

## 4.5 Reactor Materials

This information in this section of the reference ABWR DCD, including all subsections, is incorporated by reference with the following departure and supplement.

STD DEP 4.5-1

### 4.5.1.1 Material Specifications

(1) *Material List*

*The following material listing applies to the control rod drive (CRD) mechanism supplied for this application. The position indicator and minor non-structural items are omitted. The listing includes materials for reactor pressure boundary components that must meet all ASME Code, Section III, Class 1 requirements (Subsection NB).*

*The properties of the materials selected for the CRD mechanism shall be equivalent to those given in Appendix I to Section III of the ASME Code or Parts A and B of Section II of the ASME Code, or are included in Regulatory Guide ~~1.85~~ 1.84, except that cold-worked austenitic stainless steels shall be controlled by limiting hardness, bend radius, or the amount of induced strain.*

(a) Spool Piece Assembly

<i>Spool Piece Housing</i>	<i><u>ASME SA-182 Grade F304L, F304*, F316L, or F316* ASME SA-336 Grade F304* or F316*</u></i>
<i>Seal Housing</i>	<i><u>ASME SA-182 Grade F304L, F304*, F316L or F316* ASME SA-336 Grade F304* or F316*</u></i>
<i>Drive Shaft</i>	<i><u>ASME 479 Grade XM-19 ASTM A 479 Type 316**</u> <i>(Hard surfaced with <del>Colmonoy</del> Stellite No. 6)</i></i>
<i>Ball Bearings</i>	<i><u>ASTM A756 A 276 Type 440C**</u></i>
<i>Gland Packing Spring</i>	<i><u>Inconel X-750 AMS 5699 Alloy N07750**</u> <i>(Alloy X-750)</i></i>

(b) Ball Spindle	
Ball Screw Shaft	<u>ASTM A-564 TP630 Type 630 (17-4PH)**</u> <u>Condition H-1100</u>
Ball Nut	<u>ASTM A-564 TP630 Type 630 (17-4PH) **</u> <u>Condition H-1100</u>
Balls	<u>ASTM A756 A 580 Type 440C**</u>
Guide Roller	<u>Stellite No. 3, or equivalent nickel base alloy</u>
Guide Roller Pin	<u>Haynes Alloy No. 25, or equivalent ferrous base alloy</u>
Spindle Head Bolt	<u>Stellite No. 6B Haynes No. 6B</u>
Spindle Head Bushing	<u>Stellite No. 12</u>
Separation Spring	<u>Inconel X-750 ASTM B 637 or AMS 5699</u> <u>Alloy N07750**</u> <u>(Alloy X-750)</u>
Separation Magnet	<u>Alnico No. 5/ASTM A479 Type 316**/**</u>
(c) Buffer Mechanism	
Buffer Disk Spring	<u>Inconel X-750 ASTM B 637 or AMS 5542</u> <u>Alloy N07750**</u> <u>(Alloy X-750)</u>
Buffer Sleeve	<u>ASTM A 479 Type 316**/**<del>316L</del></u> <u>(Hard surfaced with Colmonoy No. 6)</u>
Guide Roller	<u>Stellite No. 3, or equivalent nickel base alloy</u>
Guide Roller Pin	<u>Haynes Alloy No. 25, or equivalent ferrous base alloy</u>
Stop Piston	<u>ASTM A 479 Type 316**/**<del>316L</del></u> <u>(Hard surfaced with Stellite No. 6)*</u>

(d)	Hollow Piston	
	<i>Piston Tube</i>	<del>XM-19</del> <u>ASTM A 312 Grade TPXM-19</u>
	<i>Piston Head Drive Piston</i>	<del>316L (Hardsurfaced with Stellite No. 3)</del> <u>ASTM A 479 Type 316*/** (Hard surfaced with Stellite No. 6)</u>
	<i>Latch</i>	<del>Inconel X-750</del> <u>ASTM B 637 Alloy N07750** (Alloy X-750)</u>
	<i>Latch Spring</i>	<del>Inconel X-750</del> <u>AMS 5699 Alloy N07750** (Alloy X-750)</u>
	<i>Bayonet Coupling</i>	<del>Inconel X-750</del> <u>ASTM B 637 Alloy N07750** (Alloy X-750)</u>
(e)	Guide Tube	
	<i>Guide Tube</i>	<del>316L</del> <u>ASTM A 312 Grade TP316*/**</u>
(f)	Outer Tube Assembly	
	<i>Outer Tube</i>	<del>XM-19</del> <u>ASTM A 312 Grade TPXM-19</u>
	<i>Middle Flange</i>	<del>ASME SA-182 Grade F304LC, F304*, F316L or F316*</del> <u>ASME SA-336 Grade F304* or F316*</u>
(g)	Miscellaneous Parts	
	<i>Ball for Check Valve</i>	<del>Haynes</del> <u>Stellite No.3, or equivalent cobalt base alloy</u>
	<i>O-Ring Seal (Between CRD ) Housing and CRD</i>	<del>321SS</del> <u>Type 321 stainless steel <del>Coated</del> coated with a qualified material</u>
	<i>CRD Installation Bolts</i>	<u>ASME SA-193 Grade B7</u>

