yd^3 for each class of concrete. UFSAR Table B.1-4 requires six standard cylinders for compressive testing be prepared from concrete samples taken every 150 yd^3 of concrete placed in Category I structures other than the containment. Two cylinders each are tested for compressive strength at 7, 28, and 91 days. Concrete acceptance is based on the 91-day result, however, the 7- and 28-day results were used to monitor the compressive strength development during concrete production. Concrete testing frequency for the containment conforms to the ANSI Standard.

ACI 349-76, "Code Requirements for Safety-Related Concrete Structures," establishes a compressive strength test frequency of one for every 150 yd^3 of concrete placed for safety-related structures other than the containment. Section 4.3.1 of ACI

349 allows an increase in the number of cubic yards representative of a single test by 50 yd^3 for each 100 psi lower than a standard deviation of 600 psi. Table CC-5200-1 of the Summer 1981 Addenda of the ASME Boiler and Pressure Vessel Code, Section III, Division 2, allows a testing frequency of every 200 yd^3 if the average strength of at least the latest 30 consecutive compressive strength tests exceed the specified strength f_c' by an amount expressed as:

$$f_{cr} = f_c' + 1.419\,(f_c' / 8.69)$$

At Byron/Braidwood Stations, the average compressive strength consistently exceeded this f_{cr} for all the concrete placed.

Concrete compressive strength testing and sampling for the restoration of the containment opening following steam generator replacement was as follows:

One set of cylinders was made at the beginning, middle, and end of the concrete pour. Two cylinders each were tested at 1, 7, and 28 days.

B.1.14 Consolidation of Concrete

Consolidation of concrete conformed to requirements in Section 8.3.4 of ACI 301, and the following:

a. All concrete was consolidated by sufficient vibration so that concrete was worked around reinforcement, around embedded items, and into corners of forms, eliminating air or stone pockets.

b. When a layer of concrete was being consolidated, the vibrator spud penetrated at least 6 inches into the previously consolidated layer.

c. Spacing of vibrator insertions and withdrawals caused overlapping "spheres of influence," generally at about 18 inch spacing.

d. Vibrators were not used to effect horizontal movement of concrete.

e. If in the opinion of the inspector, segregation was occurring prior to adequate consolidation, adjustment of mixture or pattern of vibration was considered.

f. Internal vibrators used in the work had a minimum frequency of 8000 vibrations per minute.

B.1.15 Concrete Finishes

Concrete finishes for all unformed surfaces conformed to the finishes indicated on the drawings and to Sections 11.7, 11.8 and 11.9 of ACI 301 and to the following addition to ACI 301:

a. Section 11.7.1: Brooming exposed some of the aggregate and scored the surface to provide mechanical bond for the separate finish.

b. Section 11.8.1: A scratch finish was used for the top of turbine and equipment foundations and top of concrete duct runs.

c. Section 11.7.2: Spreading of cement or a cement-sand mixture directly on top of concrete was not permitted. The finish surface was not marked off in areas or scored in any manner.

d. Section 11.8.2: A float finish was used for the top of concrete walls, floors of tunnels, crib houses, manholes, sump pits, elevator pits, valve pits and miscellaneous pits.

e. Section 11.8.3: A troweled finish was used for floors, stair treads and for the top surface of curb, piers, pads, pedestals, switchyard foundations and other outdoor equipment foundations where top surfaces were exposed after completion of the work.

f. Section 11.7.4: Strokes were square across the surface and made so as to produce regular scoring without tearing the surface or exposing aggregate. Scoring ran transverse to the direction of traffic.

g. Section 11.8.4: This finish was used for driveways. This finish was used for other surfaces only if specifically indicated.

For floor surfaces covered with chemical-resistant floor the finish surface was dropped 1/4 inch so that the chemical-resistant finish was flush with adjacent floor areas.

B.1.16 Curing and Protection

Curing and protection conformed to the requirements of Chapter 12 in ACI 301 and the following:

a. Subsections 12.2.1.1 through 12.2.1.6 and 12.2.2 of ACI 301 did not apply.

b. Where forms were stripped before completion of specified curing period, curing compound was applied immediately after completion of specified surface treatment.

c. Prior to initial use of specified compounds, the manufacturer's technical representative visited the jobsite and personally gave instructions on the correct use of materials.

d. To control membrane thickness, compounds were applied at the rate of approximately 300 ft^2/gal, unless otherwise instructed by manufacturer.

e. Curing was continued for not less than the minimum periods specified in Section 12.2.3 of ACI 301 before applying any other surfacing or before opening to traffic.

Regulatory Guide 1.94, in effect at the time of construction, references Regulatory Guide 1.55 "Concrete Placement in Category I Structures" which endorses the use of ACI 301.

Items (a) and (b) above take exception to the portion of ACI 301-72 Section 12.2.2 requirement that reads "Moisture loss from surfaces placed against wooden forms or metal forms exposed to heating by the sun shall be minimized by keeping the forms wet until they can be safely removed."

The practice of wetting the forms is primarily intended for hot and dry weather conditions typical of arid regions and especially for thin members where wooden forms can easily desiccate. The plastic impregnated plywood forms used in the Byron and Braidwood Stations reduce the moisture loss to minimum regardless of being exposed to heating by the sun. Also, the midwest summers are humid and sun radiation is not as intense as in arid regions for which the provisions in ACI 301 were intended. Furthermore, thin concrete sections exposed to a hot and dry environment do not exist in concrete structures for nuclear power stations.

The concrete for the restoration of the containment opening following steam generator replacement was cured and protected in accordance with ACI 305R, 306R, and 308.

B.1.17 Preplaced Aggregate Concrete

Preplaced aggregate concrete conformed to provisions of Chapter 7, "Preplaced Aggregate Concrete" of ACI Standard 304, "Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete," and to the following:

a. Time of efflux for the premixed grout was in the range of 20 to 24 seconds when measured immediately after mixing in accordance with CRD-C79, "Flow of Grout Mixtures (Flow-Cone Method)," and

b. The preplaced aggregate concrete test specimens made in accordance with CRD 84 attained a strength of 5500 psi in 91 days.

B.1.18 Evaluation and Acceptance of Concrete

The evaluation and acceptance of concrete was accomplished in conformity to Chapters 17 and 18 of ACI 301.

