

6.0 Engineered Safety Features

Engineered safety features (ESF) mitigate the consequences of accidents by maintaining the integrity of the fuel cladding, the reactor coolant pressure boundary, and the primary reactor containment; and by limiting releases of radioactive material so that offsite and main control room doses meet the criteria of 10 CFR 52.47(a)(2)(iv) and GDC 19, respectively.

Table 15.0-8 identifies the ESFs used to mitigate the consequences of postulated events in the accident analyses described in Chapter 15.

6.1 Engineered Safety Features Materials

6.1.1 Metallic Materials

This section provides information on the selection of materials and the fabrication methods for ESF components, addresses the compatibility of the materials with the specific fluids to which they are subjected, addresses the cleaning of components, and discusses thermal insulation of the ESF components. Components used in ESF systems are fabricated to quality standards commensurate with the importance of the safety functions to be performed, in compliance with 10 CFR 50.55a. The ESF components are fabricated of materials recognized by the ASME Boiler and Pressure Vessel Code (BPV), Section III (Reference 1) as acceptable for uses consistent with the assigned Code Class (GDC 1).

ESF construction materials are compatible with the fluids to which they may be exposed during normal operation, maintenance, testing, and postulated accident conditions (GDC 4). To maintain the integrity of the reactor coolant pressure boundary (RCPB), ESF components that are part of, or interface with, the RCPB are fabricated of materials that provide a low probability of significant degradation or rapidly propagating fracture (GDC 14, GDC 31). Section 5.2.3 provides additional information on the RCPB materials.

The safety injection system/residual heat removal system (SIS/RHRS) provides the emergency core cooling function for the U.S. EPR. Materials of the SIS/RHRS are selected in accordance with appropriate quality standards to enhance the likelihood of achieving the necessary emergency core cooling in case of an accident (GDC 35).

Combustible gas control in containment is addressed in Section 6.2.5.

Processes for welding, heat treating, and nondestructive examination of ESF components are controlled in accordance with applicable codes and standards to avoid conditions adverse to quality. Controls for cleaning ESF materials and equipment are in accordance with RG 1.37 and provide assurance that contaminants to which they could be exposed will not damage or deteriorate the materials, alter their properties,

accelerate aging, or increase susceptibility to stress corrosion cracking. Process controls during plant construction are covered under the appropriate quality assurance program (Section 17.2).

Section 3.2 identifies the quality groups assigned to ESF components. Materials for Quality Group A, Quality Group B, and Quality Group C components meet the requirements of Article NB-2000, Article NC-2000, and Article ND-2000 respectively, of Division 1 of Reference 1.

6.1.1.1 Materials Selection and Fabrication

Table 6.1-1—Pressure-Retaining Material Specifications for Engineered Safety Features lists the fabrication materials used in the principal pressure-retaining ESF components. Materials for the main control room air conditioning system are identified in Section 9.4.1. Base and welding materials for the SIS/RHRS, in-containment refueling water storage tank system (IRWST), extra borating system (EBS), and annulus ventilation system are austenitic stainless steel and ferritic steel. Materials are selected for their compatibility with reactor coolant and borated water from the in-containment refueling water storage tank and the extra borating system as required by Paragraph NX-2160 and Subsubarticle NX-3120 as appropriate for the assigned ASME Code Class. Materials exposed to core coolant or borated water are corrosion resistant austenitic stainless steel materials; therefore, they have a corrosion allowance of 0.00 in. Materials that are not exposed to core coolant or borated water may be ferritic materials, which have a corrosion allowance of 1/16 in. Pressure-retaining ESF materials are selected from material specifications permitted by Division 1 of Reference 1 as identified in Parts A, B, and C of the ASME BPV Code Section II (Reference 2). Acceptable Code Cases described by RG 1.84 may be used with the above ASME specifications. Section 5.2.1.1 identifies the design baseline ASME Code edition and addenda.

Unstabilized austenitic stainless steel used in ESF component fabrication is provided in the solution annealed and rapidly cooled condition to optimize the resistance to intergranular corrosion in accordance with RG 1.44. Sensitized austenitic stainless steel material is not used in the ESF components. The delta ferrite content of the weld filler material is controlled as required by RG 1.31. A COL applicant that references the U.S. EPR design certification will review the fabrication and welding procedures and other QA methods of ESF component vendors to verify conformance with RGs 1.44 and 1.31. Austenitic stainless steel base metal has a limited carbon content not exceeding 0.03 wt%.

Austenitic stainless steels are used extensively throughout ESF systems in current operating nuclear power plants, including locations that may be exposed to coolant during a LOCA with minimum degradation. These materials are chosen for their general corrosion resistance and ease of fabrication for the required applications.

Following RG1.44 helps to minimize the potential stress corrosion degradation of austenitic stainless steels in the ESF systems environment, as shown through operational experience.

No cold-worked grade austenitic stainless steels are used in the ESF components.

Abrasive work on austenitic stainless steel is controlled to minimize the cold-working of surfaces and the introduction of contaminants that promote stress corrosion cracking per RG 1.37. Tools for abrasive work (e.g., grinding, polishing, wire brushing) do not contain, and are not contaminated by previous usage on, ferritic carbon steel or other materials that could contribute to intergranular cracking or stress-corrosion.

Ferritic materials used in ESF applications meet the fracture toughness requirements of the ASME Code Section III, Subarticles NB-2300, NC-2300, and ND-2300, as appropriate for the assigned quality group as stated in Section 3.2.2. The minimum preheat for welding of low alloy ferritic materials is in accordance with Appendix D (Article D-1000) of ASME Section III, Division I and RG 1.50. Moisture control on low hydrogen welding materials conforms to the requirements of the ASME Code, Section III, Articles NB, NC, or ND-2000 and 4000, and AWS D1.1 (Reference 3).