\* The base material shall be qualified to ensure that it is free from sensitization. Carbon content specified to be 0.02% maximum.

\*\* Equivalent materials have been provided. Materials with similar chemical composition, mechanical properties, and operating experience are considered equivalent.

(2) *Special Materials*

~~The bayonet coupling, latch and latch spring, separation spring, and gland packing spring are fabricated from Alloy X-750 in the high temperature (1093°C) annealed condition, and aged 20 hours at 704°C to produce a tensile strength of ~~1137.7~~ 1103 MPa minimum, yield of ~~724~~ 689 MPa minimum, and elongation of 20% minimum. The ball screw shaft and ballnut are ASTM A 564, ~~Type TP-630 (17-4PH)~~ (or its equivalent) in condition H-1100 (aged 4 hours at 593°C), with a tensile strength of ~~965~~ 265.3 MPa minimum, yield of ~~795~~ 792.92 MPa minimum, and elongation of ~~15~~ 14% minimum.~~

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

*All materials for use in this system shall be selected for their compatibility with the reactor coolant as described in Articles NB-2160 and NB-3120 of the ASME Code.*

~~All materials, except SA479 or SA249 Grade XM-19, have been successfully used for the past at least ~~15~~ 25 to ~~30~~ 20 years in similar drive mechanisms. Extensive laboratory tests have demonstrated that ASME SA479 or SA249 Grade XM-19 are suitable materials and that they are resistant to stress corrosion in a BWR environment.~~

*No cold-worked austenitic stainless steels except those with controlled hardness or strain are employed in the Control Rod Drive (CRD) System. During fabrication and installation, special controls are used to limit the induced strain, and the bend radii are kept above a minimum value.*

#### 4.5.1.2 Austenitic Stainless Steel Components

(1) *Processes, Inspections and Tests*

*All austenitic stainless steels are used in the solution heat treated condition. In all welded components which are exposed to service temperature exceeding 93°C, the carbon content of 300 series stainless steel is limited not to exceed 0.020%. On qualification, there is a special process employed which subjects selected 300 series ~~Series~~ stainless steel components to temperatures in the sensitization range. The drive shaft, buffer sleeve, piston head and buffer are hard surfaced with Colmonoy 6 (or its Stellite 6 equivalent). ~~Colmonoy (or its equivalent) hard~~ Hard-surfaced components have performed successfully for the past ~~25~~ 15 to ~~30~~ 20 years in drive mechanisms. It is normal practice to remove some CRDs at each refueling outage. At this time, ~~the Colmonoy (or its equivalent) hard surfaced parts are~~ accessible for visual examination. This inspection program is adequate to detect any incipient defects before they could become serious enough to cause operating problems (see Subsection 4.5.3.1 for COL license information). The degree of conformance to Regulatory Guide 1.44 is presented in Subsection 4.5.2.4.*

#### 4.5.1.4 Cleaning and Cleanliness Control

Site or warehouse storage specifications require inside heated storage comparable to Level B of ANSI N45.2.2 NQA-1, Part II, Subpart 2.2.