TABLE B.1-1

AIR CONTENT

COARSE AGGREGATE		ALLOWABLE LIMITS TOTAL AIR CONTENT (VOL.) %			
ASTM C 33	NOMINAL MAXIMUM SIZE IN COARSE AGGREGATE (in.)	FREEZING AND THAWING RESISTANCE REQUIRED		FREEZING AND THAWING RESISTANCE NOT REQUIRED	
		Allowable Limits	Extreme Limits	Allowable Limits	Extreme Limits
8	3/8	7 to 9	6 to 10	3 to 9	3 to 10
67	3/4	5 to 7	4 to 18	2 to 7	2 to 8
57	1	4 to 6	3 to 7	1.5 to 6	1.5 to 7

TABLE B.1-2

LIMITS FOR SLUMP

CONCRETE TEMPERATURE AS PLACED (°F)	ALLOWABLE LIMITS (in.)		EXTREME LIMITS (in.)	
	Minimum	Maximum	Minimum	Maximum
Below 55	2	5	1	6.0
Between 55 and 64	2	4.5	1	5.5
Between 65 and 74	2	4	1	5.0
Between 75 and 85	1.5	3.5	1	4.0

TABLE B.1-3

PLACING TEMPERATURE

Exposed concrete face(s) normal to the thickness of the pour		ALLOWED LIMITS FOR CONCRETE TEMPERATURE AS PLACED (°F)			EXTREME VALUES FOR CONCRETE TEMPERATURE AS PLACED (°F)		
		Thin Section	Moderately Massive Section	Massive	Thin Section	Moderately Massive Section	Massive
One face exposed		≤12	12 to 48	>48	≤12	12 to 48	>48
Two opposite faces exposed		≤18	18 to 72	>72	≤18	18 to 72	>72
	Between 90 and 81	Max. 80	Max. 75	Max. 70	Max. 85	Max. 80	Max. 75
TEMPERATURE OF AIR SURROUNDING CONCRETE (°F)	Between 80 and 46	Max. 90	Max. 80	Max. 70	Max. 90	Max. 85	Max. 75
	Between 45 and 26	Max. 90 Min. 55	Max. 80 Min. 50	Max. 75 Min. 45	Max. 90 Min. 50	Max. 85 Min. 45	Max. 80 Min. 40
	Between 25 and 0	Max. 90 Min. 60	Max. 80 Min. 55	Max. 75 Min. 50	Max. 90 Min. 55	Max. 85 Min. 50	Max. 80 Min. 45

TABLE B.1-3 (Cont'd)

Notes:

1. No concrete was poured when surrounding air in contact with the concrete was below 0°F.

2. In all cases subsequent freezing of concrete was prevented by providing the protection recommended in Table 1.4.2 of ACI 306.

3. Since metal deck and noninsulated formwork do not prevent heat dissipation significantly, concrete surfaces in contact with them were considered as having exposed faces.

4. When concrete was placed at a temperature exceeding 70°F, cement was added and mix adjusted if water-cement ratio exceeded that of the mix design. In computing water-cement ratio, total water available as mixing water in concrete from whatever source was considered. Adjusted mix proportions, including total water available, were shown in the inspector's report and were reported with the strength test results.

TABLE B.1-4

CONCRETE COMPRESSION TESTING

TYPE	TEST	ASTM	CONTAINMENT*			CATEGORY I OTHERS		
Normal Sampling for strength of concrete for total yards of concrete in each continuous placement			Number of Samples	Number of Cylinders	Testing of Cylinders	Number of Samples	Number of Cylinders	Testing of Cylinders
≤500 yd^3	Compression Cylinder Compressive Strength	C 31 C 39	One (1) each from every 100 cubic yards or each day's placement if less than 100 cubic yards	Six (6) required from each Sample	Tested at 7, 28 and 91 days	One (1) each from every 150 cubic yards or each day's placement if less than 150 cubic yards	Six (6) required from each Sample	Tested at 7, 28 and 91 days
500 yd^3 to 2000 yd^3	Compression Cylinder	C 31	One (1) each from every 100 cubic yards	Six (6) required from every even sample (Example 2,4,6,8, etc.	Tested at 7, 28 and 91 days	One (1) each from every 150 cubic yards	Six (6) required from every even sample (Example 2,4,6,8, etc.)	Tested at 7, 28 and 91 days
	Compressive Strength	C 39		Two (2) required from every odd sample (Example 1,3,5,7, etc.)	Tested at 91 days		Two (2) required from every odd sample (Example 1,3,5,7, etc.)	Tested at 91 days

TABLE B.1-4 (Cont'd)

TYPE	TEST	ASTM	CONTAINMENT*			CATEGORY I	OTHERS	
			Number of Samples	Number of Cylinders	Testing of Cylinders	Number of Samples	Number of Cylinders	Testing of Cylinders
>2000 yd^3	Compression Cylinder	C 31	One (1) each from every 100 cubic yards	Six (6) required from every third Sample (Example 3, 6,9,12, etc.)	Tested at 7, 28 and 91 days	One (1) each from every 150 cubic yards	Six (6) required from every third Sample (Example 3, 6,9,12, etc.)	Tested at 7, 28 and 91 days
	Compressive Strength	C 39		Two (2) required from re-maining Samples (Ex-amples 1,2, 4,5,7,8, etc.)	Tested at 91 days		Two (2) required from remaining Samples (Ex-amples 1,2, 4,5,7,8, etc.) etc.)	Tested at 91 days

*External Concrete: Reactor cavity, tendon tunnel, and containment basemat, shell, and dome.