Nickel-base alloy base materials with primary pressure retaining applications are used in the solution annealed and thermally treated condition to optimize resistance to intergranular corrosion. The use of nickel-base alloys in primary pressure-retaining ESF applications is limited to Alloy 690 and its associated weld metals (Alloys 52, 52M, and 152). The EPRI Report MRP-111 (Reference 4) details the prevention of and resistance to primary water stress corrosion cracking (PWSCC) in Alloy 690, 52/52M and 152 in pressurized water reactors (PWR). The report concludes that wrought Alloy 690 and its weld metals (Alloys 52/52M and 152) are highly corrosion resistant materials deemed acceptable for replacing Alloy 600 in PWR applications. No stress corrosion degradation of Alloy 690 materials had been observed in any replacement application as of the time MRP-111 was written (early 2004) and since the first use of Alloy 690 in PWRs (approximately 14 years).

During fabrication of ESF components, processing fluids and materials used for manufacture of austenitic stainless steel and high alloy components are controlled to preclude contamination of surfaces from chlorides, fluorides, and low melting point metals (e.g., lead, zinc, copper, and mercury).

The use of cobalt base hardfacing alloys are minimized in locations that are in contact with reactor coolant.

Welder qualification for areas of limited accessibility, and the monitoring and certifying of such welds, are performed in accordance with RG 1.71. The weld

materials used to join various ESF materials meet the requirements of the ASME Code as follows:

- Welding materials used for joining ferritic ESF materials are in conformance with the requirements of Reference 1 and with Reference 2, Part C Material Specifications SFA 5.5, 5.17, 5.18, 5.20, 5.23, 5.28, and 5.29.
- Welding materials used for joining austenitic stainless steel ESF materials are in conformance with the requirements of Section III of the ASME Code and with ASME Section II, Part C Material Specifications SFA 5.4, 5.9, and 5.22. Austenitic stainless steel welding materials have a carbon content not exceeding 0.03 wt%.
- Welding materials used for joining nickel-chromium-iron (NiFeCr) alloys in similar base material combination and in dissimilar ferritic or austenitic base material combination are in conformance with the requirements of Section III of the ASME Code and with ASME Section II, Part C Material Specifications SFA 5.11 and 5.14. Alloy 82/182 weld materials are not used in primary pressure retaining ESF applications.

6.1.1.2 ESF Fluids

The RCS water chemistry is controlled to minimize negative impacts of chemistry on materials integrity, fuel rod corrosion, fuel design performance, and radiation fields, and is routinely analyzed for verification. The water chemistry parameters are based on industry knowledge and industry experience as summarized in the EPRI PWR Primary Water Chemistry Guidelines (Reference 5). The parameters of the RCS water chemistry are addressed in Section 5.2.3, including additives for controlling reactivity, pH, and dissolved oxygen.

A passive system controls the pH of the water in containment after a loss of coolant accident, further limiting corrosion. In postaccident situations where the containment is flooded with water containing boric acid, pH is adjusted by releasing tri-sodium phosphate from storage baskets into the water draining to the IRWST (refer to Section 6.3). This raises the pH above 7.0, per the guidance of BTP 6-1, to reduce the probability of stress-corrosion cracking of austenitic stainless steel components. Refer to Section 15.0.3.12 for an evaluation of postaccident Reactor Building water chemistry control.

Containment spray is not part of the U.S. EPR design basis accident mitigation approach, although the design does include a limited containment spray system for severe accident mitigation that draws suction from the pH-controlled water of the IRWST, as described in Section 19.2.

As discussed above, ESF components are fabricated primarily from austenitic stainless steels, which are not susceptible to corrosion when exposed to these ESF fluids. For

ferritic steel materials, protective coatings are applied inside containment, as addressed in Section 6.1.2.

The use of aluminum and zinc in components in containment that could be exposed to postaccident conditions is minimized to avoid hydrogen gas generation. Combustible gas control in containment through the use of passive autocatalytic recombiners is addressed in Section 6.2.5.

Materials used in the fabrication of ESF components are designed, qualified, and procured to withstand postulated accident environments.

6.1.1.3 Component and Systems Cleaning

To prevent stress corrosion cracking, austenitic stainless steel materials used in the fabrication, installation, and testing of ESF components and systems are handled, protected, stored, and cleaned according to recognized and accepted methods, as identified in the applicable procedures and specifications. As applicable, these procedures and specifications supplement the equipment specifications and purchase order requirements of the individual austenitic stainless steel components or systems that are procured for the ESF components and systems, regardless of the ASME Code classification. The procedures and specifications follow the guidance of RG 1.37 and RG 1.44.

Where minor leaks are anticipated (e.g., valve packing and pump seals), only materials compatible with the coolant are used. In these areas, the ferritic materials will show increased general corrosion rates. However, component integrity can be verified because this corrosion can be readily observed during the inservice visual or nondestructive inspection programs.

6.1.1.4 Thermal Insulation

Portions of the ESF systems are insulated and portions within containment may be exposed to the insulation on the reactor coolant system (RCS) at their juncture with the RCPB, or other insulation if dislodged during an accident. The RCS insulation is primarily constructed of reflective stainless steel. Similarly, ESF systems insulation, from RCS to the first reactor coolant pressure boundary (RCPB) isolation valves, is primarily constructed of reflective stainless steel. Additional insulation for ESF systems inside containment, where required for plant personnel protection, is primarily constructed of reflective stainless steel. ESF systems insulation outside containment, where required for plant personnel protection, is primarily constructed of non-metallic insulation. The use of non-metallic insulation is controlled in accordance with RG 1.36. To prevent stress corrosion cracking, non-metallic insulation is designed with low leachable chloride and fluoride concentrations that do not exceed the limits identified in RG 1.36 relative to associated sodium and silicate concentrations.

Insulation on the reactor coolant pressure boundary is addressed in Section 5.2.3.

