Question

RAI 3.6.2.2.2-1a (High Voltage Insulators)

LRA 3.6.2.2.2 Degradation of Insulator Quality due to Presence of Any Salt Deposits and Surface Contamination, and Loss of Material due to Mechanical Wear

Regulatory Basis

Section 54.21(a)(1) of 10 CFR requires the applicant to identify and list those structures and components subject to an aging management review. Section 54.21(a)(3) of 10 CFR requires the applicant to demonstrate that the effects of aging for structures and components within the scope of license renewal and subject to an AMR pursuant to 10 CFR 54.21(a)(1) will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation. As described in SRP-LR, an applicant may demonstrate compliance with 10 CFR 54.21(a)(3) by referencing the GALL Report when evaluation of the matter in the GALL Report applies to the plant.

Section 3.6.2.2.2 of SRP-LR, "Reduced Insulation Resistance due to Presence of Any Salt Deposits and Surface Contamination, and Loss of Material due to Mechanical Wear Caused by Wind Blowing on Transmission Conductors" states that: "Loss of material due to mechanical wear caused by wind blowing on transmission conductors could occur in high-voltage insulators. The GALL Report recommends further evaluation of a plant-specific AMP to ensure that this aging effect is adequately managed." The GALL report also recommends further evaluation of plant-specific AMP for potential salt deposits and surface contamination.

Background

In LRA 3.6.2.2.2, the applicant references SRP-LR for further evaluation of the above aging mechanisms and effects for high-voltage insulators. Table 3.6.1, line item numbers 3.6.1-2 and 3.6.1-3 identify the component as: "High voltage insulators composed of porcelain, malleable iron, aluminum, galvanized steel and cement." The corresponding items in Table 3.6.2 of the LRA identify the materials as: "Porcelain, galvanized metal and cement."

During the onsite audit /walkdown, the staff noted that in-scope high-voltage insulators on the 230 kV transmission lines are constructed of polymer material rather than the porcelain material listed in LRA Table 3.6.1 and Table 3.6.2. The applicant stated that the porcelain insulators had been replaced with new insulators made of polymeric material in 2008. The actual material (polymer) used in construction of the polymer in-scope high-voltage insulators are not identified in the applicant's LRA.

Staff issued RAI 3.6.2.2.2-1 to obtain clarification on why the LRA did not address the replacement components and aging effects related to polymer high-voltage insulators. The RAI and the applicant's response are documented in ADAMS Accession No. ML 18051A531, dated February 20, 2018. In its response, the applicant provided update to LRA section 3.6.2.1 as well as adding a new line item to AMR table 3.6.2 for polymer high-voltage insulators. The applicant also provided further evaluation discussions in response to RAI 2.6.2.2.2-1 for these components and concluded that there are no aging effects requiring management and did not propose a site-specific aging management program.

The staff's review of the RAI response as well as industry literature, vendor documents, RBS procedures and work orders identified some material used in the construction of the polymer high-voltage insulators that were not listed in the applicant's changes to the LRA. Specifically, according to vendor and EPRI literature provided by the applicant, the missing material include: epoxy, silicone gel, sealants, and ductile iron.

The staff's review of the RAI response and relevant technical information provided by the applicant further identified pertinent aging effects and mechanisms not addressed in the applicant's response. These include:

- Stress corrosion cracking of glass fibers
- Swelling of silicone rubber (SIR) layer due to chemical contamination
- Sheath wetting caused by chemicals absorbed by oil from SIR compound
- Brittle fracture of rods resulting from discharge activity, flashunder, and flashover
- Chalking and crazing of insulator surfaces resulting in contamination, arcing, and flashover
- Bonding failure at rod and sheathing interface
- Water ingress through end fittings causing flashunder, corrosion and fracture of glass fibers

The staff also noted that rodent and bird excrement containing aggressive chemicals such as phosphates, uric acid, and ammonia create an environment that can cause sheath layer damage and subsequent failures of the core material and fittings. Susceptibility of these components to this environment, which has not been reviewed in GALL needs to be addressed.

According to research results, aging studies and handbook material provided by the applicant, polymer insulators have been shown to have unique failure modes with little advance indications. This information also indicates that contamination can be worse for SIR (compared to porcelain insulators) due to absorption by silicone oil, especially in late stages of service life.

The staff and representatives of the applicant held a public telephone conference call on April 18, 2018, to discuss the applicant's responses to RAI 3.6.2.2.2.2-1 and issues outlined below.