TABLE B.1-4 (Cont'd)

TYPE	TEST	ASTM	CATEGORY II Number of Samples	Number of Cylinders	Testing of Cylinders
Normal sampling for strength of concrete for total yards of concrete in each continuous placement of ≤ 500 yd^3	Compression Cylinder Compressive Strength	C 31 C 39	One (1) each from every 200 cubic yards or each day's placement if less than 200 200 cubic yards	Six (6) required from each Sample	Tested at 7, 28 and 91 days
500 yd^3 to 2000 yd^3	Compression Cylinder	C 31	One (1) each from every 200 cubic yards	Six (6) required from every even Sample (Example 2,4,6,8, etc.)	Tested at 7, 28 and 91 days
	Compressive Strength	C 39		Two (2) required from every odd Sample (Example 1,3,5,7, etc.)	Tested at 91 days
> 2000 yd^3	Compression Cylinder	C 31	One (1) each from every 200 cubic yards	Six (6) required from every third Sample (Example 3,6,9,12, etc.)	Tested at 7, 28 and 91 days
	Compressive Strength	C 39		Two (2) required from remaining Samples (Example 1,2,4,5,7,8, etc.)	Tested at 91 days

TABLE B.1-5

CONCRETE TESTING

TYPE	TEST	ASTM	CATEGORY I: CONTAINMENT*	CATEGORY I: OTHERS	CATEGORY II
Fresh Concrete, Normal Sampling	Slump Air Content Temperature	C 143 C 173 C 231	First batch placed each day and for each 50 yd^3 placed.	For each 50 yd^3 of concrete, or for each day's placement, if less than 50 yd^3.	
	Unit Weight/ yield	C 138	Daily during production		Not Required
	Mixer Uniformity	C 94	Initially and every 6 months		Not Required
Fresh Concrete Tightened Sampling	Slump Air Content Temperature	C 143 C 173 C 231	When tests on normal samples showed measurement of a concrete property temperature, slump, or air content out of allowable limits but within the extreme values, an Additional Sample was taken from chute of the next available truck. If measurement of this additional sample showed this property to be within allowable limits, and deviations were not directly attributable to the transport from the truck chute to the forms, this truck load was placed. If not within allowable limits a second additional sample was then taken from the next available truck and tested. This procedure was continued until tests on two successive additional samples had indicated that the concrete properties were within allowable limits. Normal sampling was then resumed.		

*External Concrete: Reactor cavity, tendon tunnel, and containment basemat, shell, and dome.

TABLE B.1-6

GRADATION OF HEAVYWEIGHT AGGREGATE

Fine Aggregate:* Sieve Size	Spec. Required
3/8 in.	100
#4	75 - 95
#8	55 - 85
#16	30 - 60
#30	15 - 45
#50	10 - 30
#100	5 - 15

Coarse Aggregate:* Sieve Size	Spec. Required
1 in.	100
3/4 in.	90 - 100
1/2 in.	--
3/8 in.	20 - 55
#4	2 - 15
#8	0 - 8

*Fine Aggregate: 10% of the material passing the 3/8-inch sieve was allowed to pass the No. 200 sieve if the material passing the No. 200 sieve was shown to be essentially free of clay or shale.

B.2 REINFORCING STEEL

B.2.1 Requirements for Category I Materials

Reinforcing bars for all Category I structures were Grade 60 deformed bars tested in accordance with criteria in NRC Regulatory Guide 1.15 for "Testing of Reinforced Bars for Category I Concrete Structures." They met the requirements of ASTM A615, "Specifications for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement," with the following modifications. Paragraphs 4.2, 7.3, 8.3 and all of Sections 9 and 10 as indicated below were used in lieu of the same parts as specified in A615.

a. 4.2 The chemical composition thus determined was transmitted to Purchaser or his representative.

b. 7.3 The percentage of elongation for bars Nos. 3 through 11 was as prescribed in Table 2.

c. For bars Nos. 14 and 18, the minimum elongation in 8 inches (full-section specimens) was 12%.

d. 8.3 Bars of size Nos. 14 and 18 were bend tested as required below in Section 9.3.

e. 9. Test Specimens

   9.1 All tension test specimens were full-section of the bar as rolled and randomly sampled.

   9.1.1 The test procedures were in accordance with ASTM A-370, "Methods and Definitions for Mechanical Testing of Steel Products."

   9.1.2 Delete.

   9.2 The unit stress determinations on full size specimens were based on the nominal bar cross-sectional area as in Table 1.

   9.3 The bend test specimen was full-section of the bar as rolled. The pin diameter for the 90° Bend Test was equal to 10d for Bars Nos. 14 and 18.

f. 10. Number of Tests.

   10.1 At least one specimen from each bar size was tested for each 50 tons or fraction thereof, of the reinforcing bars that were produced from each heat.

   10.2 Testing included both tension tests and bend tests.

10.3 If any test specimen developed flaws, it was discarded and another full-section specimen of the same size bar from the same heat substituted.

10.4 If any of the tensile properties of one out of the total number of test specimens corresponding to a heat was less than that specified in Section 7 as modified herein but was greater than the limits shown below, retest was allowed:

	Grade 60
Tensile strength, psi	83,000
yield stress, psi	55,000
Elongation in 8 inches, percent Bar no.	
3, 4, 5, 6	6
7, 8, 9, 10, 11	5
14, 18	9

10.4.1 The retest consisted of at least two additional full-section tensile tests on samples of the same bar size and heat fraction.

10.4.2 Each one of the additional test specimens and the average of all of the test specimens corresponding to the same bar size for this heat, (including the original one) met the requirements of Section 7 of ASTM A615, as modified herein.

10.5 If the original test failed to meet the limits indicated in Paragraph 10.4, or if any tensile or bending property of specimens retested in accordance with Paragraphs 10.4.1 and 10.4.2 did not meet the requirements of Section 7 of ASTM A615, as modified herein, that material was rejected.

10.6 If any tensile property of the tension test specimen was less than that specified in Section 7 of ASTM A615, as modified in Paragraph 10.4, and any part of the fracture was outside the middle third of the gauge length, as indicated by scribe scratches marked on the specimen before testing, a retest was permitted.

All reinforcing was tagged or marked in a manner to ensure traceability to the Certified Material Test Report (CMTR) during production, fabrication, transportation and storage.

Traceability for all reinforcing bars was by the original heat number.

Traceability of all reinforcing was completed up to the placing of the reinforcing, which was considered as the last hold point for the bars.

B.2.2 Reinforcing Bar Fabrication

Fabrication for all reinforcing bars conformed to the requirements in Chapter 7 of CRSI "Manual of Standard Practice" and to the following:

a. Bar ends for bars which were spliced using Cadweld procedures were checked for clearance after shearing, using a test sleeve with a standard Cadweld sleeve.

B.2.3 Cadweld Splicing

Splices in reinforcing bar sizes No. 11 and smaller were lapped in accordance with ACI 318, "Building Code Requirements for Reinforced Concrete," or Cadweld spliced. Bar sizes No. 14 and No. 18 were Cadweld spliced. The splice was designed to develop the specified minimum ultimate strength of the reinforcing bar.