6.1.2 Organic Materials

Many surfaces within the U.S. EPR use organic and inorganic coatings for corrosion protection, or to facilitate surface decontamination. If these coatings were to detach from plant surfaces through delaminating, peeling, or flaking, they could be ingested into safety-related system components and impact the operation of engineered safety systems.

Coating degradation can result from exposure to the following conditions: abrasion or wear including high energy spray, corrosion in the presence of chemicals or liquids including chemical decontamination processes, localized high temperatures, and ionizing radiation. These degradation mechanisms could be present during plant operation, maintenance activities, or accident conditions. Enforcing coatings quality and classification system restrictions provides assurance of coating integrity under operating and accident conditions.

A listing of organic materials in the containment is maintained as equipment is installed and the materials are evaluated for their potential interaction with ESFs.

6.1.2.1 Description of Protective Coatings

Protective coatings are used both inside and outside the Reactor Containment Building. These two general areas are further categorized below. Protective coatings used in these various areas generally carry a Service Level I, II, or III designation depending on location and use.

Inside Containment

- Service Level I—Radiologically controlled areas (RCA) with a direct path to the IRWST (e.g., the coating on the containment's carbon steel liner) or other ESFs.
- Service Level II—Radiologically controlled areas with no direct path to the IRWST (e.g., isolated compartments within the containment) or other ESFs.

Outside Containment

- Service Level II—Radiologically controlled areas where coatings will not communicate with ESFs.
- Service Level III—Areas with a potential path to ESFs (e.g., coatings applied to the emergency diesel generators' air intakes or coatings applied to essential service water heat exchanger tube sheets).
- No Service Level—Balance of plant (BOP) — Non-radiologically controlled areas with no potential path to ESFs.

6.1.2.1.1 Coating Service Levels

Protective coatings are classified into service levels based on the potential impact of coating failure on ESFs. In addition, the type or system of coatings used depends on the material to be coated and the type of protection required. Coating service levels are described below, in accordance with guidance from RG 1.54, Revision 1 and ASTM D5144-00 (Reference 6).

6.1.2.1.1.1 Service Level I

The Service Level I coating classification refers to coatings applied to plant structures, systems or components (SSC) inside containment where failure could impair safe shutdown by adversely affecting the post-accident operation of fluid systems, including ESFs and safety-related functions of other plant SSC. This class of protective coatings is classified as safety related.

Service Level I coatings are appropriate for safety-related use within the plant and must be design basis accident (DBA) tested and DBA qualified. A DBA-qualified coating system, as defined in ASTM D5144-00, is a coating system used inside containment that has passed the required laboratory testing, including subsection to irradiation and a simulated DBA environment, and that has adequate quality documentation to support its use as DBA qualified. Once testing is completed, the coating system is evaluated in accordance with ASTM D3911-03 and plant licensing requirements for suitability. DBA testing provides reasonable assurance that, when properly applied and maintained, the coating will not detach under normal or accident conditions.

Service Level I coatings are also typically tested to validate their continued performance in other specific service environments. Service environments can include coated surface exposure to: abrasion or wear including high energy spray, corrosion in the presence of chemicals or liquids including chemical decontamination processes, and localized high temperatures. These coatings are selected to maximize service life and minimize maintenance, and therefore, maintain personnel dose exposure as low as reasonably achievable (ALARA).

6.1.2.1.1.2 Service Level II

The Service Level II coating classification is normally restricted to coatings used in RCAs outside of containment. The U.S. EPR defines the Service Level II coating classification as referring to coatings applied in RCAs both inside and outside of containment where coating failure could impair, but not prevent, normal operating performance. Service Level II coatings are used primarily to provide protection from corrosion and radiation exposure, and to aid in radionuclide decontamination of SSC located in RCAs. Failure of Service Level II coatings will not adversely affect the

function of ESFs. Therefore, these protective coatings are classified as non-safety related.

Service Level II coating systems are not DBA qualified. As noted in ASTM D5144-00, there are no specific testing or qualification requirements for Service Level II coatings. Selection of a coating system for a Service Level II area is based on industry operating experience for that particular coating or testing. Various standards may be considered for use when selecting a coating by testing methods, including ASTM D3912, ASTM D4060, ASTM D4082, ASTM D4541, and ASTM D5139.

Service Level II coatings are evaluated for continuous performance in specific service environments. Service environments can include coated surface exposure to: abrasion or wear, corrosion in the presence of chemicals or liquids including chemical decontamination processes, localized high temperatures, and ionizing radiation. Evaluation methods include the use of industry operating experience and:

- Tests replicating immersion coating conditions.
- Tests for related service conditions, including ionizing radiation.
- Physical tests (e.g., pull-off tests and abrasion tests).
- Chemical resistance tests.

These coatings are selected to maximize service life and minimize maintenance, and therefore, maintain personnel dose exposure ALARA.

6.1.2.1.1.3 Service Level III

Service Level III coatings are applied in non-RCAs outside of containment where detachment could adversely affect the safety function of a safety-related SSC. Therefore, this class of protective coatings is classified as safety related.

Service Level III coating systems are not DBA qualified, or resistant to ionizing radiation. However, Service Level III coatings are evaluated for adequate performance in specific service environments. Service environments can include coated surface exposure to: abrasion or wear, corrosion in the presence of chemicals or liquids including chemical decontamination processes, and localized high temperatures. Evaluation methods include the use of industry operating experience and:

- Tests replicating immersion coating conditions.
- Tests for related service conditions.
- Physical testing (e.g., pull-off tests and abrasion tests).
- Chemical testing.

These coatings are selected to maximize service life and minimize maintenance, and therefore, minimize risk to ESFs.

6.1.2.1.1.4 No Service Level

Coatings that have no service level are classified as balance of plant (BOP) and are used in non-RCAs. Failure of these coatings has no impact on the ESFs; therefore, they are classified as non-safety related.