<u>Issues</u>

1. The material listed in the applicant's response to RAI 3.6.2.2.2.2-1 seems to have omitted certain material that are used in construction of the polymer insulators. According to vendor and EPRI literature, these include: epoxy, silicone gel, sealants, and ductile iron.
2. The aging effects and mechanisms addressed in the applicant's response to RAI 3.6.2.2.2.2-1 seem to have addressed some, but not all relevant aging effects requiring management (AERM). The AERMs not considered in the response include the following:
   a. Stress corrosion cracking (SCC) of glass fibers due to sheath degradation
   b. Swelling of SIR layer due to chemical contamination
   c. Sheath wetting caused by chemicals absorbed by oil from SIR compound
   d. Brittle fracture of rods resulting from discharge activity, flashunder, and flashover
   e. Chalking and crazing of insulator surfaces resulting in contamination, arcing, and flashover
   f. Water penetration through the sheath followed by electrical failure
   g. Bonding failure at rod and sheathing interface
   h. Water ingress through end fittings causing flashunder, corrosion and fracture of glass fibers
3. Additionally, aggressive environment due to excrements from birds and rodents containing chemicals such as uric acid, phosphates, and ammonia that can accelerate degradation of polymers is not addressed in the applicant's response to RAI 3.6.2.2.2.2-1. This environment and material combination has not previously been evaluated in the GALL Report and constitutes a condition that should be assessed for RBS.
4. The applicant concluded, in its response to RAI 3.6.2.2.2.2-1, that an aging management program will not be implemented for polymer high-voltage insulators. The staff noted that polymer insulators have shown to have unique failure modes with little advance indications. Furthermore, contamination buildup can be worse for SIR (compared to porcelain insulators) due to absorption by silicone oil, especially in late stages of service life. It appears that the applicant's conclusion is based on the

assumption that polymer insulators are more reliable than porcelain and less likely to be affected by aging degradation, primarily due to the hydrophobic characteristics of the polymers and reduced possibility of chemicals and particulate matter buildup on the surfaces of the insulators. The staff notes that the licensee's response does not include consideration of new and unique degradation mechanisms and sensitivity to the environment, especially during later stages of service life, typically past the twenty-year period. It is not clear to the staff whether the applicant's conclusion considers all aspects of polymer insulators' degradation and aging that can result in aging effects such as reduced insulation resistance and loss of material which may require aging management.

Request

1. Explain why epoxy, silicone gel, sealants, and ductile iron are not listed in the response to RAI 3.6.2.2.2-1 as materials that are used in construction of polymer high-voltage insulators.

2. Explain why certain aging effects and mechanisms that have been identified for polymer high-voltage insulators, by industry as a result of operating experience reviews and aging study research, have not been considered in response to RAI 3.6.2.2.2-1. These aging effects and mechanisms are listed above under the heading "Issues," items 2 (a) through (h).

3. Explain why aggressive environment due to excrement from birds and rodents containing chemicals such as uric acid, phosphates, and ammonia that can accelerate degradation of polymers has not been addressed in the response to RAI 3.6.2.2.2-1. This environment and material combination has not previously been evaluated in the GALL Report and constitutes a site-specific condition to be assessed for RBS.

4. Considering polymer insulators' degradation, aging, and failure mechanisms that may require aging management, provide a discussion of any site-specific aging management program needed to ensure that the aging effects such as reduced insulation resistance and loss of material for these components composed of polymers, epoxy, silicone gel, sealants, and ductile iron will be adequately managed. Describe what parameters will be monitored or inspected to detect the AERM and how the frequency of inspection will be established. If no program will be used, justify why loss of material, reduced insulation resistance, presence of deposits, rod fiber glass degradation, SCC of fiber glass material, wetting and swelling of SIR, accelerated aging of polymer material due to discharge current activity and corona, chalking and crazing of surfaces, tracking, corona, loosening of sheath layers, bonding failure at rod/sheath interface, separation of seals and sealants, water ingress through end fittings, and surface contamination are not applicable for the polymer high-voltage insulators exposed to air-outdoor and chemicals such as uric acid, phosphates and ammonia from birds and rodents.

