4.5 Reactor Materials

The 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

STD DEP Vendor

4.5.1 Control Rod Drive System Structural Materials

4.5.1.1 Material Specifications

STD DEP 4.5-1

(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 reactor pressure boundary of *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

Spool Piece Housing	*ASME* SA-*182*/182M *Grade F304L*, F304*, F316L, F316*or ASME SA-336/336M Grade F304*, F316*
Seal Housing	*ASME* SA-*182*/182M *Grade F304L*, F304*, F316L, F316* or ASME SA-336/336M Grade F304*, F316*
Drive Shaft	*~~ASME 479 Grade XM~~*ASME SA-479/479M Type 316*, 316L or ASTM A479/479M Type 316*/**, 316L** *(Hard surfaced with ~~Colmonoy No. 6~~*Colmonoy No.6 or equivalent Nickel base alloy*)*
Ball Bearings (in water)	*ASTM* A756 Type440C** or*~~A756~~* A 276 *Type 440C**

Ball Bearings (in air)	AISI 52100**
Gland Packing Spring	~~*Inconel X-750*~~ AMS 5699 Alloy N07750** (Alloy X-750)
Separation Spring	AMS 5699 Alloy N07750** (Alloy X-750)
Separation Magnet	Alnico No. 5 and ASME SA-479/479M Type 316*, 316L or ASTM A479/479M Type 316*/**, 316L**

(b) Ball Spindle

Ball Screw Shaft	ASME SA-564/564M Type 630 Condition H-1100 or *ASTM A-564*/564M ~~*TP630*~~ Type 630 *(17-4PH)***
	Condition H-1100
Ball Nut	ASME SA-564/564M Type 630 Condition H-1100 or *ASTM A-564*/564M ~~*TP630*~~ Type 630 *(17-4PH)* **
	Condition H-1100
Balls	*ASTM* A756 Type 440C** or ~~*A756*~~ A 580/580M *Type 440C*** or A276 Type 440C**
Guide Roller	*Stellite No. 3*, or nickel base alloy
Guide Roller Pin	~~*Haynes Alloy No. 25,*~~ ASME SA-479/479M Type XM-19 (Nitrided) or ASTM A479/479M Type XM-19** (Nitrided) or equivalent ferrous base alloy
Spindle Head Bolt	~~*Stellite No. 6B*~~ Stellite No. 6B**
Spindle Head Bushing	*Stellite No. 12***
~~*Separation Spring*~~	~~*Inconel X-750*~~
~~*Separation Magnet*~~	~~*Alnico No. 5/*~~

(c) Buffer Mechanism

Buffer Disk Spring	ASME SB-637 Alloy N07750 or~~*Inconel X-750*~~ ASTM B 637 Alloy N07750**or AMS 5542 Alloy N07750**
	(Alloy X-750)
Buffer Sleeve	ASME SA-479/479M Type 316*,316L (Hard surfaced with Colmonoy No.6) or ASTM A 479/479M Type 316*/**~~*316L*~~, 316L**
	(Hard surfaced with Colmonoy No. 6)
Guide Roller	*Stellite No. 3*, or nickel base alloy

Guide Roller Pin	~~*Haynes Alloy No. 25,*~~ ASME SA-479/479M Type XM-19 (Nitrided) or ASTM A479/479M Type XM-19** (Nitrided) or equivalent ferrous base alloy
Stop Piston	ASME SA-479/479M Type 316*,316L (Hard surfaced with Stellite No.6) or ASTM A 479/479M Type 316*/**~~*316L*~~, 316L**
	(Hard surfaced with Stellite No. 6)~~*~~

(d) Hollow Piston

Piston Tube	ASME SA-312/312M Grade TPXM-19 or~~*XM-19*~~ ASTM A 312/312M
	Grade TPXM-19
~~*Piston Head*~~ Drive Piston	ASME SA-479/479M Type 316*, 316L (Hard surfaced with Stellite No.6) or~~*316L (Hardsurfaced with Stellite No. 3)*~~ ASTM A 479/479M Type 316*/** 316L**
	(Hard surfaced with Stellite No. 6)
Latch	~~*Inconel X-750*~~ ASME SB-637 Alloy N07750 or ASTM B 637 Alloy N07750**
	(Alloy X-750)
Latch Spring	~~*Inconel X-750*~~ AMS 5699 Alloy N07750**
	(Alloy X-750)
Bayonet Coupling	ASME SB-637 Alloy N07750 or ~~*Inconel X-750*~~ ASTM B 637 Alloy N07750**
	(Alloy X-750)