BOP coatings are usually applied to protect surfaces of structures and equipment from exposure to one or a combination of the following conditions: abrasion or wear including maintenance activities, corrosion in the presence of chemicals or liquids including housekeeping activities, and localized high temperatures.

6.1.2.1.2 Material Selection

For each of the above coating service levels and plant application areas, various coating systems may be used, depending upon the material to be protected (i.e., substrate) and specific operating environment. Each coating type and its associated applications is summarized below and in Table 6.1-2.

6.1.2.1.2.1 Inside Containment

Carbon Steel – Service Level I

Carbon steel surfaces requiring Service Level I protection are normally coated with a Service Level I-qualified epoxy-type coating system. These coatings provide long-term protection of critical carbon steel surfaces (e.g., the containment's steel pressure boundary) and are qualified to remain intact following a DBA. Although epoxy coating systems are preferred, in certain cases such as high temperature applications (i.e., areas experiencing temperatures above 250°F), Service Level I-qualified inorganic zinc (IOZ) coating systems (not topcoated) are used. Although decontamination tests show that radiological activity is somewhat easier to remove from epoxy systems, both the IOZ and epoxy type systems are considered acceptable in terms of decontamination.

Steel surfaces in Service Level I areas subject to immersion during normal operating conditions are normally composed of stainless steel. In cases where the substrate is not composed of stainless steel, a Service Level I epoxy-type coating that has undergone service environment testing or evaluation may be applied.

Carbon Steel – Service Level II

For in-containment carbon steel components requiring Service Level II protection, both epoxy and IOZ-type systems (not top coated) are viable options. As with Service Level I applications, most structural steel supports, piping, pipe supports, stairways,

and tanks inside and outside containment will be coated with epoxy coating systems unless high temperatures (above 250°F) are experienced in the immediate area.

Steel surfaces in Service Level II areas subject to immersion during normal operating conditions are also normally composed of stainless steel. In cases where the substrate is not composed of stainless steel, a Service Level II epoxy-type coating that has undergone service environment testing or evaluation may be applied.

Galvanized Surfaces

In areas where painting is impractical, structural carbon steel components and other miscellaneous carbon steel items (e.g., stairs, decking, grating, ladders, railing, conduit, ducts, cable trays) may be hot-dip galvanized for corrosion protection. Hot-dip galvanization produces a zinc-rich surface layer bonded to the carbon steel substrate. This process is not considered to be a coating evolution, and does not require a service level designation.

The installation of galvanized surfaces is limited and tracked to allow control of the total amount zinc materials within the containment. This action supports hydrogen generation concerns as generated from zinc-based surfaces, and is discussed in Section 6.2.5.

Concrete – Service Level I

Concrete surfaces inside containment are coated primarily to reduce dusting, and to shield exposed substrates from chemical attack and radioactive liquid absorption. Unprotected concrete could be an ALARA concern in terms of both general area exposure and airborne dust.

Concrete floors surfaces inside containment requiring Service Level I protection (subject to both light and heavy traffic), and certain exposed concrete wall areas, are coated with a Service Level I-qualified epoxy-type coating system (non-self-leveling). Areas not subject to traffic or constant wear (e.g., ceilings, upper wall areas, bay areas), may require only a qualified epoxy sealer.

Surfaces in Service Level I areas subject to immersion in high-temperature borated water following a DBA are normally composed of stainless steel. In cases where the substrate is concrete, a Service Level I epoxy-type coating that has undergone service environment testing or evaluation may be applied when used in environments subject to temperatures below 250°F.

Concrete – Service Level II

Concrete floor surfaces inside containment requiring Service Level II protection (subject to both light and heavy traffic), and certain exposed concrete wall areas, are

coated with a Service Level II-qualified epoxy-type coating system (non-self-leveling). Areas not subject to traffic or constant wear (e.g., ceilings, upper wall areas, bay areas) may require only a qualified epoxy sealer.

Surfaces in Service Level II areas subject to immersion in high-temperature borated water following a DBA are normally composed of stainless steel. In cases where the substrate is concrete, a Service Level II epoxy-type coating that has undergone service environment testing or evaluation may be applied when used in environments subject to temperatures below 250°F.

6.1.2.1.2.2 Outside Containment

Carbon Steel – Service Level II

Exposed carbon steel surfaces outside containment in RCAs require Service Level II coating application to protect the surface from corrosion and abrasion or wear because of maintenance activities. These coatings must be resistant to ionizing radiation and are classified as non-safety related. Both epoxy and untopcoated IOZ-type Service Level II coatings are appropriate for application to carbon steel substrates in this case, with the latter preferred for higher temperature applications (i.e., above 250°F).

Surfaces in Service Level II areas subject to immersion during normal operating conditions are normally composed of corrosion resistant materials (e.g., stainless steel). In cases where carbon steel surfaces are exposed, a Service Level II epoxy-type coating that has undergone service environment testing or evaluation may be applied when used in environments subject to temperatures below 250°F.

Carbon Steel – Service Level III

Coatings may also be applied in non-RCAs located outside of containment. In certain areas, detachment could adversely affect the safety function of a safety-related SSC. Therefore, these coatings systems are safety related, and are classified as Service Level III coatings. Service Level III coatings are selected, specified, and applied in a manner that optimizes performance and standardization in each specific service environment. Both epoxy and non-top coated IOZ-type Service Level III coatings are appropriate for application to carbon steel substrates in this case, with the latter preferred for higher temperature applications (i.e., above 250°F).

Surfaces in Service Level III areas subject to immersion during normal operating conditions are normally composed of corrosion resistant materials (e.g., stainless steel). In cases where carbon steel surfaces are exposed, a Service Level III epoxy-type coating that has undergone service environment testing or evaluation may be applied when used in environments subject to temperatures below 250°F.

