4.5 REACTOR MATERIALS

4.5.1 CONTROL ROD SYSTEM STRUCTURAL MATERIALS

4.5.1.1 Material Specifications

The following material listing applies to the control rod drive mechanism supplied for this application. The position indicator, and minor non-structural items are omitted.

(1) Cylinder, Tube and Flange Assembly

Flange	ASME SA 182 Grade F304, F304L
Plugs	ASME SA 182 Grade F304
Cylinder	ASTM A269 Grade TP 304
Outer Tube	ASTM A269 Grade TP 304
Tube Upper	ASME SA 351 Grade CF3
Spacer	ASME SA 351 Grade CF3

(2) Piston Tube Assembly

Piston Tube	ASME SA 249 Grade XM-19
Stud	ASME SA 479 Grade XM-19
Head	ASME SA 182 Grade F304
Ind. Tube	ASME SA 312 Type 316
Cap	ASME SA 182 Grade F3

(3) Drive Assembly

Coupling Spud	Inconel X-750
Index Tube	ASME SA 249 Grade XM-19
Piston Head	Armco 17-4 PH ASTM A564 Grade 630
Piston Coupling	ASME SA 312 Grade TP 304 or ASTM A511 Grade MT 304
Magnet Housing	ASME SA 312 Grade TP 304 or

(4) Collet Assembly

Collet Piston	ASTM A269 Grade TP 304 or ASME SA 312 Grade TP 304
Finger	Inconel X-750
Retainer	ASTM A269 Grade TP 304 o ASTM A511 Grade MT 304
Guide Cap	ASTM A269 Grade TP 304

(5) Miscellaneous Parts

Stop Piston	ASTM A276 Type 304
Connector	ASTM A276 Type 304
O-Ring Spacer	ASME SA 240 Type 304
Nut	ASME SA 193 Grade B8 ASME SA479 XM-19
Barrel	ASTM A269 Grade TP 304 or ASME SA 312 Grade TP 304 or ASME SA 240 Type 304
Collet Spring	Inconel X-750
Ring Flange	ASME SA 182 Grade F304

The materials listed under ASTM specification number are all in the annealed condition (with the exception of the outer tube in the cylinder, tube and flange assembly), and their properties are readily available. The outer tube is approximately 1/8 hard, and has a tensile of 90,000/125,000 psi, yield of 50,000/85,000 psi, and minimum elongation of 25%.

The coupling spud, collet fingers and collet spring are fabricated from Inconel X-750 in the annealed or equalized condition, and heat treated to produce a tensile of 165,000 psi minimum, yield of 105,000 psi minimum and elongation of 20% minimum. The piston head is Armco 17-4 PH (ASTM A564 Grade 630) in condition H 1100, with a tensile of 140,000 psi minimum, yield of 115,000 psi minimum and elongation of 15% minimum.

These are widely used materials, whose properties are well known. The parts are readily accessible for inspection and replacement if necessary.

All materials, including SA 479 Grade XM-19, have been successfully used for years in similar drive mechanisms. Extensive laboratory tests have demonstrated that ASME SA 479 Grade XM-19 is a suitable material and that it is resistant to stress corrosion in a BWR environment.

4.5.1.2 Special Materials

No cold worked austenitic stainless steels with a yield strength greater than 90,000 psi are employed in the Control Rod Drive mechanism. Hardenable martensitic stainless steels are not used. Armco 17-4 PH (ASTM A564 Grade 630 precipitation hardened stainless steel) is used for the piston head. This material is aged to the H-1100 condition to produce resistance to stress corrosion cracking in the BWR environments. Armco 17-4 PH (ASTM A564 Grade 630), (H-1100) has been successfully used for years in BWR drive mechanisms.

4.5.1.3 Processes, Inspections and Tests

All austenitic stainless steel used in the Control Rod Drive mechanisms are solution annealed material with one exception, the outer tube in the cylinder, tube, and flange assembly. See Subsection 4.5.1.1. Proper solution annealing is verified by testing per ASTM-A262 "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels."

Two special processes are employed which subject selected components to temperatures in the sensitization range.

a. The cylinder (cylinder, tube and flange assembly) and the retainer (collet assembly) are hard surfaced with Colmonoy 6.

b. The following components are nitrided to provide a wear resistant surface:

- Piston tube (piston tube assembly)
- Index tube (drive line assembly)
- Collet piston and guide cap (collet assembly)

Colmonoy hard-surfaced components have performed successfully for years in drive mechanisms. Nitrided components have also accumulated many years of BWR service. It is normal practice to remove some Control Rod Drives at each refueling outage. At this time, both the Colmonoy hard surfaced parts and nitrided surfaces are accessible for visual examination. In addition, dye penetrant examinations have been performed on nitrided surfaces of the longest service drives. This inspection program is adequate to detect any incipient defects before they could become serious enough to cause operating problems.