(e) Guide Tube

Guide Tube	~~*316L*~~ ASME SA-312/312M Grade TP316*, TP316L or ASTM A 312/312M Grade TP316*/**, TP316L**

(f) Outer Tube Assembly

Outer Tube	ASME SA-312/312M Grade TPXM-19 or ~~*XM-19*~~ ASTM A 312/312M Grade TPXM-19**
Middle Flange	*ASME SA-~~182~~/182M Grade F304L~~C~~,* F304*, F316L, F316* or ASME SA-336/336M Grade F304*, F316*

(g) Miscellaneous Parts

Ball for Check Valve	~~*Haynes*~~ *Stellite No.3,* or equivalent cobalt base alloy
O-Ring Seal (Between CRD Housing and CRD)	~~*321SS*~~ Type 321 stainless steel ~~*Coated*~~coated *with a qualified material*
CRD Installation Bolts	*ASME SA-~~193~~/193M Grade B7*

* The material shall be qualified to ensure that it is free from sensitization. Carbon content specified to be 0.020% 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~~*solution heat treated *condition, and aged 20 hours at 704°C to produce a tensile strength of ~~1137.7~~* 1034 *MPa minimum, yield of ~~724~~* 655 *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~~* yield strength 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~~*Special *materials,* (X-750, 17-4PH)*~~except SA479 or SA249 Grade XM-19,~~ have been successfully used for ~~the~~ ~~past~~* at least *~~15 to 20~~*25 *years in similar*

drive mechanisms (LPCRD or FSCRD). ~~*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

STD DEP 4.5-1

(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*~~ drive piston, stop piston~~*head and buffer*~~ *are hard surfaced with* ~~*Colmonoy 6 (*~~Colmonoy No.6 *or* ~~*its /*~~an *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

STD DEP 4.5-1

STD DEP Vendor

Semiannual examination of 10% of the units humidity indicators is required to verify that the units are dry and in satisfactory condition. This inspection shall be performed with a ~~*GE Engineering*~~ *designated representative present. The position indicator probes are not subject to this inspection.*

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 Reactor Materials

STD DEP 4.5-1

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-580-2-~~*Nickel Chrome Iron Alloy, ASME SB166 or SB168*~~

- ***Shroud, Core Plate, and Grid***—ASME SA-240/240M Type 316L or Type 316* and SA479/479M Type XM-19, ~~*SA182,*~~ SA-479/479 Type 316L, ~~*SA312, SA249, or SA213 (all Type 304L or 316L)*~~SA-182/182M Grade F316L

- ***Peripheral Fuel Supports***—**ASME** ~~*SA312 Grade Type 304L or 316L*~~SA-479/479M Type 316* or Type 316L

- ***Core Plate and Top Guide Studs, Nuts, and Sleeves***~~—*ASME SA-479 (Type 304, 316, or XM 19) (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-479/479M Type 316* or Type 316L 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-336/336M Grade F316* or ASME SA-312/312M TP316*

- ***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-312/312M Grade TP316* or Type 316L (Body), SA-479/479M Type XM-19 (Base), SA 312/312M Grade TPXM-19 (Sleeve)

- ***Orificed Fuel Support***—*ASME SA-351*/351M *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*~~or ASME SA-240/240M Type 316L

- *Forgings—ASTM A182 Grade* ~~*304L or*~~ F*316L* or ASME SA-182/182M Grade F316L

- *Bars*~~—*ASTM A276 Type 316L or 304L*~~ ASTM A 479 Type 316L or ASME SA-479/479M Type 316L

- *Pipe—ASTM A 312 Grade TP ~~304L or~~316L* or ASME SA-312/312M Grade TP 316L
- *Tube—ASTM A269 Grade TP ~~304L or~~ 316L* or ASME SA-312/312M Grade TP 316L or SA-403/403M WP 316L
- *Castings—ASTM A 351 Grade* CF3~~*CF8, CF8M*~~or ASME SA-351/351M Grade CF3
- Steam Dryer Seismic Blocks—ASTM A 240 Type XM-19 or ASME SA-240/240M Type XM-19
- Steam Dryer Vanes—ASTM A 240 Type 304L or 316L or ASME SA-240/240M 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

STD DEP 4.5-1

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

STD DEP 4.5-1

~~*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

STD DEP 4.5-1

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

STD DEP 4.5-1

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

(1) ~~SA479~~ 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-580-2

(3) ~~SA637 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 (~~2000~~1093°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~~ A 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.