B.2.3.1 Qualification of Operators

Prior to production splicing, each Cadweld operator prepared two qualification splices for each position used in his work. These were tested and met the joint acceptance standards for workmanship, visual quality, and minimum tensile strength.

B.2.3.2 Procedure Specifications

All joints were made in accordance with the manufacturer's instructions, "Cadweld Rebar Splicing," plus the following additional requirements:

a. A manufacturer's representative, experienced in Cadweld splicing of reinforcing bars, was required to be present at the jobsite at the outset of the work to demonstrate the equipment and techniques used for making quality splices. He was present for the first 25 production splices to observe and verify that the equipment was being used correctly and that quality splices were being obtained. For the restoration of the steam generator replacement containment opening, the manufacturer's representative was present for a minimum of the first 10 production splices. The Cadweld manufacturer furnished the Certified Material Test Report for each lot of splice sleeve material delivered. This report included the physical and chemical properties of the sleeve material. The splice sleeves, exothermic powder, and graphite molds were stored in a clean dry area with adequate protection from the elements to prevent absorption of moisture.

b. Each splice sleeve was visually examined immediately prior to use to ensure the absence of rust and other foreign material on the inside diameter surface, and to ensure the presence of grooves in the ends of the splice sleeve.

c. The graphite molds were preheated with an oxyacetylene or propane torch to drive off moisture at the beginning of each shift when the molds were cold or when a new mold was used.

d. Bar ends to be spliced were power-brushed to remove all loose mill scale, loose rust, concrete, and other foreign material. Prior to power-brushing, all water, grease, and paint were removed by heating the bar ends with an oxyacetylene or propane torch.

e. A permanent line was marked 12 inches back from the end of each bar for a reference point to confirm that the bar ends were properly centered in the splice sleeve. In those cases where the 12 inch gauge length was not practical, different gauge lengths were used, provided they were properly documented.

f. Immediately before the splice sleeve was placed into final position, the previously cleaned bar ends were preheated with an oxyacetylene or propane torch to ensure complete absence of moisture.

g. Special attention was given to maintaining the alignment of sleeve and pouring basin to ensure a proper fill.

h. The splice sleeve was externally preheated with an oxyacetylene or propane torch after all materials and equipment were in position. Prolonged and unnecessary overheating was avoided.

i. Each splice was examined by the operator prior to forming to ensure compliance with all requirements. All completed splices and sister test specimens were stamped with the operator identification mark.

B.2.3.3 Visual Examination

All completed splices (including the sister test specimens) were inspected to ensure compliance with the visual examination acceptance standards. Splices that failed any requirement were rejected and replaced and not used as tensile test samples.

All visual examinations on completed splices were performed only after the splices had cooled to ambient temperature. The visual examination acceptances standards were:

a. Filler metal was visible at the end(s) of the splice sleeve and at the tap hole in the center of the sleeve. Except for voids, the filler metal recession was not more than 1/2 inch from the end of the sleeve.

b. Splices did not contain slag or porous metal in the tap hole or at the end(s) of the sleeves. When in doubt as to whether filler metal or slag was in the tap hole, the riser was broken with a punch or file, filler metal shines while slag remains dull. If slag was found, the inspector removed slag at the tap hole and searched for filler metal. This requirement was not cause for rejection unless the slag penetrated beyond the wall thickness of the sleeve.

c. A single shrinkage bubble present in the tap hole was distinguished from general porosity and it was not cause for rejection.

d. The total void area at each end of the sleeves did not exceed the following limits (for splicing bars up to Grade 60):

    1. for No. 18 bars - 2.65 in^2

    2. for No. 14 bars - 2.00 in^2

    3. for No. 11 bars - 1.5 in^2

    4. for No. 10 bars and splice Catalog Number RBT-10101 (H) - 1.58 in^2

    5. for No. 5 bars - 0.53 in^2

e. The distance between the gauge lines for a type "T" splice was 24-1/4 inches ± 1/2 inch for the 12 inch gauge lengths, or (X + Y + 1/4) ± 1/2 inch when the X and Y gauge lengths are used. The center of the gauge line connecting the gauge marks fell within the diameter of the tap hole.

f. The distance between the gauge line and the structural steel for Type "B" splice was 12-1/4 inches ± 1/4 inches or any other documented distance.

B.2.3.4 Sampling and Tensile Testing

Splice samples were production splices and sister splices. Production splice samples were not cut from the structure when Type "B" splices were used, or when Type "T" splices were used for curved reinforcing bars. Representative straight sister splice samples were used in such cases, using the same frequency as Type "T" splices on straight bars, except that all splice samples are sister splices. Separate sampling and testing cycles were established for Cadweld splices in horizontal, vertical, and diagonal bars, for each bar grade and size, and for each splicing operator as follows:

a. one production splice out of the first ten splices,

b. one production and three sister splices for the next ninety production splices, and

c. one splice, either production or sister splices for the next subsequent units of 33 splices. At least 1/4 of the total number of splices tested were production splices.

The splice sample testing for the containment opening restoration following steam generator replacement was based on sister splices in accordance with Section CC-4333.5.2 and CC-4333.5.3 of 1989 ASME Section III, Division 2. One splice was tested for each unit of 100 production splices.

The tensile testing acceptance standards were:

a. The tensile strength of each sample tested was equal or exceeded 125% of the minimum yield strength specified in the ASTM A615 for the grade of reinforcing bar using loading rates as stated in ASTM A370 for the grade of reinforcing bar.

b. The average tensile strength of each group of 15 consecutive samples was equal to or exceeded the ultimate tensile strength specified in ASTM A615 for the grade of reinforcing bar.

Procedure for Substandard Tensile Test Results:

a. If any production splice used for testing failed to meet the strength requirements in (a) above and failure did not occur in the bar, the adjacent production splices on each side of the failed splice were tested. If any sister splice used for testing failed to meet the strength requirements in (b) above and failure did not occur in the bar, two additional sister splices were tested. If either of these retests failed to meet the strength requirements, splicing was halted. Splicing was not resumed until the cause of failures were corrected and resolved to the satisfaction of Sargent & Lundy.

b. If the running average tensile strength indicated in (b) above failed to meet the tensile requirements stated therein, splicing was halted. Sargent & Lundy investigated the cause, determined what corrective action (if any) was necessary, and notified the Contractor to perform the corrective action (if any).

c. When mechanical splicing was resumed, the sampling procedure was started anew.

