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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE U.S. NUCLEAR REGULATORY COMMISSION

August 6, 2010

Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
Via Mail: Office of Secretary
Via Email hearingdocket@nrc.gov

RE: Supplement (1) to Pilgrim Watch 2.206 Petition Regarding Inadequacy of Entergy's Management of Non-Environmentally Qualified Inaccessible Cables & Wiring at Pilgrim Station

INTRODUCTION

Pilgrim Watch herein files a supplement to *Pilgrim Watch 2.206 Petition Regarding Inadequacy of Entergy's Management of Non-Environmentally Qualified Inaccessible Cables & Wiring at Pilgrim Station.* Added to the Petition are two documents. (1) NRC Integrated Inspection Report *05000293/2010003*, 1RO6 Flood Protection Measures[1]; and (2) NUREG/CR-7000 BNL-NUREG-90318-2009[2]. Our initial comments on the documents are included; we request that they be part of the teleconference call scheduled for Monday, August 9, 2010 at 2:00.

In addition during the call we wish to focus on two broad issues.

(1) Our contention that NRC is knowingly allowing Pilgrim to operate outside the regulations; that NRC does not know the extent of PNPS' non compliances; and that NRC does not have the authority to do this without a license amendment.

(2) We ask as part of this Petition that every cable, cable splice and connector that is potentially exposed to submergence or moisture be identified and inspected.

[1] ADAMS Accession No: ML102100150

[2] Available http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/

Template: EDO-001

E-RIDS: EDO-01

A. NRC Integrated Inspection Report *05000293/2010003*, 1RO6 Flood Protection Measures

On July 19, 2010, Pilgrim Watch filed *Pilgrim Watch 2.206 Petition Regarding Inadequacy of Entergy's Management of Non-Environmentally Qualified Inaccessible Cables & Wiring at Pilgrim Station.* Ten days later, on July 29, 2010, NRC issued Pilgrim Nuclear Power Station - NRC Integrated Inspection Report *05000293/2010003*. The report identified a finding directly pertinent to Pilgrim Watch's 2.206 Petition and provides clear evidence in its support.

Specifically, the inspectors observed partially and fully submerged medium voltage cables" in the three cable vaults sampled. (Report, pg.7) The report made clear that flooding is a recurring issue; and demonstrates that both NRC oversight and Entergy's compliance are inadequate to provide "reasonable assurance" that these electric wires will function when required - leaving protection of public safety to chance.

The Report's main finding describes a sample taken on April 28, 2010, where the inspectors observed water in the three (3) manholes and vaults inspected. It says that,

> On April 28, 2010, the inspectors observed water in each of the manholes and vaults listed above. The inspectors noted that no dewatering or drainage systems existed in the manholes. Entergy procedure EN-DC-346, Revision 0, "Cable Reliability Program," was issued and effective on December 31, 2009. This procedure discusses manhole inspections and dewatering, and requires, in part, "If manual inspections and pumping are used to maintain a cable system dry, the intervals must be sufficient to keep the cables dry. Adjust intervals as necessary, based on inspection results." Discussions with Entergy personnel involved with these inspections indicated that *cables in Manhole 2A were periodically found submerged or partially submerged, and that cables in Manholes 4 and 5 were always found submerged.* The cables that were submerged included cables that were installed from the 4160V, non-safety related startup transformer and connected to the A2 and A4 non-safety related busses. The inspectors identified that *Entergy had previously identified submerged cables in August and September of 2009, however, corrective actions were not sufficient to preclude these cables from being submerged.* The inspectors also determined that *Entergy had not implemented the Cable Reliability Program guidance in a timely manner to ensure that the degrading effects of this environmental condition were minimized* (i.e., pumping intervals were not sufficient to maintain the cables dry). (Pg., 8, emphasis added)

NRC Integrated Inspection Report *05000293/2010003*, 1RO6 Flood Protection Measures- Analysis

NRC's inspection findings, analysis and enforcement demonstrate that both NRC and Entergy have ignored regulations[3].

1. NRC regulations[4] require that plant owners ensure that electrical wiring is qualified to perform in the environmental conditions experienced during normal operation and during accidents. At page 8 of the Report, it says that, "The inspectors noted that *no dewatering or drainage systems existed in the manholes"* (and) "These cables are *not rated for continuous submergence in water*." (Emphasis added)

Specifically, the regulations require Entergy to qualify the electrical wires for "The environmental conditions, including....submergence at the location where the equipment must perform..." and that, "electrical wires be assured to function even if they are submerged during normal operations and/or under accident conditions."

