

4.5 Reactor Materials

4.5.1 Control Rod and Drive System Structural Materials

4.5.1.1 Materials Specifications

The parts of the control rod drive mechanisms and control rod drive line exposed to reactor coolant are made of metals that resist the corrosive action of the coolant. Three types of metals are used exclusively: stainless steels, nickel-chromium-iron alloys, and, to a limited extent, cobalt-based alloys. These materials have provided many years of successful operation in similar control rod drive mechanisms. In the case of stainless steels, only austenitic and martensitic stainless steels are used. Where low or zero cobalt alloys are substituted for cobalt-based alloy pins, bars, or hard facing, the substitute material is qualified by evaluation or test.

Pressure-containing materials comply with the ASME Code, Section III. The material specifications for portions of the control rod drive mechanism that are reactor coolant pressure boundary are included in Table 5.2-1. These parts are fabricated from austenitic (Type 316, 316L, 316LN and Type 304, 304L, 304LN) stainless steel. Nickel-chromium-iron alloy (Alloy 690) is used for the reactor vessel head penetration. For pressure boundary parts, austenitic stainless steels are not used in the heat-treated conditions which can cause susceptibility to stress-corrosion cracking or accelerated corrosion in pressurized water reactor coolant chemistry and temperature environments. Pressure boundary parts and components made of stainless steel do not have specified minimum yield strength greater than 90,000 psi.

The material selection is based in part on the duty cycle specified for the control rod drive mechanisms and control rods. The materials are specified so that the components do not suffer adverse effects, such as excessive wear or galling, as a result of a minimum 300 trips from full power and 60 coupling and decoupling cycles of the drive rod coupling assembly. The material for the control rod drive mechanisms and the control rod assemblies are selected for acceptable performance. That is, the design goal is to achieve a service life of 9×10^6 full-step cycles. Inspection or changes in operation indicate the need for replacement or refurbishment. The worst case result of undetected wear of a control rod drive mechanism or drive rod is a rod assembly drop or a failure to drop an assembly during a trip. Both events are accounted for in safety analyses. The pressure boundary components are not subject to significant wear due to stepping cycles.

Internal latch assembly parts are fabricated of heat-treated martensitic and austenitic stainless steel. Heat treatment is such that stress-corrosion cracking is not initiated. Components and parts made of stainless steel do not have specified minimum yield strength greater than 90,000 psi. Magnetic pole pieces are immersed in the reactor coolant and are fabricated from Type 410 stainless steel. Nonmagnetic parts, except shims, pins, and springs, are fabricated from Type 304 stainless steel. A cobalt alloy or qualified substitute is used to fabricate the latch, link, and link pins. Springs and shims are made from nickel-chromium-iron alloy (Alloy X-750 and Alloy 625). Lock screws are fabricated of Type 316 stainless steel. Latch arm tips fabricated of stainless steel may be surfaced with a suitable hard facing material to provide improved resistance to wear. Hard chrome plate is used selectively for bearing and wear surfaces.

The drive rod assembly is also immersed in the reactor coolant and uses a Type 410 stainless steel drive rod. The drive rod coupling is machined from Type 403 or 410 stainless steel. The protective sleeve and disconnect button are also Type 410 stainless steel. The remaining parts are Type 304 or Type 304L stainless steel with the exception of the springs, button retainer, and locking button, which are fabricated of nickel-chromium-iron alloy.

The absorber rodlets in the rod control cluster assemblies and the gray rod cluster assemblies are closed stainless steel tubes (cladding) containing absorber material. The other rodlets in the gray rod cluster assemblies are constructed of a material similar to the stainless steel cladding of the absorber rods. The stainless steel cladding isolates from the reactor coolant, the absorber material, and other substances inside the tubes. The containment function of the control rod cladding and the effects of neutron flux in the control rod materials are addressed in Section 4.2. The outside surface of the absorber and other rodlets is chromium plated to enhance resistance to wear due to the stepping motion and vibration of the rods. The rods included in one rod control cluster assembly or gray rod cluster assembly are attached at the top to a common hub which connects with the drive rod of the control rod drive mechanism. The hub is fabricated of type 316 stainless steel.

The coil housing is exposed to containment atmosphere and requires a magnetic material. Low carbon cast steel and ductile iron are qualified by tests or other evaluations for this application. The finished housings are electroless nickel plated to provide resistance against general corrosion.

Coils are wound on composite bobbins, with double glass-insulated copper wire. Coils are vacuum impregnated with silicone varnish. A wrapping of mica sheet is secured to the coil outside diameter. The result is a well-insulated coil capable of sustained operation at 392°F (200°C).

4.5.1.2 Fabrication and Processing of Austenitic Stainless Steel Components

The discussions provided in subsection 5.2.3.4 concerning the processes, inspections, and tests on austenitic stainless steel components to prevent increased susceptibility to intergranular corrosion caused by sensitization are applicable to the austenitic stainless steel pressure-housing components of the control rod drive mechanism. The discussions provided in subsection 5.2.3.4, concerning the control of welding of austenitic stainless steels especially control of delta ferrite are also applicable. Subsection 5.2.3.4 discusses the compliance with the guidelines of Regulatory Guides 1.31, 1.34, and 1.44. The welded control rod drive mechanism austenitic stainless steels that come into contact with the primary reactor coolant meet the guidance of Regulatory Guide 1.44.