#### 4.5.2.1 Material Specifications

##### **Materials Used for the Core Support Structure:**

- **Shroud Support**—Niobium modified Nickel-Chromium-Iron Alloy 600 per ASME Code Case No. N-580-1-Nickel-Chrome-Iron-Alloy, ASME SB166 or SB168
- **Shroud, Core Plate, and Grid**—ASME SA-240 Type 316L, SA182, SA-479 Type 316L, SA312, SA249, or SA213 (all Type 304L or 316L) SA-182 Grade F316L
- **Peripheral Fuel Supports**—ASME SA312 Grade Type 304L or 316L SA-479 Type 316\*
- **Core Plate and Top Guide Studs, Nuts, and Sleeves**—ASME SA-479 (Type 304, 316, or XM19) (all parts); or SA-193 Grade B8 Type 304 (studs); or SA-194 Grade 8 (Type 304) (nuts); or SA-479 (Type 304L or 316L), SA-182 (Grade F304L or F316L), SA-213 (Type 304L, 316 or 316L), SA-249 (Type 304L, 316, or 316L) (sleeves) ASME SA-479 Type 316\* and XM-19
- **Control Rod Drive Housing**—ASME SA-312 Grade TP304L or 316L SA-182 Grade F304L or F316L, and ASME SA-351 Type CF3 (Type 304L) or Type CF3M (Type 316L) ASME SA-336 Grade F316\*
- **Control Rod Guide Tube**—ASME SA-351 Type CF3 or CF3M, or SA-358, SA-312, or SA-249 (Type 304L or 316L) ASME SA-312 Grade TP316\* (Body), SA-479 Type XM-19 (Base), SA 312 Grade TPXM-19 (Sleeve)
- **Orificed Fuel Support**—ASME SA-351 Grade CF3 Type CF3 (Type 304L) or CF3M (Type 316L)
- The base material shall be qualified to assure that it is free from sensitization. Carbon content is specified to be 0.02% maximum.

##### **Materials Employed in Shroud Head and Separator Assembly and Steam Dryer Assembly:**

All materials are ~~304L or 316L~~ stainless steel except castings, Steam Dryer Vanes, and Steam Dryer Seismic Blocks.

- **Plate, Sheet and Strip**—ASTM A 240 Type ~~304L or 316L~~ and Strip
- **Forgings**—ASTM A182 Grade ~~304L or F316L~~ or A 336 Grade F316L
- **Bars**—ASTM A276 Type ~~316L or 304L~~ ASTM A 479 Type 316L
- **Pipe**—ASTM A 312 Grade TP-~~304L or 316L~~

- Tube—ASTM A269 Grade TP-~~304L~~ or 316L
- Castings<sup>1</sup> ASTM A 351 Grade CF3~~CF8~~, ~~CF8M~~
- Steam Dryer Seismic Blocks—ASTM A 240 Type XM-19
- Steam Dryer Vanes—ASTM A 240 Type 304L or 316L

*All core support structures are fabricated from ASME specified materials, and designed in accordance with requirements of ASME Code Section III, Subsection NG. The other reactor internals are noncoded, and they are fabricated from ASTM or ASME specification materials or other equivalent specifications.*

#### 4.5.2.2 Controls on Welding

*Core support structures are fabricated in accordance with requirements of ASME Code Section III, Subsection NG-4000, and the examination and acceptance criteria shown in NG-5000. ~~Other internals are not required to meet ASME Code requirements. ASME Section IX B&PV Code requirements are followed in fabrication of core support structures.~~*

The internals, other than the core support structures, meet the requirements of the industry standards, e.g., ASME or AWS, as applicable. ASME B&PV Code Section IX qualification requirements are followed in fabrication of core support structures. All welds are made with controlled weld heat input.

#### 4.5.2.3 Non-Destructive Examination of Wrought Seamless Tubular Products

*Wrought seamless tubular products for CRD housings and peripheral fuel supports are supplied in accordance with ASME Section III, Class CS, which requires examination of the tubular products by radiographic and/or ultrasonic methods according to Paragraph NG-2550. ~~The examination will satisfy the requirements of NG-5000.~~ The stainless steel CRD housings (CRDHs), which are partially core support structures (inside the reactor vessel), serve as the reactor coolant pressure boundary outside the reactor vessel. The CRD housing material is supplied in accordance with ASME Section III Class 1 requirements. The CRDHs are examined and hydrostatically tested to the ASME Section III Class 1 requirements as well as Class CS requirements.*