There can be no assurance if the wires are "periodically found submerged or partially submerged" or "always found submerged" as was the case described in this inspection report. It is basic that water and moisture cause corrosion; neither the coating on the wires nor the conduits containing the wires are specified to operate in a moist and submerged environment.

2. The NRC staff evaluated the finding described in the foregoing with a "Green," to indicate low safety significance; despite describing the finding, at 8, as,

> ... limiting the likelihood of those events that upset plant stability and challenge critical safety functions during shutdown as well as power operations. Specifically, continued submergence of the non-safety related power cables (from the start-up transformer to electrical buses A2 and A4) could lead to cable failure and cause an event that would affect plant stability

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[3] General design criterion 4 within Appendix A to 10 CFR Part 50 and §50.49 of 10 CFR.

[4] 10 CFR 50.49, "Environmental qualification of electric equipment important to safety for nuclear power plants," available online at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0049.html; for a list of Guidance Documents see *NRC's Regulatory Issue Resolution Protocol, Inaccessible or Underground Cable Performance Issues at Nuclear Power Plants*, August 19, 2009 (Adams ML092460425), Appendix A

NRC's rationale for a finding of low safety significance was that, "the condition did not contribute to both the likelihood of a reactor trip and the unavailability of mitigating systems equipment." However, this contradicts the fundamental approach to safety in the nuclear industry, defense-in-depth. Time and again, defense-in-depth is used to provide layers. The intent is to provide numerous, highly reliable layers. When multiple layers are provided with each layer having as few and as small holes as possible, the risk that all the holes line up to cause all layers to fail is minimized.

But NRC here relies on a single layer compromising public safety and providing no real incentive for Entergy adhere to regulations.

NRC knows better. NRC's *Regulatory Issue Resolution Protocol, Inaccessible or Underground Cable Performance Issues at Nuclear Power Plants*, August 19, 2009 (Adams ML092460425) says that,

> Electric cables are one of the most important components in a nuclear plant to provide the various plant systems function to mitigate the effects of an accident and preserve the safety of the plant during normal, abnormal, and anticipated operational occurrences. If cable degradation from aging or other mechanisms remain undetected, it can lead to deterioration of cable performance or result in cable failure when it is relied on to mitigate design bases accidents and transients. (At 10)

3. <u>Enforcement</u>: NRC gave four reasons for not administering enforcement action. They said that "Traditional Enforcement did not apply, as the issue did not have actual or potential safety consequence." However the issue did have potential safety consequence as explained above; and the measure cannot be that it did not result in a design basis accident or transient at that time because if timing was different it could have resulted in a design basis accident or transient. Second the staff said there were "no willful aspects;" However, Entergy "willfully" chose insufficient corrective measures and not to implement the Cable Reliability Program guidance in a timely manner. (See pg., 8) The third reason given was that Entergy "did not impact the NRC's ability to perform its regulatory function." This does not make any sense without further explanation. The fourth reason, "This finding did not involve enforcement action because no regulatory requirement violation was identified" (pg., 9) is not accurate.

4. <u>Sampling,</u> Pg., 7: The inspectors looked at a sample of flood protection measures affecting cables located in only (3) underground manholes. They selected an inspection of cable pits 2A, 4 and 5 that contain non-safety related power cables for the start up transformer to electrical buses A2 and A4 near the

main transformer and the south side of the switchyard near the start –up transformer. These locations, from our map of the site, appear to on the uphill (west side) of the property, away from the coastline. No indication is provided regarding how representative these samples are of other manholes or of underground electrical cables not accessible by manholes.

5. Insufficient Information Provided in Report: The report says that the inspectors assessed the condition of the power cables, splices, and supports; and reviewed Entergy's Cable Reliability Program and corrective actions taken for this issue. The documents reviewed during the inspection are listed in the attachment; however they do not appear to be accessible on Adams; and no analysis is provided of what they discovered in their review.

6. Entergy's Response, Condition Report CR-PNP-2010-1529

The CR says that it specified actions to,

> identify all underground medium voltage cables included in the Cable Reliability Program, and to identify which manholes should have dewatering capability. Entergy also created a corrective action to increase the frequency of the dewatering activities for these areas. In addition, the Electric Power Research Institute has generated a cable testing database that will be used to compare the test results of cables that have been removed from service to evaluate the potential for degradation of in-service cables.

However there is insufficient information provided to evaluate whether or not any of these measures will provide reasonable assurance. (a) What does "identify" mean? Does it include important information such as the age of the wiring, repair history, moisture surrounding the conduits and wires, all wires not simply those accessible by manholes? (b) The CR includes increasing the frequency of the dewatering activities for these areas; however increasing to what is never said or a rationale provided. (c) Cables that have been removed from service will be compared to EPRI's cable testing database to evaluate the potential for degradation of in-service cables. However on what basis is there to assume that those removed from service are comparable in all respects relevant to corrosion to those not removed?