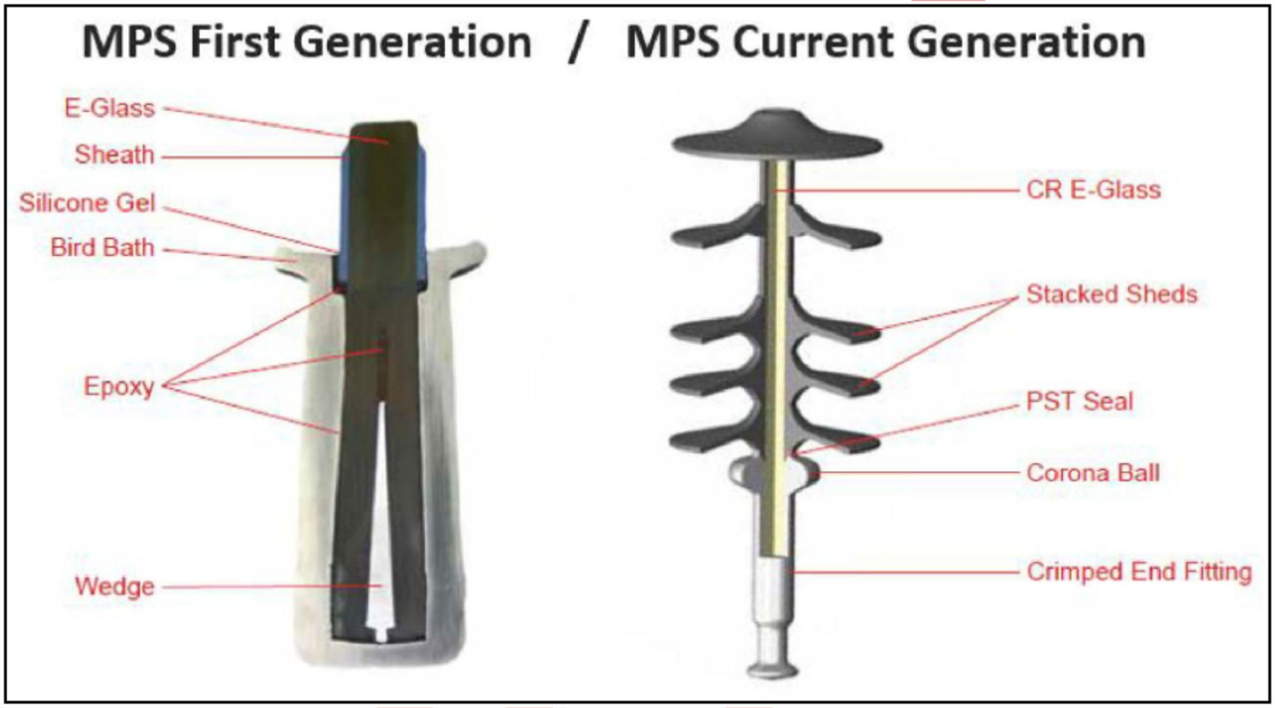
Response

Part 1

Information from the manufacturer (MacLean Power Systems or MPS) of the RBS polymer insulators does not discuss "ductile iron" for the corona ring or the end fittings, which are the only metal components on the insulators. The connection hardware does include ductile iron.

The response to RAI 3.6.2.2.2-1 stated, "The RBS polymer high-voltage insulators and connection hardware have the following materials: fiberglass, silicone rubber, aluminum and aluminum alloy, steel and steel alloys, galvanized metal (galvanized ductile iron, galvanized forged steel, steel hot dip galvanized).” Therefore, galvanized ductile iron is explicitly identified.

The RBS polymer high-voltage insulators are a recent generation of MPS polymer insulators that have been manufactured since 2007. The RBS polymer insulators do not use epoxy. The following figure shows the difference between the first generation of MPS polymer insulators and the generation of MPS polymer insulators that are used at RBS.



The MPS polymer insulators in service at RBS use a PST sealing system, which is a triple seal design. The triple seal or PST seal comprises the primary seal (P), the secondary seal (S), and the tertiary seal (T). The primary seal is a silicone rubber sheath compressed into the chamfer of the crimped end fitting. The secondary seal is RTV (room temperature vulcanizing) silicone applied to the rod, sheath, and end fitting interface. The tertiary seal is a final external RTV silicone seal applied to the sheath and end fitting interface. The RBS polymer insulators do not utilize silicone gel. The response to RAI 3.6.2.2.2-1 included silicone rubber, but did not explicitly identify RTV silicone as a type of silicone rubber. The silicone rubber material includes the RTV silicone that is part of the PST seal system. The RBS polymer insulators do not include silicone gel or sealants other than RTV silicone.