4.5.1.3 Other Materials

For the cobalt alloy used to fabricate the latch, link, and link pins in latch assemblies, stress-corrosion cracking has not been observed in this application. Where hardfacing material is used in the latch assembly, a cobalt base alloy equivalent to Stellite-6 or qualified low or zero cobalt substitute is used. Low or zero cobalt alloys used for hardfacing or other applications where cobalt alloys have been previously used are qualified using wear and corrosion tests. The corrosion tests qualify the corrosion resistance of the alloy in reactor coolant. Low cobalt or cobalt free wear

resistant alloys considered for this application include those developed and qualified in industry programs.

The springs in the control rod drive mechanism are made from nickel-chromium-iron alloy (Alloy 750), ordered to Aerospace Material Specification (AMS) 5698 or AMS 5699 with additional restrictions on prohibited materials. Operating experience has shown that springs made of this material are not subject to stress-corrosion cracking in pressurized water reactor primary water environments. Alloy 750 is not used for bolting applications in the control rod drive mechanisms.

4.5.1.4 Contamination Protection and Cleaning of Austenitic Stainless Steel

The control rod drive mechanisms are cleaned prior to delivery in accordance with the guidance provided in NQA-1 (see Chapter 17). Process specifications in packaging and shipment are discussed in subsection 5.2.3. Westinghouse personnel conduct surveillance of these operations to verify that manufacturers and installers adhere to appropriate requirements as described in subsection 5.2.3.

Tools used in abrasive work operations on austenitic stainless steel, such as grinding or wire brushing, do not contain and are not contaminated with ferritic carbon steel or other materials that could contribute to intergranular cracking or stress-corrosion cracking.

4.5.2 Reactor Internal and Core Support Materials

4.5.2.1 Materials Specifications

The major core support material for the reactor internals is SA-182, SA-336, SA-376, SA-479, or SA-240 Types 304, 304L, 304LN, or 304H stainless steels. Fabricators performing welding of any of these materials are required to qualify the welding procedures for maximum carbon content and heat input for each welding process in accordance with Regulatory Guide 1.44. For threaded structural fasteners the material used is strain hardened Type 316 stainless steel and for the clevis insert-to-vessel bolts either UNS N07718 or N07750. Remaining internals parts not fabricated from Types 304, 304L, 304LN, or 304H stainless steels typically include wear surfaces such as hardfacing on the radial keys, clevis inserts, alignment pins (Stellite™ 6 or 156 or low cobalt hardfacing); dowel pins (Type 316); hold down spring (Type 403 stainless steel (modified)); clevis inserts (UNS N06690); and irradiation specimen springs (UNS N07750). Instrument guide assembly materials that are not Types 304, 304L, 304LN, or 304H stainless steel are the guide bushings and guide stud tip (UNS S21800) and the instrument guide tube spring (UNS N07718). Core support structure and threaded structural fastener materials are specified in the ASME Code, Section III, Appendix I as supplemented by Code Cases N-60 and N-4. The qualification of cobalt free wear resistant alloys for use in reactor coolant is addressed in subsection 4.5.1.3.

The use of cast austenitic stainless steel (CASS) is minimized in the AP1000 reactor internals. If used, CASS will be limited in carbon (low carbon grade: L grade) and ferrite contents and will be evaluated in terms of thermal aging effects.

The estimated peak neutron fluence for the AP1000 reactor internals has been considered in the design. Susceptibility to irradiation-assisted stress corrosion cracking or void swelling in reactor

internals identified in the current pressurized water reactor fleet are being addressed in reactor internals material reliability programs. The selection of materials for the AP1000 reactor internals considers information developed by these programs. Ni-Cr-Fe Alloy 600 is not used in the AP1000 reactor internals.

4.5.2.2 Controls on Welding

The discussions provided in subsection 5.2.3.4 are applicable to the welding of reactor internals and core support components.

4.5.2.3 Nondestructive Examination of Tubular Products and Fittings

The nondestructive examination of wrought seamless tubular products and fittings is in accordance with ASME Code, Section III, Article NG-2500. The acceptance standards are in accordance with the requirements of ASME Code, Section III, Article NG-5300.

4.5.2.4 Fabrication and Processing of Austenitic Stainless Steel Components

The discussions provided in subsection 5.2.3.4 and Section 1.9 describes the conformance of reactor internals and core support structures with Regulatory Guides 1.31 and 1.44.

The discussion provided in Section 1.9 describes the conformance of reactor internals with Regulatory Guides 1.34 and 1.71.

4.5.2.5 Contamination Protection and Cleaning of Austenitic Stainless Steel

The discussions provided in subsection 5.2.3 and Section 1.9 are applicable to the reactor internals and core support structures describe the conformance of the process specifications with Regulatory Guide 1.37. The process specifications follow the guidance of NQA-1 (Reference 1).

4.5.3 Combined License Information

This section has no requirement for additional information to be provided in support of the Combined License application.