B.2.4 Reinforcing Steel Repair for Steam Generator Replacement Project Containment Opening

Reinforcing steel of the containment was damaged during the concrete removal process of the steam generator replacement project. The steel was repaired by a welding process in accordance with AWS D1.4-92. The reinforcing steel has a carbon equivalent in excess of 0.55%, and ASME Section III, Division 2 specifically limits fusion welding of reinforcing bar to heats with carbon equivalents not greater than this level. AWS D1.4-92 allows welding of reinforcing steel with carbon equivalents in excess of 0.55%, provided that low hydrogen electrodes of the appropriate strength level are used, the electrode storage conditions are controlled to preserve their low hydrogen characteristics, and the appropriate minimum preheat and interpass temperatures are maintained.

The repair process represents a deviation from the Code; however, the NRC approved the relief request, as documented in a letter from R. A. Capra (Office of Nuclear Reactor Regulation) to I. M. Johnson, dated September 22, 1997, and the NRC's Safety Evaluation Report for approval of a request for relief related to repair requirements for damaged reinforcement steel.

B.3 POST-TENSIONING TENDONS

B.3.1 General

A Birkenheimer, Brandestini, Ross, and Vogt (BBRV) post-tensioning system was used. Tendons consisted of 170 1/4-inch diameter parallel lay wires. Positive anchorage at ends was provided by buttonheading. The materials, erection and fabrication procedures, and testing requirements conformed to the technical provisions of Sections CC-2400, CC-4400, and CC-5400 of the 1973 ASME B&PV Code, Section III, Division 2, Proposed Standard Code for Concrete Reactor Vessels and Containments, issued for interim trial use and comments with the exception of CC-4464.

B.3.2 Materials

B.3.2.1 Tendon Material

The 1/4-inch diameter wire conformed to cold-drawn ASTM A421, Type BA, stress-relieved, having a guaranteed minimum ultimate tensile strength, (f_{pu}), of 240,000 psi and a minimum yield strength not less than 0.80 f_{pu}, as measured by the 1.0% extension under load method.

B.3.2.2 Buttonheads

The positive anchorage of tendons to anchor heads was provided by buttonheading of the wires. All buttonheads were cold-formed after threading wires through wire holes of anchor heads. Buttonheads were formed symmetrically about the axis of wires and were free from harmful seams, fractures, and flaws.

B.3.2.3 Tendon Sheathing

Tendon sheathing through the foundation consisted of black seamless steel pipe, ASTM A53, Grade B and the wall sheathing was a black interlocked steel strip conduit, 22 gauge minimum wall thickness, fabricated to be watertight. The inside diameter of the sheathing was approximately 4.75 inches. All splices were sealed to prevent intrusion of cement paste. The tendon sheath splice was made using a snug fitting coupling approximately 1 foot long. The joints between the sheath and the coupling were taped. The minimum radius of curvature used was 30 feet, except in certain cases where a smaller radius of curvature was shown to be acceptable. Some of the original tendon sheathing was removed during restoration of the containment opening following steam generator replacement at Byron Unit 1.

B.3.2.4 Permanent Corrosion Protection

A corrosion preventing grease, Viscono Rust 2090 P-4, Nuclear Grade was used as a tendon casing filler.

B.3.2.5 Anchor Heads

For Byron Station, the anchor heads conformed to ASTM A-322, "Specifications for Hot-Rolled Alloy Steel Bars," AISI 4140/4142 hot rolled, vacuum degassed, and heat treated to Rc 42 ± 2 per MIL-H-6875D with a guaranteed maximum annealed hardness of 217 Brinell.

For Braidwood Station, the anchor heads conformed to ASTM A-322 "Specifications for Hot-Rolled Alloy Steel Bars," AISI 4140/4142 Hardness Number of 38 to 43 per MIL-H-6875D.

B.3.2.6 Bearing Plates and Shims

Bearing plate and shim materials conformed to hot rolled ASTM A-36 plate to silicone-killed fine-grain practice. For 1/8” shims, material may also conform to either ASTM A607 Grade 50 or hot-rolled open hearth .4/.5 carbon steel (20% or 17% ductility).

B.3.3 Quality Control

B.3.3.1 Testing

The erection and fabrication procedures conformed to Section CC-4400 with the exception that the welding procedures and welder qualifications were in accordance with AWS D1.1.

B.3.3.1.1 Tendon Tests

Tensile tests were performed on 100-inch long samples taken at a rate of 1% of all tendons including all anchorage hardware. One test was performed on the vertical group, one test on the dome group and two tests were performed on the horizontal group. The tendons were required to carry a load corresponding to 100% of the guaranteed ultimate tensile strength of the tendon without failure. Failure of any anchorage component was unacceptable.

B.3.3.1.2 Tests on Wires and Buttonheads

Wires were tested in accordance with ASTM A421, "Specifications for Uncoated Stress-Relieved Wire for Prestressed Concrete." A bend test and buttonhead test was made on each coil of wire. The bend test specimen was cold bent back and forth in one place 90° in each direction over pins with a 5/8-inch radius. Each return to vertical was one complete bend. The wire must have sustained a minimum of six bends before complete fracture. The buttonhead test was a static test performed to check the buttonhead machine and to confirm the integrity of the buttonhead. The buttonhead was acceptable if failure occurred within the shaft of the wire. The buttonhead machine was routinely checked at the beginning of each shift. Ten percent of the wires in each tendon were checked for buttonhead size and conformance with a "Go, No-Go" gauge. All buttonheads were visually examined to ensure that splits, cracks, and/or slips did not exceed acceptance criteria.

Also, one rupture test of wire was performed in the field similar to that used in the tendon. A 12-inch long sample of wire was tested using a portable tensile test apparatus prior to initiating the buttonhead operation on the respective tendon. The sample was prepared using the same equipment and operators that performed the buttonheading operation.

B.3.3.1.3 Tests on Corrosion Preventative Grease

The manufacturer of corrosion preventative tendon coating materials performed chemical analyses to measure the presence of water soluble chlorides, nitrates, and sulphides and provided certification of compliance with the acceptance criteria given in the ASME Code, Section III, Division 2. In addition, each shipment of permanent corrosion preventative grease was retested in the field to verify that the material had remained contaminant free.