All austenitic stainless steel is purchased in the solution heat treated condition. Welding is performed in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. Heat input for stainless steel welds is restricted to a maximum of 50,000 Joules per inch and interpass temperature to 350°F. Heating above 800°F (except for welding) is prohibited unless the welds are subsequently solution annealed. These controls are employed to avoid severe sensitization. Compliance with Regulatory Guide 1.44 is discussed in Section 3.13.

4.5.1.4 Control of Delta Ferrite Content

All type 308 weld metal is purchased to a specification which requires a minimum of 5% delta ferrite. This amount of ferrite is adequate to prevent any micro-fissuring (hot cracking) in austenitic stainless steel welds.

START HISTORICAL

An extensive test program performed by General Electric Company, with the concurrence of the Regulatory Staff, has demonstrated that controlling weld filler metal ferrite at 5% minimum produces production welds which meet the requirements of Regulatory Guide 1.31. A total of approximately 400 production welds in five BWR plants were measured and all welds met the requirements of the Interim Regulatory Position to Regulatory Guide 1.31.

END HISTORICAL

4.5.1.5 Protection of Materials During Fabrication, Shipping, and Storage

All the Control Rod Drive parts listed above (Subsection 4.5.1.1) are fabricated under a process specification which limits contaminants in cutting, grinding and tapping coolants and lubricants. It also restricts all other processing materials (marking inks, tape etc.) to those which are

completely removable by the applied cleaning process. All contaminants are then required to be removed by the appropriate cleaning process prior to any of the following:

(1) Any processing which increases part temperature above 200°F.
(2) Assembly which results in decrease of accessibility for cleaning.
(3) Release of parts for shipment.

The specification for packaging and shipping the Control Rod Drive provides the following:

The drive is rinsed in hot deionized water and dried in preparation for shipment. The ends of the drive are then covered with a vapor tight barrier with desiccant. Packaging is designed to protect the drive and prevent damage to the vapor barrier. The planned storage period considered in the design of the container and packaging is two years. This packaging has been qualified and in use for a number of years.

Periodic audits have indicated satisfactory protection.

The degree of surface cleanliness obtained by these procedures meets the requirements of Regulatory Guide 1.37.

Site or warehouse storage specifications require inside heated storage comparable to level B of ANSI 45.2.2. After the second year, a yearly inspection of 10% of the humidity indicators (packaged with the drives) is required to verify that the units are dry.

4.5.2 REACTOR INTERNAL MATERIALS

4.5.2.1 Material Specifications

Materials used for the Core Support Structure:

Shroud Support - Nickel Chrome Iron Alloy, ASME SB166 or SB168.

Shroud, core plate, top guide, and internal structures welded to these components, ASME SA240, SA182, SA479, SA312, SA249, or SA213 (Type 304 and 304L).

Peripheral fuel supports - SA312 Type 304.

Core plate and top guide studs and nuts. ASME SA479, SA193 Grade B8, SA194 Grade 8, ASTM A276 (all Type 304).

Top guide pins, ASME SA 479 (Type 316 or XM-19), ASTM A276 T304.

Control rod drive housing. ASME SA312 Type 304, SA182 Type 304.

Control rod drive guide tube. ASME SA351 Type CF8, SA358, SA312, SA249 (Type 304).

Orificed fuel support. ASME SA351 Type CF8.

Materials Employed in Other Reactor Internal Structures.

(1) Steam Separator

All materials are Type 304 stainless steel.

Plate, Sheet and Strip	ASTM A240, Type 304
Forgings	ASTM A182, Grade F304
Bars	ASTM A479 Type 304
Pipe	ASTM A312 Grade TP 304
Tube	ASTM A269 Grade TP 304
Castings	ASTM A351 Grade CF8

Replacement materials for the steam separator may be Type 316 stainless steel.