NUREG/CR-7000 BNL-NUREG-90318-2009 (January 2010) Brookhaven National Laboratory

Essential Elements of an Electric Cable Condition Monitoring Program

OVERVIEW

Pilgrim Watch, for convenience, pasted pertinent sections of the document below with emphasis added. The Brookhaven Report provides support for Pilgrim Watch's 2.206 Petition.

(1) Entergy is operating Pilgrim outside regulation; and that NRC is knowingly allowing Pilgrim to do so, does not know the extent of the non compliance, and NRC does not have the authority to do this without a license amendment.

> The 10 CFR Part 50 regulations require licensees to assess the condition of their components, to monitor the performance or condition of SSCs in a manner sufficient to provide reasonable assurance that they are capable of fulfilling their intended functions, and to establish a test program to ensure that all testing required to demonstrate that components will perform satisfactorily in service is identified and performed. [Brookhaven 5.1]

This is a threat to public safety,

> most of these underground distribution systems are largely inaccessible, the wetted and flooding conditions remain undetected for extended periods of time. Eventually, power and control cables that are not designed to operate in the submerged state will experience early failures, often resulting in significant safety consequences. [Brookhaven, pgs., 4-16]

(2) Pilgrim Watch requests that every cable, cable splice and connector that is potentially exposed to submergence or moisture be identified (location, age, material) and inspected. This is necessary to provide reasonable assurance due, for example, to Pilgrim's location adjacent to Cape Cod Bay, age of reactor and materials that the components are made.

For example NUREG/CR-7000 says in regard to wetting that,

> cables can tolerate occasional wetting, but are not qualified for extended operation in a submerged state;" "medium-voltage cables are operating in submerged or wetted conditions for which they are not designed, they can often fail very prematurely. [2-14]
>
> local adverse environmental stressors can cause excessive aging and degradation in the exposed sections of a cable that could significantly shorten its qualified life and cause unexpected early failures. [5.1]
>
> Unless the installed cables have been procured specifically for continuous submerged or submarine operation, the cables installed in duct banks, manholes and bunkers, and direct burial applications are susceptible to moisture- and submergence-related failure mechanisms as listed in Table 2-1.

Moreover, Pilgrim has not had an updated hydrological/geological study since the Dames and Moore 1967 report and due to time and later construction groundwater flow has likely changed. Further climate change has affected tidal surges. Therefore, neither Entergy nor NRC knows what components are or are not submerged.

Age: Pilgrim is now 38 years old; NUREG/CR 7000 says, for example, in regard to age and cable failure that,

> Analysis of the reported cable failures also indicated a trend toward early cable failures occurring prior to the end of the original 40-year license period." [XI]
>
> The failure data showed a trend toward early failure, the majority occurring in the range of 11-20 years of service and 21-30 years of service; this is shorter than the plants' original 40-year licensing period. The NRC staff noted in its conclusions that "...the predominant factor contributing to cable failures at nuclear power plants appears to be the presence of water/moisture or exposure to submerged conditions." [NUREG, 4-18]

In regard to materials, the NUREG says that,

> note that cables are not qualified for submerged operation unless they have been specifically procured as submarine cables [2.1]
>
> no manufacturer or insulation type is immune from failure. [4-18]

In conclusion, Brookhaven recommended that,

> Special consideration should be given the problem of monitoring the operating environment for cable circuits routed through inaccessible underground cable ducts and conduits, covered cable distribution trenches, and manhole vaults because they can frequently become flooded resulting in power and control cables operating in wetted and completely submerged conditions for extended periods of time. Unless the installed cables have been procured specifically for continuous submerged or submarine operation, the licensees should ensure that cables installed in duct banks, manholes, bunkers and direct burial applications, are provided with proper drains, sumps, alarms and other protective measures and inspection activities to ensure that they are monitored and maintained in a dry environment. [5.2]

During the Conference Call and in response to the Petition, we expect to learn the specifics regarding the status of Entergy's compliance with these recommendations at PNPS to "ensure that cables installed in duct banks, manholes, bunkers and direct burial applications, are provided with proper drains, sumps, alarms and other protective measures and inspection activities to ensure that they are monitored and maintained in a dry environment;" and the status of NRC's efforts/plans to evaluate and require that Entergy provides this assurance.