B.3.3.1.4 Anchorage Hardware Tests and Inspections

Anchor heads were tested to 120% of the minimum ultimate tensile strength of the prestressing steel employing a test machine that was chosen to simulate the actual loading condition as close as possible. All welds were given 100% visual examination for completeness, workmanship, and slag removal.

B.3.3.2 Fabrication Tolerances

The differential length of any two wires in the same tendon did not exceed 1/16 inch for wires up to 100 feet long and 1/8 inch for wires over and up to 200 feet long, and an additional 1/8 inch for each 100 feet increment in length over 200 feet. Trumpet perpendicularity was measured to ensure that the angle between the trumpet and the bearing surface of the bearing plate was within a tolerance of ± 0.3 degrees. Eccentricity of a buttonhead from the axis of the wire was not permitted to exceed 0.010 inch. Wire holes in anchor heads must have been within 0.010 inch of the specified location on the buttonhead bearing surface. Drift was within 0.035 inch from the centerline. Wire hole diameter must have fallen within the range of 0.257 inch to 0.264 inch.

B.3.3.3 Field Installation Tolerances

Tendon bearing plates were installed with a tolerance of ± 0.25 inch from the specified locations. Critical dimensions were established for the placing of tendon sheathing and the tolerance on these critical dimensions was ± 0.5 inch. All gauges, instruments and jacks were calibrated against known standards that were traceable to the National Bureau of Standards. Elongation measurements commenced at 20% GUTS. The tolerance on lockoff pressure during the stressing operation was established by the criteria that stress in the tendon wires at the anchor point after anchoring must have been at least equal to, but could not have exceeded, the specified value by more than 5%. The number of broken or defective wires or button-heads was limited to a maximum of three per tendon. This limit may be exceeded if an analysis shows that the condition is acceptable. The total number of broken or defective wires in any one group of tendons (hoop, vertical, or dome) was not allowed to exceed 1% of the total wires in the tendon group.

B.3.3.4 Corrosion Protection

Tendons were protected from corrosive elements during fabrication, shipping, storage, and installation by application of a thin film of Visconorust 1601 Amber, as made by Viscosity Oil Company, immediately after fabrication. Further, tendons were shipped and stored in polyethylene bags. Tendons were not permitted to be exposed to inclement weather, condensation, or injurious agents such as solutions containing chloride. Damaged or corroded tendons were rejected on inspection. Exterior exposed surfaces of bearing plates and grease retaining caps were protected from corrosion by application of a prime and a finish coat of paint. The prime coat of paint was required to have a minimum dry film thickness of two mils.

B.4 STRUCTURAL STEEL

B.4.1 Structural Steel Materials

Structural support steel was ASTM A36, ASTM A572, Grade 50 and ASTM A588 high strength, low alloy corrosion-resistant steel. Structural steel tubing was ASTM A500, Grade B and ASTM A501.

B.4.2 Structural Steel Connections and Connection Material

B.4.2.1 Bolted Connections

Structural steel bolted connections used ASTM A325, Type 1 and ASTM A490, friction-type high strength bolts. These high strength bolted connections conformed to "Specification for Structural Joints using ASTM A325 or A490 Bolts" issued by the Research Council on Riveted and Bolted Joints of the Engineering Foundation and endorsed by the AISC, and to Framed Beam Connections, Table I or II of the AISC Manual. ASTM A307 and A325 bolts were used for non-friction type applications in specified connections in the containment building. For non-friction type sliding connections, the load nut was torqued to a specified range (50-100 ft-lbs) and a jam nut was installed snugtight against the load nut. ASTM A36, "Specifications for Structural Steel," nuts were used, with ASTM A36 threaded rods and all ASTM A307, "Specifications for Carbon Steel Externally and Internally Threaded Standard Fasteners," bolts.

B.4.2.2 Welded Connections

Standard welded beam connections conform to Table III or IV of AISC Manual. Shop and field welding procedures were in accordance with AWS Specifications listed in Table 3.8-2. Selection of electrodes and recommended minimum preheat and interpass temperature were in accordance with AWS requirements. All welders and welding operators were certified by an approved testing laboratory and were qualified under AWS procedure as stated in AWS Specifications.

B.4.3 Quality Control

B.4.3.1 General

Quality assurance requirements applied to the fabrication and testing of structures and components. Certified material test reports were furnished stating the actual results of all chemical analyses and mechanical tests required by ASTM specifications. Identifying heat numbers were furnished on all structural steel to trace the steel to the specific heat in which the steel was made.

B.4.3.2 Testing and Inspection of Weldments

One hundred percent of all complete penetration groove welds had complete radiographic examination, except that welds impractical to radiograph were examined by ultrasonic, magnetic particle, or liquid penetrant methods.

The above nondestructive test methods were in compliance with the following ASTM specifications:

a. E94, "Recommended Practice for Radiographic Testing,"

b. E142, "Controlling Quality of Radiographic Testing,"

c. E164, "Recommended Practice for Ultrasonic Contract Examination of Weldments,"

d. E109, "Dry Powder Magnetic Particle Inspection,"

e. E138, "Wet Magnetic Particle Inspection," and

f. E165, "Recommended Practice for Liquid Penetrant Inspection Method."

B.4.3.3 Fabrication

The fabrication of structural steel conformed to AISC specifications.

B.5 CONTAINMENT LINER WITHIN THE CONTAINMENT BACKED BY CONCRETE

B.5.1 General

The materials, erection and fabrication procedures, and testing requirements conformed to the technical provisions of Sections CC-2500, CC-4500, and CC-5500 of the 1973 ASME B&PV Code, Section III, Division 2.

B.5.2 Materials

The containment liner materials performing only a leaktight function (excluding leak test channels), within the containment backed by concrete met the requirements of the ASME B&PV Code, Section III, Division 2, Paragraph CC-2500, and complied with the following specifications:

APPLICATION	SPECIFICATION
Liner Plate	SA 516 GRADE 60
Containment Liner Anchors	A36

B.5.3 Quality Control

B.5.3.1 Testing of Welds

B.5.3.1.1 General

All nondestructive examination procedures were in accordance with Section V of the ASME B&PV Code.