Galvanized Surfaces

As is the case inside containment, areas outside the containment where painting is impractical may be hot-dip galvanized for corrosion protection. This method of surface protection does not require service level designation.

Concrete – Service Level II

Concrete floor surfaces outside containment requiring Service Level II protection (subject to both light and heavy traffic) and certain exposed concrete wall areas are coated with a Service Level II-qualified epoxy-type coating system (non-self-leveling). Areas not subject to traffic or constant wear (e.g., ceilings, upper wall areas, bay areas) may require only a qualified epoxy sealer.

Surfaces in Service Level II areas subject to immersion during normal operating conditions are normally composed of corrosion resistant materials (e.g., stainless steel). In cases where concrete surfaces are exposed, or additional protection or corrosion control is necessary, a Service Level II epoxy-type coating that has undergone service environment testing or evaluation may be applied when used in environments subject to temperatures below 250°F.

6.1.2.1.2.3 Balance of Plant

For the balance of the plant, commercial-grade coatings are used and applied according to the expected service conditions. Although most structural steel supports, piping, pipe supports, stairways, and tanks outside containment are coated with epoxy-type coating systems, these coatings are not considered safety related because they do not have an impact on engineered safety functions. Therefore, these coatings do not require a service level assignment.

6.1.2.2 Safety Evaluation

6.1.2.2.1 Coating Integrity and Other Safety Measures

Service Level I coatings are used inside containment in areas where coatings failure and subsequent transport to the IRWST sump screens could result in recirculation flow blockage. The Service Level I coatings are tested and qualified to remain intact during a DBA and will not impact the operation of ESFs. Other design features also help to limit the amount of debris that will reach the IRWST following an accident, as follows:

1. Several screen defenses located upstream of the IRWST screens facilitate enhanced debris collection. Trash racks and retention baskets are installed upstream of the IRWST screens to intercept debris, limiting the amount of material reaching the screens. In addition, the weir at the base of the trash rack serves to restrain debris

entrained in the coolant pool volume that approaches the IRWST following a DBA. Section 6.3 provides an evaluation of solid debris that reaches the IRWST.

2. Although the U.S. EPR severe accident heat removal system (SAHRS) takes suction from the IRWST to provide a containment spray function during beyond design basis accidents, manual actuation following a DBA is possible. However, if containment spray were to be manually actuated during a DBA, the coating systems inside containment that could be contacted by containment spray would not be subject to chemical attack, as they would when subject to caustic spray, because of the near-neutral pH range of the suction source.
3. Components in the vicinity of the IRWST are composed of corrosion resistant materials (e.g., stainless steel). All materials within the IRWST or composing the IRWST are uncoated.

Service Level II coatings are not DBA qualified, but may be used inside containment in areas where failed coatings could not enter a safety-related system or reach the IRWST.

Service Level III coatings are qualified as safety related, but are not DBA qualified. Therefore, they are selected for use outside of containment in areas where detachment could adversely affect the function of a safety-related SSC.

In addition to failure and delamination, protective coatings can be a source of combustible hydrogen under certain conditions. The production of hydrogen from coatings and other organic and inorganic materials is addressed in Section 6.2.5. The evaluation assesses the potential for formation of coating decomposition products under DBA conditions, and also examines radiation and chemical effects.

In addition to coatings, other organic materials used in the plant are evaluated for their potential interaction with ESFs to confirm that safety functions are not affected.

6.1.2.2.2 Coating Repairs and Limitations on Coating Thickness

Approved maintenance and repair techniques are used on protective coatings, as documented in maintenance procedures specific to each coating system and type. This is particularly important with respect to coating thickness because the performance of coatings repairs hold the potential for increasing coating thicknesses beyond the qualified or manufacturer-recommended thicknesses. Therefore, localized repairs are performed in accordance with approved procedures, and do not generally involve over-coating. Coatings repair and maintenance are tracked by the coatings program, and these records are available for any required IRWST sump recirculation evaluations or other safety analyses.

6.1.2.3 Quality Assurance

Quality assurance programs provide confidence that safety-related coating systems inside and outside containment will perform as intended. This assurance is achieved through program control of procurement, application, and monitoring of Service Level I, II, and III coating systems. The quality assurance requirements for Service Level I coatings conform to the requirements of ASME NQA-1-1994 (Reference 7), ASTM D3843-00 (Reference 8), and 10 CFR 50, Appendix B, Criterion IX. The quality assurance requirements for Service Level III coatings conform to the requirements of ASME NQA-1-1994 and 10 CFR 50, Appendix B, Criterion IX.

The service level classifications of coatings are generally consistent with the guidance in RG 1.54, Revision 1 and associated standards, with the exception of the use of the Service Level II classification in some areas inside containment. Exceptions to RG 1.54, Revision 1 are identified in Section 6.1.2.4 and primarily involve the use of industry standards updated subsequent to the release of RG 1.54, Revision 1.

6.1.2.3.1 Special Processes

In accordance with ASTM D5144-00, the performance of Service Level I and III coatings work is considered a special process, as defined in 10 CFR 50, Appendix B, Criterion IX.

6.1.2.3.2 Service Level I Coatings

Service Level I coating systems must be DBA qualified, providing reasonable assurance that the coating will not detach under normal or accident conditions when properly applied and maintained. Additional testing of Service Level I coatings is performed as part of the coating selection process to verify performance in other specific service environments. To preclude the use of DBA-unqualified coatings in Service Level I areas, the procurement of Service Level I coatings used inside containment is considered a safety-related activity. Therefore, 10 CFR 50, Appendix B applies to Service Level I coatings procurement.

To the extent practical, all carbon steel vendor-manufactured components used within containment that require Service Level I protective coatings are procured coated in accordance with 10 CFR 50, Appendix B, Criterion IX (including pipe hangers, lighting, electrical panels, pumps, motors, and valve operators). If components cannot be procured with DBA-qualified coatings applied by the component manufacturer, a COL applicant that references the U.S. EPR design certification must do one of the following:

- Procure the component as uncoated and apply a DBA-qualified coating system in accordance with 10 CFR 50, Appendix B, Criterion IX.