Part 2

The aging effects on polymer high-voltage insulators are the same as the aging effects on porcelain high-voltage insulators. Those aging effects are reduced insulation resistance and loss of material. Polymer degradation is an additional mechanism unique to polymer high-voltage insulators that can cause the aging effect of reduced insulation resistance.

The items identified in part 2 of the issue as Items a) through h) are discussed in the following sections. Each discussion describes how the item was considered in the aging management review of RBS polymer high-voltage insulators. The functions of high-voltage insulators are to insulate and support a high-voltage conductor. The failure of one high-voltage insulator does not cause the loss of the function of the high-voltage insulator system to insulate and support a high-voltage conductor.

a) Rod failures of early generation polymer insulators have been linked to stress corrosion cracking (SCC) resulting from infiltration of water into the fiberglass/glass reinforced plastic ~~(GRP)~~ rod. The failures have been attributed to either acid or water leaching of the metallic ions in the glass fibers resulting in stress corrosion cracking. SCC in an E-glass polymer composite results from the combined effect of low mechanical tensile stresses applied along the fibers and chemical attack of either organic or inorganic acids. Known in the industry as brittle fracture this failure of the polymer insulator rods is generally associated with high-voltage applications in which nitric acid or other acids can be present. In order to avoid such failures, water is prevented from migrating into the end fittings of polymer insulators. In-service failures have been observed when nitric acid forms and reaches the rod surface. The polymer high-voltage insulators installed on the 230 kV offsite power recovery paths for RBS are specifically manufactured to eliminate the conditions that can cause brittle fracture of the polymer insulator support rod. For these insulators, the fiberglass rod is a boron-free corrosion-resistant (CR) E-Glass, which is resistant to nitric acid attacks. There has never been a brittle facture failure of a ~~MPS~~ CR E-glass rod in an MPS polymer insulator in over 30 years of use. Review of industry literature applicable to RBS polymer high-voltage insulators did not identify any aging effects requiring management related to brittle fracture of the glass support rods.

b) Swelling of SIR layer due to chemical contamination is not identified in industry documents as a cause of loss of function in high-voltage polymer insulators. One industry document, published in October 2003, discusses that solvents can swell polymers, and that some polymer characterization tests are based upon the degree of swelling of the unknown polymer in different solvents; the swelling ratios can fingerprint the polymer. The other discussion of swelling in this document is that studies could be performed to determine chemical environments (unique chemicals or cocktails) that would theoretically assess the potential for swelling or other degradation that could change the water permeability or hydrophobic properties of the water shed polymer. No studies were found for using solvents to create potential problems for silicone rubber polymers. Also, solvents are not found in the air environment of high-voltage insulators at RBS. Review of industry literature for the type of polymer insulator used at RBS did not identify any aging effects requiring management related to swelling of silicone rubber insulator components due to chemical contamination for polymer high-voltage insulators.

c) Sheath wetting caused by chemicals absorbed by oil from SIR compound was not found as a failure cause for polymer insulators. Discussions of sheath wetting were not identified for polymer insulators. There are industry documents that contain statements from an old reference citing that silicone rubber insulators, due to the presence of the silicone oils, collect more contaminants than glass or ceramic surfaces. Later industry documents refuted this old reference, by stating that silicone rubber (SR) is naturally hydrophobic, has excellent resistance to UV, and minimizes leakage currents on the surface of the insulator, all of which help polymer insulators perform well in contaminated environments. This position was discussed in greater detail in the response to RAI 3.6.2.2.2-1. Review of industry literature for the type of polymer insulator used at RBS did not identify any aging effects requiring management related to sheath wetting caused by chemical absorption for polymer high-voltage insulators.

d) Failure of rods resulting from discharge activity, flashunder, and flashover is not called brittle facture in industry documents. Brittle fracture due to stress corrosion cracking is discussed in item 2(a) above.