#### 4.5.2.4 Fabrication and Processing of Austenitic Stainless Steel—Regulatory Guide Conformance

*Significantly cold-worked stainless steels are not used in the reactor internals except for vanes in the steam dryers; cold work is controlled by applying limits on hardness, bend radii and surface finished on ground surfaces. Furnace sensitized material are not allowed. Electroslag welding is not applied for structural welds. The delta ferrite content for weld materials used in welding austenitic stainless steel assemblies is verified on undiluted weld deposits for each heat or lot of filler metal and electrodes. The delta ferrite content is defined for weld materials as a minimum average 5-0 Ferrite Number (FN) minimum of 8 8-0 FN, with no individual reading less than 5 FN, average and 20 FN maximum. This ferrite content is considered adequate to prevent any micro fissuring (Hot Cracking) in austenitic stainless steel welds. This procedure complies with the requirements of Regulatory Guide 1.31.*

*The limitation placed upon the delta ferrite in austenitic stainless steel castings is 8% minimum and a maximum value of 20% 8FN (ferrite number) minimum and a maximum value of 20FN. The maximum limit is used for those castings designed for a 60 year life such as the fuel support pieces, in order to limit the effects of thermal aging degradation. Short in-reactor lifetime components such as the fuel tie plates do not require such a limit.*

*Proper solution annealing of the 300 series austenitic stainless steel is verified by testing per ASTM A262, "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels." Welding of austenitic stainless steel parts is performed in accordance with Section IX (Welding and Brazing Qualification) and Section II Part C (Welding Rod Electrode and Filler Metals) of the ASME B&PV Code. ~~Welded austenitic stainless steel assemblies require solution annealing to minimize the possibility of the sensitizing. However, welded assemblies are dispensed from this requirement when there is documentation that welds are not subject to significant sustained loads and assemblies have been free of service failure. Other reasons, in line with Regulatory Guide 1.44, for dispensing with the solution annealing are that (1) assemblies are exposed to reactor coolant during normal operation service which is below 93.3°C temperature or (2) assemblies are of material of low carbon content (less than 0.020%). These controls are employed in order to comply with the intent of Regulatory Guide 1.44.~~*

For ABWR, the primary method used to comply with the intent of Regulatory Guide 1.44 is to require low carbon content (<0.020%) for all 300 series stainless steels exposed to high temperature reactor water. Alternately, material use is restricted to low temperature locations (T<93°C). These controls comply with the intent of Regulatory Guide 1.44.

#### 4.5.2.5 Other Materials

*Materials, other than Type-300 stainless steel, employed in reactor internals are:*

- (1) S4479-Type XM-19 stainless steel*
- (2) SB166, 167, and 168, Nickel-Chrome-Iron (Alloy 600)-Niobium modified Alloy 600 per ASME Code Case No. N-580-1*
- (3) S4637 Grade 688 Alloy X-750 ASTM B 637 or ASME SB-637, AMS 5542, AMS 5699 UNS N07750 (Alloy X-750) or equivalent*

~~Alloy 600 tubing, plate, and sheet are used in the annealed condition. Bar may be in the annealed or cold drawn condition.~~ All Nb-modified Alloy 600 is used in the solution annealed condition.

~~Alloy X-750 components are fabricated in the annealed or equalized condition and aged when required. Where maximum resistance to stress corrosion is required, Alloy X-750 the material is used in the high temperature (20001093°C) annealed plus single aged condition.~~

~~Stellite 6 (or its equivalent) hard surfacing is applied to the austenitic stainless steel HPCF couplings using the gas tungsten arc welding or plasma arc surfacing processes.~~ Hard chromium plating surface is applied to the austenitic stainless steel HPCF couplings.

~~All materials, except SA479 Grade XM-19, have been successfully used for at least 25 years in BWR applications.~~ the past 15 to 20 years in BWR applications. Extensive laboratory tests have demonstrated that XM 19 is a suitable material and that it is resistant to stress corrosion in a BWR environment.

### 4.5.3 COL License Information

#### 4.5.3.1 CRD Inspection Program

The following standard supplement addresses COL License Information Item 4.4.

CRD condition and integrity are monitored by a routine visual inspection of a selected sample of CRDs during each outage period. The number and selection process for the CRDs is based on vendor recommendations and included in the preventive maintenance program. CRD performance is monitored under the provisions of the Maintenance Rule, and this monitoring coupled with the CRD inspections detects incipient defects before they become serious enough to cause operating problems. The CRD nozzle and bolting are included in the inservice inspection program. CRD bolting is accessible for inservice examinations during normally scheduled CRD maintenance.