Replacement Steam Dryer

All materials are Type 304, 304L, 316, 316L, stainless steel, CF3, XM-19, or X-750

Plate, Sheet and Strip	ASTM A240, Type 304, 304L, 316, 316L, XM-19
Forgings	ASTM A182, Grade F304, F304L, F316, F316L, FXM-19 ASTM A965, Grade F304, F304L, F316, F316L, XM-19
Bars	ASTM A479, Type 304, 304L, 316, 316L, XM-19
Pipe	ASTM A312, Grade TP304, TP304L, TP316, TP316L ASTM A358, Grade 304, 304L, 316, 316L ASTM A376, Grade TP304, TP316
Castings	ASTM A351, Grade CF3
Bar, Forging	ASTM B637 – UNSN07750
Wire	AMS 5698, 5699G

(2) Jet Pump Assemblies

The components in the Jet Pump Assemblies are a Riser, Inlet, Mixer, Diffuser, Adaptor, and Brackets. Materials used for these components are to the following specifications.

Castings	ASTM A351 Grade CF8
Bars	ASTM A276 Type 304
Bolts	ASTM A193 Grade B8 or B8M
	ASTM A194 Grade B8
Nut	ASTM A240 Type 304 and 304L
Sheet and Plate	ASTM A269 Grade TP 304
Tubing	ASTM A358 Type 304 and
Pipe	ASTM A312 Grade TP 304
Weld Coupling	ASTM A403 Grade WP304
Forgings	ASTM A182 Grade F304
Inconel Forgings	ASTM B166

Materials in the Jet Pump Assemblies which are not Type 304 stainless steel are listed below:

(1) The Inlet Mixer Adaptor casting, the wedge casting, bracket casting adjusting screw, and the Diffuser collar casting are Type 304 hard surfaced with Stellite 6 for slip fit joints.

(2) The Adaptor is a bi-metallic component made by welding a Type 304 forged ring to a forged Inconel 600 ring, made to Specification ASTM B166.

(3) The Inlet-Mixer contains a pin, insert, and beam made of Inconel X-750. The pin and insert are made to General Electric Specification B50YP44A1 and the beam is made to ASTM B637 UNS N07750 to resist IGSCC. The Jet Pump Beam Bolt is SS316L that is nitrided.

(4) Jet Pump Beam Bolt assemblies with rachet-style keepers use a beam, keeper, lock plate, pins, and lock pins made of Alloy X-750 ASTM B-637. Additionally, they use machine screws made of XM-19 stainless steel. They use a bolt that is Type 316L stainless steel.

(5) The Auxiliary Spring Wedge Assemblies installed on the Jet Pumps in those locations necessary to ensure three point contact at the restrainer bracket set screws are made of Inconel X-750 to Specification ASTM B637.

(6) The replacement jet pump Mixer Wedge Assemblies installed on Jet Pumps in those locations necessary to ensure three point contact at the restrainer bracket are made of Inconel X-750 to Specification ASTM B637. The replacement wedges are not stellite coated. The Guide Rod and Keeper Nut are made of Type 316 stainless steel.

(7) Slip Joint Clamps are installed on select jet pumps. The slip joint clamp body is fabricated from solution heat treated ASTM A-182 Grade F XM-19 stainless steel. The adjustable bolt and ratchet lock spring are fabricated from ASME SB-637 or ASTM B-637 UNS N07750 Type 3 (Alloy X-750).

(8) Anti-Vibration Solution (AVS) hardware is installed on select jet pumps. Materials used include XM-19, X-750, 316 stainless steel, and Nitronic 60.

(9) Slip Joint Diffuser Rings are installed on select Unit 1 and Unit 2 jet pumps. The Slip Joint Diffuser Ring is fabricated from solution heat treated 300 series austenitic stainless steel with a maximum of 0.02% carbon, XM-19 (22Cr-13Ni-5Mn) stainless steel, Alloy X-750 (Ni-Cr-Fe), or Nitronic-60 (18Cr-8Ni-4Si-N).

All core support structures are fabricated from ASME and ASTM equivalent specified materials, and designed in accordance with the requirements of ASME Code Section III, Appendix I. The other reactor internals are non-coded, and they are fabricated from ASTM specification materials. Material requirements in the ASTM specifications are identical to requirements in corresponding ASME material specifications. The allowable stress levels specified in ASME Code Section III, Appendix I, are used as a guide in the design of all non-coded internal structures in the BWR.

4.5.2.2 Controls on Welding

Core support structures are fabricated in accordance with requirements of ASME Code Section III, Subsection NG. Other internals are not required to meet ASME Code requirements; however, they are fabricated to the requirements of ASME Section IX.

4.5.2.3 Nondestructive Examination of Wrought Seamless Tubular Products

For core support structures, wrought seamless tubular products were supplied in accordance with applicable ASME material specifications. These specifications require examination of the tubular product by radiographic and/or ultrasonic methods according to paragraph NG-2550 of ASME Code Section III. In addition, the specification for tubular products employed for CRD housings external to the RPV meet requirements of paragraph NB-2550. Compliance with Regulatory Guide 1.66 is discussed in Section 3.13.