Flashover occurs external to the sheath covering the rod; therefore, flashover is not applicable to failure of the rod by discharge activity. Flashunder is initiated by tracking along or through the rod under the silicone rubber sheath and occurs when internal discharge activity results in carbonization within or on the surface of the fiberglass rod. ~~Industry documents discuss two different failure modes for polymer insulator support rods.~~ Failure of the rod caused by discharge activity and flashunder are relatively slow degradation processes resulting from discharges in or along the rod. These discharges could occur when the rod is exposed to the environment because of a functional failure of either the rubber weathershed system or the end fitting seal. The MPS polymer high-voltage insulators are specifically manufactured to preclude these degradation processes. The CR E-Glass rod is housed in a concentric extruded seamless sheath of silicone rubber. The sheath and the sealing system of the MPS polymer high-voltage insulators prevent exposure of the rod to the environment, which mitigates or eliminates destruction of the rod by discharge activity and flashunder. Review of industry literature for the type of polymer insulator used at RBS did not identify any aging effects requiring management related to failure of the rod by discharge activity and flashunder for polymer high-voltage insulators.

e) Chalking and crazing of insulator surfaces resulting in contamination, arcing, and flashover are discussed in industry documents for first-generation polymer insulators. Typical problems encountered with first-generation polymer insulators included chalking and crazing after a few years of operation. Chalking is a microstructure change on the surface of the insulator forming a powdery surface; however, based on testing, service-aged silicone rubber insulators still maintain acceptable hydrophobic properties with the presence of chalking. Crazing is defined as the formation of surface cracks that do not affect the operating characteristics of the insulator. Crazing may be an early indicator of insulator degradation. Review of industry literature did not identify any aging effects requiring management related to chalking and crazing of silicone insulator surfaces as an aging mechanism for more recent generations of polymer insulators, which are used at RBS.

f) Water penetration through the sheath followed by electrical failure is discussed in industry documents for first-generation polymer insulators. One failure mode observed in first-generation polymer insulators was water penetration followed by electrical failure after a few years of operation. This is not discussed as an aging mechanism for more recent generations of polymer insulators, which are used at RBS. The discussion in 2(d) provides the information relevant to water penetration into the rod for RBS polymer insulators.

g) Bonding failure at rod and sheathing interface is discussed in industry documents for first-generation polymer insulators. Failure modes observed in first-generation polymer insulators included bonding failures and breakdowns along the rod-sheath interface after a few years of operation. There were several discussions of poor bonding of the end fittings, and this is discussed as a mechanical failure. There are manufacturer tests now for identifying poor bonding of the end fittings. End fittings used on RBS insulators are attached using a controlled / automated crimping process to achieve the required tensile strength. The end fittings are forged steel, galvanized for protection against corrosion. Therefore, this design mitigates or eliminates mechanical failures. The discussion in 2(a) for SSC and 2(d) for water penetration into the rod provides the information relevant to RBS polymer insulators.

h) Water ingress through end fittings causing corrosion and fracture of glass fibers is discussed with references to operating experience~~s~~ for early or first-generation polymer insulators. Most of the discussions of water ingress, immersion, penetration, or diffusion are associated with testing standards for manufacturers. This is not discussed as a failure cause for later-generation polymer insulators. The discussions in 2(a) for SSC, 2(d) for water penetration into the rod, and 2(g) for bonding failures provide the information relevant to RBS polymer insulators.

Industry operating experience was summarized for polymer insulators in the response to RAI 3.6.2.2.2-1. This operating experience provided information on failures from EPRI's polymer insulator database and included specific information on failures of MPS polymer insulators. In addition, the response to RAI 3.6.2.2.2-1 provided information on aging studies performed for polymer insulators. The applicable aging mechanisms and stressors identified by the industry for polymer high-voltage insulators were considered as part of the operating experience and aging studies discussion in the response to RAI 3.6.2.2.2-1, and as part of the aging effects evaluation for polymer high-voltage insulators. The aging effects of reduced insulation resistance due to deposits or surface contamination, loss of material due to mechanical wear caused by wind blowing on transmission conductors, and reduced insulation resistance due to polymer degradation were discussed.

Part 3

Based on a search of industry documents, degradation of polymer insulators from "bird" and "rodent" excrement was not identified. An industry document providing guidance on the selection, specification, and procurement of composite insulators for transmission lines discussed advantages and disadvantages for different insulator technologies including older generation composite insulators. For composite insulators, "Susceptible to damage from birds and rodents" was postulated as a disadvantage, but there was no operating experience or aging studies cited for this claim.

An environment due to excrement from rodents is not applicable to the transmission conductor polymer high-voltage insulators. Site operating experience has not identified an environment due to excrement from birds for the transmission conductors, the polymer high-voltage insulators, or the porcelain high-voltage insulators. Therefore, there is not an aggressive environment due to excrement from birds and rodents containing chemicals such as uric acid, phosphates, and ammonia for polymer high-voltage insulators.