B.5.3.1.2 Liner Plate Seam Welds

B.5.3.1.2.1 Radiographic Examinations

The first 10 feet of weld for each welder and welding position was 100% radiographed. Thereafter one spot radiography of not less than 12 inches in length was taken for each welder and welding position in each additional 50 foot increment of weld. In any case a minimum of 2% of liner seam weld was examined by radiography. All radiographic examinations were performed as soon as possible after the weld was placed. The spots selected for radiography were randomly selected. Any two spots chosen for radiographic examination were at least 10 feet apart. If a weld failed to meet the acceptance standards specified in NE-5532, Section III of the ASME B&PV Code, two additional spots were examined at locations not less than 1 foot from the spot of initial examination. If either of these two additional spots failed to meet the acceptance standards then the entire weld test unit was considered unacceptable. Either the entire unacceptable weld was removed and the joint rewelded, or the entire weld unit was completely radiographed and the defective welding repaired. The repaired areas were spot radiographed.

B.5.3.1.2.2 Ultrasonic Examinations

Ultrasonic examinations were performed on 100% of the jet deflector support embedments. If a weld failed to meet the acceptance standards specified in NE-5330 of Section III of the ASME B&PV Code, the weld was repaired and reexamined.

B.5.3.1.2.3 Magnetic Particle Examination

Magnetic particle examination was performed on 100% of liner seam welds for ferritic material. If a weld failed to meet the acceptance standards specified in CC-5533 of Section III of the ASME B&PV Code, the weld was repaired and reexamined according to the above Code using magnetic particle examination.

B.5.3.1.2.4 Liquid Penetrant Examination

Liquid penetrant examination was performed on 100% of liner seam welds for austenitic materials. If a weld failed to meet the acceptance standards specified in CC-5534 of Section III of the ASME B&PV Code, the weld was repaired and reexamined according to the ASME Code using the liquid penetrant method of examination.

B.5.3.1.2.5 Vacuum Box Soap Bubble Test

The vacuum box soap bubble test was performed on 100% of liner seam welds for leaktightness. If leakage was detected the test was repeated after the weld was repaired.

B.5.3.1.3 Leak Test Channels

Wherever leak-chase-system channels were installed over the liner welds, the channel-and-liner plate welds were tested for leaktightness by pressurizing the channels to the containment design pressure and doing a pneumatic test of 100% of the welds. A 2 psi change in pressure over a 2-hour holding period was allowed because of a possible variation in temperature during the holding period.

B.5.3.2 Fabrication and Installation

B.5.3.2.1 General

The fabrication and installation of the containment steel boundaries backed by concrete were in accordance with the ASME B&PV Code, Section III, Division 2, Paragraph CC-4500.

B.5.3.2.2 Welding Qualification

The qualifications of welders and welding procedures were in accordance with Section III, Division 2, Paragraph CC-4500 of the ASME B&PV Code.

Installation Tolerances

All pressure retaining components conformed to the applicable requirements of NE-4220 of ASME Section III.

Cylinder Tolerances:

a. For each 10 foot elevation of the liner the difference between the maximum diameter and minimum diameter did not exceed 8 inches. This requirement was satisfied by measuring diameters spaced approximately 30°.

b. The radius of the liner was within ± 6 inches of the theoretical radius.

c. The deviation of the liner from true vertical did not exceed 1 inch in any 10 feet nor 3 inches in the full height of the liner.

d. The local contour of the shell was controlled by limiting the following deviations:

    1. A 1-inch gap between the shell and a 15-foot-long template curved to the required radius when placed against the surface of a shell within a single plate section and not closer than 12 inches to a welded seam.

    2. A 1-1/2-inch gap when the template above was placed across one or more welded seams.

    3. A 3/8-inch gap when a 15-inch-long template curved to the required radius was placed against the surface of the shell within a single plate section and not closer than 12 inches to a welded seam.

    4. A 3/4-inch deviation from a 10-foot straight edge placed in the vertical direction between circumferential seams.

Dome Tolerances:

a. For each point the height of the dome above the spring line was no greater than 12 inches above theoretical height but in no case was it less than the theoretical height above the spring line.

b. Radius measurements were taken at the top of each roof course at 30° intervals, to determine the horizontal distance from the vertical centerline of the containment to the dome roof liner plate.

c. The local contour of the dome was controlled by limiting the following deviations:

   1. A 1-inch gap between the shell and a 15-foot-long template curved to the required radius when placed horizontally against the surface of the shell within a single plate section and not closer than 12 inches to a welded seam.

   2. A 1-1/2-inch gap when the template above was placed horizontally across one or more welded seams.

   3. A 3/8-inch gap when a 15-inch-long template curved to the required radius was placed horizontally against the surface of the shell within a single plate section and not closer than 12 inches to a welded seam.

   4. A 3/8-inch gap when a 15-inch-long elliptical template was placed along the meridional of the surface of the shell within a single plate section and not closer than 12 inches to a welded seam.

   5. A 1-inch gap between the shell and a 15-foot-long elliptically curved template when placed along the meridional surface of a shell within a single plate section and not closer than 12 inches to a welded seam.

   6. A 1-1/2-inch gap when the elliptical template above was placed across one or more welded seams.

B.6 CONTAINMENT STEEL BOUNDARY NOT BACKED BY CONCRETE

The materials, fabrication, installation and testing requirements were in accordance with the 1971 ASME B&PV Code, Section III, Division 1, Subsection NE, with Addenda through Summer 1973.

B.6.1 Materials

The materials complied with the requirements of the 1971 ASME B&PV Code, Section III, Division 1, Paragraph NE-2000, and also to the following specifications:

APPLICATION	SPECIFICATION
Emergency personnel airlock and equipment access hatch with integral personnel airlock	SA516 Grade 70
Penetration pipe sleeves	
(i) up to 24 inch diameter Seamless	SA-333 Grade 1 or 6
(ii) over 24 inch diameter	SA-516 Grade 60

B.6.2 Quality Control

B.6.2.1 Testing

B.6.2.1.1 General

The testing of the containment leaktight boundaries not backed by concrete were in accordance with the ASME B&PV Code, Section III, Division I, Subsection NE-5000.