Other internals are non-coded, and wrought seamless tubular products were supplied in accordance with the applicable ASTM material specifications. These specifications require a hydrostatic test on each length of tubing.

4.5.2.4 Fabrication and Processing of Austenitic Stainless Steel - Regulatory Guide Conformance

Regulatory Guide 1.31, Control of Stainless Steel Welding

All austenitic stainless steel weld filler materials were supplied with a minimum of 5% delta ferrite. This amount of ferrite is considered adequate to prevent micro-fissuring in austenitic stainless steel welds.

START HISTORICAL

An extensive test program performed by General Electric Company, with the concurrence of the Regulatory Staff, has demonstrated that controlling weld filler metal ferrite at 5% minimum produces production welds which meet the requirements of Regulatory Guide 1.31, "Control of Stainless Steel Welding". A total of approximately 400 production welds in five BWR plants were measured and all welds met the requirements of the Interim Regulatory Position to Regulatory Guide 1.31.

END HISTORICAL

Regulatory Guide 1.34, Control of Electroslag Weld Properties

Electroslag welding is not employed for any reactor internals.

Regulatory Guide 1.36, Non-metallic Thermal Insulation for Austenitic Stainless Steel

Non-metallic thermal insulation is not employed for any components in the reactor vessel.

Regulatory Guide 1.44, Control of the Use of Sensitized Stainless Steel

All wrought austenitic stainless steel was purchased in the solution heat treated condition. Heating above 800°F was prohibited (except for welding) unless the stainless steel was subsequently solution annealed. Purchase specifications restricted the maximum weld heat input to 110,000 Joules per inch, and the weld interpass temperature to 350°F maximum. Welding was performed in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. These controls were employed to avoid severe sensitization. Compliance with Regulatory Guide 1.44 is discussed in Section 3.13.

Regulatory Guide 1.71, Welder Qualification for Areas of Limited Accessibility

All weld procedures and welders were qualified in accordance with ASME Section IX and Section III. Areas of restricted access required qualification test assemblies welded under simulated access conditions. Prior to performing welding on any assembly joints requiring a mockup, qualified welders were required to perform one weld joint or a minimum of 12 inches of weld mockup under simulated space, accessibility, and adjacent component configuration. The mockup joint was welded in strict accordance with the approved welding procedure. Nondestructive examination of the mockup was by radiography or by sectioning and subject to established acceptance critieria.

4.5.2.5 Contamination, Protection, and Cleaning of Austenitic Stainless Steel

Exposure to contaminant was avoided by carefully controlling all cleaning and processing materials which contact stainless steel during manufacture and construction. Any inadvertent surface contamination was removed to avoid potential detrimental effects.

Special care was exercised to insure removal of surface contaminants prior to any heating operation. Water quality for rinsing, flushing, and testing was controlled and monitored.

The degree of cleanliness obtained by these procedures meets the requirements of Regulatory Guide 1.37.

4.5.3 Control Rod Drive Housing Supports

The American Institute of Steel Construction (AISC) Manual of Steel Construction, "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," was used in designing the CRD housing support system. However, to provide a structure that absorbs as much energy as practical without yielding, the allowable tension and bending stresses used were 90% of yield and the shear stress used was 60% of yield. These design stresses are 1.5 times the AISC allowable stresses (60% and 40% of yield, respectively).

For purposes of mechanical design, the postulated failure resulting in the highest forces is an instantaneous circumferential separation of the CRD housing from the reactor vessel, with the reactor at an operating pressure of 1086 psig (at the bottom of the vessel) acting on the area of the separated housing. The weight of the separated housing, control rod drive, and blade, plus the pressure of 1086 psig acting on the area of the separated housing, gives a force of approximately 32,000 lb. This force is used to calculate the impact force, conservatively assuming that the housing travels through a 1-in. gap before it contacts the supports. The impact force (109,000 lb) is then treated as a static load in design. The CRD housing supports are designed as Category I (seismic) equipment in accordance with Section 3.2.

All CRD housing support subassemblies are fabricated of ASTM-A-36 structural steel, except for the following items:

	Material
Grid	ASTM-A-441
Support Bars	AISI MT1015 and A36
Spring Housings	ASTM A513 Type 5
Spacers	AISI MT1015
Disc springs	Schnorr, Type BS-125-71-8
Hex bolts and nuts	ASTM-A-307
6 x 4 x 3/8 tubes	ASTM-A-500 Grade B