- Confirm that the DBA-unqualified coating is removed and that the component is recoated with DBA-qualified coatings in accordance with 10 CFR 50, Appendix B, Criterion IX.
- Add the quantity of DBA-unqualified coatings to a list that documents those DBA-unqualified coatings already existing within containment.

6.1.2.3.3 Service Level II Coatings

Service Level II coating systems are not DBA qualified, but must be tested for resistance to ionizing radiation. As necessary, qualified plant personnel evaluate Service Level II coatings for suitability to specific service environments. Procurement of Service Level II coatings used inside and outside containment is not considered a safety-related activity.

6.1.2.3.4 Service Level III Coatings

Service Level III coating systems do not need to be DBA qualified or resistant to radiation. However, these safety-related coatings systems can be used in areas where detachment could adversely affect the safety function of safety-related SSC. Therefore, qualified plant personnel evaluate Service Level III coatings for suitability to specific service environments and confirm that their use will not impact safety functions. Generally, Service Level III coatings are available only as commercial grade. An accepted methodology (e.g., that outlined in EPRI NP-5652) is used to dedicate the procured coating for a safety-related application.

6.1.2.3.5 Protective Coating and Organic Materials Program

As stated within RG 1.54, Revision 1, the maintenance rule (10 CFR 50.65) includes in its scope safety-related structures, systems, and components. This includes any Service Level I protective coatings. Thus, in addition to the quality assurance programs summarized above, a protective coating and organic materials monitoring and maintenance program maintains control and qualification of applied coatings.

The program monitors the effectiveness of the protective coatings within its scope, or demonstrates that their performance is effectively controlled through preventive maintenance. The program includes the programmatic bases and guidelines, and the standards to which the plant has been licensed. These standards encompass quality assurance and control of coating system procurement and maintenance, and training qualification of protective coating inspectors and applicators. The procurement and application, or re-application, of new and existing coating systems are monitored through the program with respect to the coating type, service level of qualification required for application in each specific case, service level at which the coating is procured, and the significance and type of application (including information such as coating repair or replacement and resultant coating thickness, including overlapping areas).

The guidance provided by RG 1.54, Revision 1 is also used to assess the coatings on buried pipes and tanks. These coatings are evaluated to limit possible damage, based on the soils or other environment encasing the pipes and tanks.

6.1.2.4 Exceptions to Regulatory Guide 1.54, Revision 1

The following exceptions are taken to RG 1.54, Revision 1:

- ASTM D5139-01 (ASTM D5139-90, Re-approved in 2001) is used instead of RG 1.54, Rev. 1 endorsed ASTM D5139-96 (ASTM D5139-90, Re-approved in 1996).
- ASTM D3911-03 is used instead of RG 1.54, Rev. 1 endorsed ASTM D3911-95. The acceptance criteria that will be utilized for ASTM D3911-03 will be as follows:
 - Peeling shall not be permitted.
 - Delamination shall not be permitted.
 - Cracking is not considered a failure unless accompanied by delamination or loss of adhesion.
 - Blisters shall be limited to intact blisters that are completely surrounded by sound coating bonded to the surface.
- ANSI N101.2-1972, “Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities”, is an acceptable standard for qualification of Service Level 1 coatings. However, acceptance criteria to be used are the same as noted above for ASTM D3911-03.
- ASTM D4082-02 is used instead of RG 1.54, Rev. 1 endorsed D4082-95.
- ASTM D4537-04a is used instead of RG 1.54, Rev. 1 endorsed D4537-96.
- ASTM D5498-01 is used instead of RG 1.54, Rev. 1 endorsed D5498-94.
- ASTM D4227-05 is used instead of RG 1.54, Rev. 1 endorsed D4227-95.
- ASTM D4228-05 is used instead of RG 1.54, Rev. 1 endorsed D4228-95.
- ASTM D4286-99 (ASTM D4286-90, Re-approved in 1999) is used instead of RG 1.54, Rev. 1 endorsed ASTM D4286-96 (ASTM D4286-90, Re-approved in 1996).
- ASTM D5163-05a is used instead of RG 1.54, Rev. 1 endorsed D5163-96.
- ASTM D4541-02 is used instead of RG 1.54, Rev. 1 endorsed D4541-95.
- ASTM D3359-02 is used instead of RG 1.54, Rev. 1 endorsed D3359-95, Rev. A.
- ASTM D5962-96 is not used. It is not considered to be an acceptable standard for maintaining DBA-unqualified coatings within Service Level 1 areas. In lieu of this

standard, the COL applicant intends to utilize ASTM D7491-08 (Standard Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants).

- ASTM D4538-05 is used instead of RG 1.54, Rev. 1 endorsed D4538-95.
- EPRI Report 1003102, November 2001, "Guideline on Nuclear Safety-Related Coatings", is used for additional information in lieu of using EPRI Report TR-109937 (referred to in RG 1.54, Rev. 1).
- For the U.S. EPR, the Service Level II coating classification refers to coatings applied in radiologically controlled areas inside and outside of containment where coating failure could impair, but not prevent, normal operating performance.

6.1.3

References

1. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Plant Power Components," The American Society of Mechanical Engineers, 2004.
2. ASME Boiler and Pressure Vessel Code, Section II, "Materials," The American Society of Mechanical Engineers, 2004.
3. ANSI/AWS D1.1/D1.1M, "Structural Welding Code – Steel," American National Standards Institute/American Welding Society, 2006.
4. EPRI Report 1009801, "Materials Reliability Program: Resistance to Primary Water Stress Corrosion Cracking of Alloys 690, 52, and 152 in Pressurized Water Reactors (MRP-111)," Electric Power Research Institute, March 2004.
5. EPRI Report 1014986, "Pressurized Water Reactor Primary Water Chemistry Guidelines," Revision 6, Electric Power Research Institute, December 2007.
6. ASTM D5144-00, "Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants," American Society for Testing and Materials, 2000.
7. ASME NQA-1-1994, "Quality Assurance Program Requirements for Nuclear Facilities," American society of Mechanical Engineers, 2004.
8. ASTM D3843-00, "Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American Society for Testing and Materials, 2000.