B.6.2.1.2 Testing of Welds

One hundred percent of all welds between penetration and flued fitting, and flued fittings and pipelines were examined by radiographic examinations. One hundred percent of all welds in the equipment hatch, personnel airlock, and penetration sleeves were inspected also by radiographic examination where possible. Where radiography could not be employed, ultrasonic examination was used. Penetration to insert plate welds and penetration to liner welds were magnetic particle or liquid penetrant examined in lieu of 100% radiography. Penetration insert plate to liner weld was spot radiographed and magnetic particle or liquid penetrant examined in lieu of 100% radiography. Penetration insert plate to frame welds for air locks and access openings were magnetic particle examined or liquid penetrant examined in lieu of 100% radiography. If a weld failed to meet the acceptance standards specified in NE-5300, Section III of the ASME B&PV Code, the entire unacceptable weld was removed and the joint rewelded. The repaired areas were radiographed.

B.6.2.2 Fabrication and Installation

B.6.2.2.1 General

The fabrication and installation of the containment steel boundaries not backed by concrete were in accordance with the ASME B&PV Code, Section III, Division I, Subsection NE-4000.

B.6.2.2.2 Qualification of Welders

The qualifications of welders and welding procedures were in accordance with Section III, Division 1, Subsection NE-4300 of the ASME B&PV Code.

B.7 STAINLESS STEEL POOL LINERS

The liner for the spent fuel pool, fuel transfer canal and spent fuel cask pit are not covered by this section. For further details on these liners refer to Subsection 9.1.2.3.

B.7.1 Materials

Stainless steel pool liners were fabricated from A240 Type 304 Material, hot rolled, annealed and pickled and further processed by cold rolling.

B.7.2 Welding

Welding procedures were in accordance with the ASME B&PV Code, Section III, Division 2, Paragraph CC-4540, and ASME Section IX. All seam welds were complete penetration groove square butt welds.

The liner plate seam welds were examined and tested as follows:

a. Radiographic examination was performed in accordance with the requirements of ASME Section V, "Nondestructive Examination." A minimum of 2% of all liner seam welds were examined.

b. Ultrasonic examination may be performed in lieu of radiography on liner seam welds when joint detail does not permit radiographic examination.

c. Liquid penetrant examination was performed on austenitic materials. The weld surfaces and at least 1/2 inch of the adjacent base material on each side of the weld were examined. The examination coverage was 100% of all shop and field seam welds.

d. Vacuum leak test was performed for leaktightness on all liner plate seam welds.

B.7.3 Erection Tolerances

Tolerances for free-standing liner work conformed to CC-4522.1.1 of Section III, Division 2 of ASME with the following additional requirements for the refueling water storage tanks:

a. The radius of the cylindrical shell was within ±3 inches of the theoretical radius. Radius measurements were made at 10 foot increments vertically and at 36° increments circumferentially.

b. The radius of the inner surface of the dome does not deviate from the design value by more than ± 3 inches. The height of the dome above the spring line was not greater than 6 inches above the design height, and in no case was it less than the design height above the spring line.

B.8 OTHER STAINLESS STEEL ELEMENTS

Stainless steel embedded plates and stainless steel checkered floor plates were fabricated from A240 Type 304 material, hot rolled, annealed and pickled.

Stainless steel bars and rounds were fabricated from A276 or A479 Type 304 material, hot rolled, annealed and pickled.

Stainless steel pipes were fabricated from A312 Type 304 or A358 Type 304 or A376 Type 304 materials, hot rolled, annealed and pickled.

Stainless steel gratings were fabricated from A240 Type 302 or Type 304 materials, hot rolled, annealed and pickled prior to fabrication and then electropolished after fabrication.

Stainless steel sump liners were fabricated from A240 Type 304 or Type 316 materials.

Stainless steel bolts were fabricated from A 193 Class 1 material.

Stainless steel nuts were fabricated from A194 material.

Stainless shapes were fabricated from A276 or A479 Type 304 materials.

For further discussion on austenitic stainless steel, refer to Subsection 5.2.3.4.

B.9 NUCLEAR STEAM SUPPLY SYSTEM (NSSS) COMPONENT SUPPORT STEEL

B.9.1 General

Material and Quality Control Programs for components support steel conformed to the requirements of Subsection NF of the 1974 ASME Code, Summer of 1975 addenda, Section III, Division I. All further references to Subsection NF in this section on NSSS component supports imply the same edition and addenda.

B.9.2 Steel Materials

Component support steel materials are summarized in Table B.9-1.

B.9.3 Welding Qualifications

All welding procedures were qualified in accordance with the welding procedure qualification requirements of NF-4300 of ASME Section III, Subsection NF.

B.9.4 Quality Control

B.9.4.1 General

Certified material test reports which provide the results of all chemical analyses and mechanical tests were furnished in accordance with the requirements of NF-2000. Test reports included the results of Charpy Impact Tests which conformed to Subsection NF of the ASME Code. Identification of material requiring traceability was provided in compliance with Section III of the ASME Code.

B.9.4.2 Lamination Tests

Plates loaded in tension during service in the through thickness (short-transverse) direction, as defined in NF-3226.5, Subsection NF of ASME, Section III, were examined by the straight beam ultrasonic method in accordance with ASME SA-578.

B.9.4.3 Nondestructive Examination of Welds

Nondestructive examinations were conducted in accordance with the requirements of ASME Section V and NF-5000 of Section III Subsection NF. Acceptance standards for radiography, ultrasonic, magnetic particle, liquid penetrant, and visual examinations, complied with the requirements of NF-5000 of Section III, Subsection NF.

B.9.5 Fabrication and Installation

The fabrication and installation of NSSS component supports were accomplished in conformity with NF-4000 of ASME Section III, Subsection NF.

B.9.5.1 Installation Tolerances

Installation tolerances for (a) NSSS component support embedment location, and (b) centerlines and work points with reference to in-place NSSS component supports are specified on the design drawings.

TABLE B.9-1

MATERIAL FOR NSSS COMPONENT SUPPORTS

MATERIAL SPECIFICATION NUMBER	PRODUCT FORM	APPLICABLE ASME CODE PROVISION
A618 GRADE III	TUBE	CODE CASE 1644
A588 GRADE A, B	PLATES, BARS SHAPES	CODE CASE 1644
SA-540 GR. B24 CLASS 1 AND CLASS 4	BOLTING MATERIAL	SECTION III SUBSECTION NA TABLE I-13.3
A490	BOLTING MATERIAL	CODE CASE 1644
SA-194 GR 7	NUTS	SUBSECTION NA TABLE I-13.3
SA-533 CLASS 2	PLATE	SUBSECTION NA TABLE I-1.1