Part 4

As discussed in the in the response to RAI 3.6.2.2.2-1, the following aging effects for polymer high-voltage insulators were evaluated.

- reduced insulation resistance due to deposits or surface contamination
- loss of material due to mechanical wear caused by wind blowing on transmission conductors
- reduced insulation resistance due to polymer degradation

As stated in the response to RAI 3.6.2.2.2-1, the aging effect of loss of material due to mechanical wear caused by wind blowing on transmission conductors is the same for polymer high-voltage insulators as for porcelain high-voltage insulators. The end components and the connection hardware for the polymer high-voltage insulators are similar in design and material to those of the porcelain high-voltage insulators. As discussed in LRA Section 3.6.2.2.2 for porcelain high-voltage insulators, loss of material (wear) and fatigue that could be caused by transmission conductor vibration or sway are not applicable aging effects in that they would not cause a loss of intended function if left unmanaged for the period of extended operation. LRA Table 3.6.2 was updated to include a polymer insulator line item to align with Table 3.6.1, Item 3.6.1-2.

For discussions of aging management and LRA Table 3.6.2, the other two aging effects listed in the response to RAI 3.6.2.2.2-1 were combined into reduced insulation resistance. As previously indicated, reduced insulation resistance is the aging effect, which can be due to the mechanisms of polymer degradation or surface contamination.

While reduced insulation resistance is not expected, RBS will include preventive maintenance activities in the Periodic Surveillance and Preventive Maintenance Program to provide assurance that the effects of aging will not prevent the polymer high-voltage insulators from continuing to perform their intended function during the period of extended operation.

Preventive maintenance activities will include performing a corona scan (UV) and visual inspection of polymer high-voltage insulators on the RSS#1 and RSS#2 lines to the plant every 6 years to detect indications of reduced insulation resistance.

The changes to LRA Table 3.6.2, and Sections A.1.34 and B.1.34 follow with additions underlined and deletions lined through.

Table 3.6.2: Electrical and I&C Components

Structure and/or Component or Commodity	Intended Function	Material	Environment	Aging Effect Requiring Management	Aging Management Program	NUREG-1801 Item	Table 1 Item	Notes
High-voltage insulators – Polymer (high-voltage insulators for SBO recovery)	IN	Fiberglass, silicone rubber, aluminum and aluminum alloy, steel and galvanized metals	Air – outdoor	~~None~~ Reduced insulation resistance	~~None~~ Periodic Surveillance and Preventive Maintenance	--	--	F
High-voltage insulators – Polymer (high-voltage insulators for SBO recovery)	IN	Fiberglass, silicone rubber, aluminum and aluminum alloy, steel and galvanized metals	Air – outdoor	None	None	VI.A.LP-32 VI.A-10 (LP-11)	3.6.1-2	I

A.1.34 Periodic Surveillance and Preventive Maintenance

Credit for program activities has been taken in the aging management review for the following components or commodities.

- Inspect the surface of the polymer high-voltage insulators for transmission conductors on the RSS#1 and RSS#2 lines
- Perform corona scans (UV) of the polymer high-voltage insulators for transmission conductors on the RSS#1 and RSS#2 lines

A.4 LICENSE RENEWAL COMMITMENT LIST

No.	Program or Activity	Commitment	Implementation Schedule	Source (Letter Number)
24	Periodic Surveillance and Preventive Maintenance	Enhance the PSPM Program as described in LRA Section A.1.34.	Prior to February 28, 2025, or the end of the last refueling outage prior to August 29, 2025, whichever is later.	RBG-47735 RBG-47861

B.1.34 PERIODIC SURVEILLANCE AND PREVENTIVE MAINTENANCE

Credit for program activities has been taken in the aging management review for the following commodities, systems and structures.

Polymer high-voltage insulators for the transmission conductors on the RSS#1 and RSS#2 lines	Perform a corona scan (UV) of polymer high-voltage insulators to detect reduced insulation resistance due to deposits or surface contamination, and reduced insulation resistance due to polymer degradation.
Polymer high-voltage insulators for the transmission conductors on the RSS#1 and RSS#2 lines	Perform a visual inspection of the polymer high-voltage insulators via routine aerial patrol of transmission lines to detect deposits or surface contamination, and loss of material due to mechanical wear.