**Table 6.1-1—Pressure-Retaining Material Specifications for Engineered
Safety Features
Sheet 1 of 6**

Component	Material
Reactor Building Liner and Penetrations	
All	Refer to Sections 3.8.1.6.4 and 3.8.2
Safety Injection System/Residual Heat Removal System	
Piping	SA-312 Grade TP304L ^{1, 2, 4} SA-312 Grade TP316LN ^{1, 2, 4} SA-106 Grade B
Fittings	SA-403 Grade WP304L Class S ^{1, 2} SA-403 Grade WP316LN ¹ SA-182 Grade F304L ¹ SA-182 Grade F316L ¹ SA-182 Grade F316LN ¹
Valves	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-351 Grade CF3 SA-351 Grade CF3A SA-351 Grade CF3M SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Accumulators	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-336 Grade F304 ^{1, 2} SA-336 Grade F304L ^{1, 2} SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹

**Table 6.1-1—Pressure-Retaining Material Specifications for Engineered
Safety Features
Sheet 2 of 6**

Component	Material
Low Head Safety Injection Heat Exchangers Tube Sheet, and Channel Head (primary side)	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-240 Type 316 ^{1, 2} SA-240 Type 316L ¹ SA-336 Grade F304 ^{1, 2} SA-336 Grade F304L ^{1, 2} SA-336 Grade F316 ^{1, 2} SA-336 Grade F316L ^{1, 2} SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Low Head Safety Injection Heat Exchangers Tube (primary side)	SA-213 Grade TP304 ^{1, 2} SA-213 Grade TP304L ^{1, 2}
Low Head Safety Injection Heat Exchangers Shell (secondary side)	SA-508 Grade 3 Class 1 or Class 2 SA-533 Type B Class 1 or Class 2 ³
Low Head Safety Injection Pump	SA-351 Grade CF3 SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-336 Grade F304 ^{1, 2} SA-336 Grade F304L ^{1, 2} SA-564 Type 630 ³ SA-194 Grade 6 ³ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-240 Type 316 ^{1, 2} SA-240 Type 316L ¹ SA-193 Grade B8 ¹ SA-193 Grade B8M ¹ SA-194 Grade 8 ¹ SA-194 Grade 8M ¹

**Table 6.1-1—Pressure-Retaining Material Specifications for Engineered
Safety Features
Sheet 3 of 6**

Component	Material
Medium Head Safety Injection Pump	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-336 Grade F304 ^{1, 2} SA-336 Grade F304L ^{1, 2} SA-453 Grade 660 SA-564 Type 630 ³ SA-194 Grade 6 ³ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-240 Type 316 ^{1, 2} SA-240 Type 316L ¹ SA-193 Grade B8 ¹ SA-193 Grade B8M ¹ SA-194 Grade 8 ¹ SA-194 Grade 8M ¹
Welding material	
<ul style="list-style-type: none"> Ferritic 	SFA 5.5, 5.17, 5.18, 5.20, 5.23, 5.28, and 5.29
<ul style="list-style-type: none"> Austenitic Stainless Steel 	SFA 5.4 E308, E309, E316 SFA 5.9 ER308, ER309, ER316 SFA 5.22 E308, E309, E316
<ul style="list-style-type: none"> NiCrFe 	SFA 5.11 ENiCrFe-7 SFA5.14 ERNiCrFe-7, ERNiCrFe-7A
In-Containment Refueling Water Storage Tank System	
Liner	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-240 Type 316 ^{1, 2} SA-240 Type 316L ¹ SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Process piping	SA-312 Grade TP304L ^{1, 2, 4}
Fittings	SA-403 Grade WP304L Class S ^{1, 2} SA-182 Grade F304L ¹

**Table 6.1-1—Pressure-Retaining Material Specifications for Engineered
Safety Features
Sheet 4 of 6**

Component	Material
Valves	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-351 Grade CF3 SA-351 Grade CF3A SA-351 Grade CF3M SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Welding material (Austenitic Stainless Steel)	SFA 5.4 E308, E309, E316 SFA 5.9 ER308, ER309, ER316 SFA 5.22 E308, E309, E316
Extra Borating System	
Tanks	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-240 Type 304 ^{1, 2} SA-240 Type 304L ¹ SA-240 Type 316 ^{1, 2} SA-240 Type 316L ¹ SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Process piping	SA-312 Grade TP304L ^{1, 2, 4}
Fittings	SA-403 Grade WP304L Class S ^{1, 2} SA-182 Grade F304L ¹

**Table 6.1-1—Pressure-Retaining Material Specifications for Engineered
Safety Features
Sheet 5 of 6**

Component	Material
Valves	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-182 Grade F316 ^{1, 2} SA-182 Grade F316L ¹ SA-351 Grade CF3 SA-351 Grade CF3A SA-351 Grade CF3M SA-479 Type 304 ^{1, 2} SA-479 Type 304L ¹ SA-479 Type 316 ^{1, 2} SA-479 Type 316L ¹
Pumps	SA-182 Grade F304 ^{1, 2} SA-182 Grade F304L ¹ SA-336 Grade F304 ^{1, 2} SA-336 Grade F304L ^{1, 2} SA-453 Grade 660 SA-193 Grade B6 SA-194 Grade 6 ³
Welding material (Austenitic Stainless Steel)	SFA 5.4 E308, E309, E316 SFA 5.9 ER308, ER309, ER316 SFA 5.22 E308, E309, E316

Table 6.1-1—Pressure-Retaining Material Specifications for Engineered Safety Features
Sheet 6 of 6

Component	Material
Annulus Ventilation System	
Ducts (accident trains)	ASTM A-240 Type 304 ^{1,2}
Ducts (normal operation trains)	ASTM A-36 ASTM A-653
Main control room air conditioning system	
All	Refer to Section 9.4.1
Reactor Building Liner and Penetration Sleeves	
Liner Plate	Carbon Steel SA-516 Grades 55, 60, 65 or 70 (ASME Section III, Division 2, Subsection CC)
Penetration Sleeves	
<ul style="list-style-type: none"> Pipe Material 	<ul style="list-style-type: none"> Carbon Steel SA-333 Grade 6, SA-106 Grades A, B or C Austenitic Stainless Steel SA-312 Grades TP304 or TP 304L (ASME Section III, Division 1, Subsection NE)
<ul style="list-style-type: none"> Plate Material 	<ul style="list-style-type: none"> Carbon Steel SA-516, Gr. 55, 60, 65 or 70, and SA-537 Class 1 or 2 (ASME Section III, Division 1, Subsection NE)
Welding Material	
<ul style="list-style-type: none"> Carbon Steel 	<ul style="list-style-type: none"> E70XX (AWS D1.1, SFA-5.1) ER70S-X or E70C-XC (AWS D1.1, SFA-5.18) E7XT-X (AWS D1.1, SFA-5.20)
<ul style="list-style-type: none"> Low Alloy Steel 	<ul style="list-style-type: none"> E80XX-X (AWS D1.1, SFA-5.5) ER80S-XXX or E80C-XXX (AWS D1.1, SFA-5.28) E8XTX-X (AWS D1.1, SFA-5.29)
<ul style="list-style-type: none"> Stainless Steel 	<ul style="list-style-type: none"> E308L-XX, E309L-XX or E316L-XX (AWS D1.6, SFA-5.4) ER308L, ER309L or ER316L (AWS D1.6, SFA-5.9) E308LTX-X, E309LTX-X or E316LTX-X (AWS D1.6, SFA-5.22)

Notes:

- Solution annealed and rapidly cooled.
- Carbon not exceeding 0.03 wt%.

- 3. Quenched and tempered.
- 4. Piping should be seamless.

Table 6.1-2—Coatings Classifications and Uses
Sheet 1 of 2

Areas of Use	Components	Surface Materials	Coating Type	Environmental Conditions
Safety-Related Service Level I				
Inside Containment	Containment Liner	Carbon Steel Surfaces (ST1)	Epoxy Coating System	Design Basis Accident Conditions Radiation Decontamination Humid Environment
	Areas Outside the IRWST (Structural)	Carbon Steel Surfaces (ST1)	Epoxy Coating System (Note 1)	
	Areas Outside the IRWST (Walls, Ceilings)	Concrete Surfaces (C1)	Epoxy Coating System	
	Areas Outside the IRWST (Floors)	Concrete Surfaces (C2)	Epoxy Coating System	
	Areas Within the IRWST	N/A	N/A	Design Basis Accident Conditions Radiation Decontamination Humid Environment Immersion Conditions
	High Temperature Areas	Carbon Steel Surfaces (ST1)	Inorganic Zinc Coating System	Design Basis Accident Conditions Radiation Decontamination Humid Environment Elevated Temperatures
Non-Safety-Related Service Level II				
Immersion Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Notes 2, 4	Radiation Decontamination Humid Environment Operating / Immersion Conditions
	Walls & Ceilings	Concrete Surfaces (C1)	Notes 2, 4	
	Floors	Concrete Surfaces (C2)	Notes 2, 4	
Non-Immersion Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Note 4	Radiation Decontamination Humid Environment
	Walls & Ceilings	Concrete Surfaces (C1)	Note 4	
	Floors	Concrete Surfaces (C2)	Note 4	

Table 6.1-2—Coatings Classifications and Uses
Sheet 2 of 2

Areas of Use	Components	Surface Materials	Coating Type	Environmental Conditions
High Temperature Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Inorganic Zinc Coating System	Radiation Decontamination Humid Environment Elevated Temperatures
Safety-Related Service Level III				
Outside Containment Immersion Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Notes 2, 4	Operating / Immersion Conditions Humid / Corrosive Environment
	Walls & Ceilings	Concrete Surfaces (C1)	Notes 2, 4	
	Floors	Concrete Surfaces (C2)	Notes 2, 4	
Outside Containment Non-Immersion Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Notes 3, 4	Humid / Corrosive Environment
	Walls & Ceilings	Concrete Surfaces (C1)	Notes 3, 4	
	Floors	Concrete Surfaces (C2)	Notes 3, 4	
High Temperature Conditions	Steel Structures	Carbon Steel Surfaces (ST1)	Inorganic Zinc Coating System	Humid / Corrosive Environment Elevated Temperatures

Notes:

1. Most structural steel supports, piping, pipe supports, stairways, and tanks will be coated with epoxy coating systems inside and outside containment. The service level required inside containment will be either Service Level I or II depending on location. No service level will be required for these components when coated outside containment. In areas where painting is impractical, structural steel and other miscellaneous carbon steel components inside and outside containment (e.g., cable trays, stairs components, gratings, railings, ducts, conduit) may be hot-dip galvanized for corrosion protection. This type of corrosion protection mechanism is not a coating process, and therefore, has no service level.
2. For immersion coatings, there is a possibility of ingestion into safety systems (e.g., raw water or clean cooling systems that service safety-related components, storage tanks for reactor grade water, and emergency fuel oil systems).
3. For non-immersion coatings, there is a possibility of ingestion into safety systems (e.g., the emergency diesel generator intakes).
4. Coatings applied in these locations are chosen with respect to specific environmental conditions and surface type.

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