NUREG/CR 7000- EXTRACTED TEXT [Emphasis Added]

The 10 CFR Part 50 regulations require licensees to assess the condition of their components, to monitor the performance or condition of structures, systems, and components in a manner sufficient to provide reasonable assurance that they are capable of fulfilling their intended functions, and to establish a test program to ensure that all testing required to demonstrate that components will perform satisfactorily in service is identified and performed. **Recent incidents** involving early failures of electric cables and cable failures leading to multiple equipment failures, as cited in IN 2002-12, "Submerged Safety-Related Cables," and Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients," suggest that licensee approaches to cable testing, such as in-service testing, surveillance testing, preventive maintenance, maintenance rule, etc., do not fully characterize the condition of cable insulation nor provide information on the extent of aging and degradation mechanisms that can lead to cable failure. Analysis of the summary of licensee responses to GL 2007-01 inquiries on licensees' experiences regarding cable failures and cable CM activities, revealed wide variations to the approaches and comprehensiveness of cable testing activities. Analysis of the reported cable failures also indicated a **trend toward early cable failures occurring prior to the end of the original 40-year license period**. These data prompted the NRC to consider whether "...licensees should have a program for using available diagnostic cable testing methods to assess cable condition." At X1

Cables are **qualified by their manufacturers to provide a specified service life (e.g., 40 years for nuclear power plants**) for a specified voltage class (based on the qualified dielectric strength of the polymer insulation) operating continuously at or below a specified maximum ambient temperature (e.g., 90oC). If the insulation and outer jacket material are undamaged, **most cables** can tolerate occasional wetting, but are **not qualified for extended operation in a submerged state**. At 2-1

Electric cables operating in nuclear power plant service can be exposed to a variety of environmental and operational stressors. Environmental stressors can include elevated temperature, high radiation, high humidity, submersion, (note that **cables are not qualified for submerged operation unless they have been specifically procured as submarine cables)** and exposure to dust, dirt, and corrosive contaminants. Operational stressors can include high voltage, electrical transients, internal ohmic heating, vibration, installation damage, manufacturing defects, and damage inflicted by operating and maintenance activity. Over time, these stressors, and combinations of these stressors, can cause aging and degradation mechanisms that will result in a gradual degradation of the cable insulation and jacket materials. At 2-1

Special consideration should be given by licensees to the problem of monitoring the operating environment for cable circuits routed through inaccessible underground cable ducts and conduits, covered cable distribution trenches, and manhole vaults. These structures can frequently become flooded resulting in power and control cables operating in wetted and completely submerged conditions for extended periods of time. **Unless the installed cables have been procured specifically for continuous submerged or submarine operation, the cables installed in duct banks, manholes and bunkers, and direct burial applications are susceptible to moisture- and submergence-related failure mechanisms as listed in Table 2-1. At 2-3**

Cable splices are exposed to the same environmental and operational stressors as the cables on which they are installed. Since cable splices are constructed of many of the same or similar materials as the electric cables on which they are installed, these stressors can also cause aging degradation of the polymer insulating materials used in the cable splice. In addition, the other subcomponents that make up an electric cable splice (insulating tape, fillers, sleeves, insulating compounds, and compression connectors) are also susceptible to aging degradation due to the various stressors to which they are exposed. **Connectors, in particular, are susceptible to stressors such as moisture**, condensation, vibration, and thermal cycling that can lead to corrosion and loosening of the conductor compression joints or solder joints [Ref. 5].

When cable splices that are not qualified for wetted or continuous submersion are exposed to moisture, or are submerged in water, they can be affected more rapidly and more severely than a cable with intact insulation in the same environment. A poorly installed or designed splice can result in multiple penetration pathways for moisture into the interior of the splice, not only around the splice materials where they abut the surface of the cable insulation, but also through the damaged or cracked outer jacket or insulation [Ref. 5]. At 2-4

2.2.3 Cable System Aging and Degradation Mechanisms

Table 2.1 indicates that elevated temperature and radiation stressors will cause embrittlement and cracking of the polymer materials used for cable insulation and jacket materials. These mechanisms will lead to a gradual decrease in the dielectric strength of the cable insulation, an increase in leakage current, and eventually will result in one of the failure modes described in subsection 2.2.1. **When the stressors of wetting or, wetting combined with higher voltage (generally 480Vac and above), are acting on cables that are not qualified to operate in a wet or submerged state, moisture intrusion, electrochemical reactions, and/or water treeing will occur.** These mechanisms will lead to a **decrease in the dielectric strength of the cable insulation, an increase in leakage current, and eventually will result in one of the failure modes** described in subsection 2.2.1. When continuously energized **medium-voltage cables are operating in submerged or wetted conditions for which they are not designed, they can often fail very prematurely** [Refs. 1 and 7]. Note that cables are not qualified for extended or continuous operation unless they have been specifically procured as submarine cables. In addition, the higher voltage stressors that exist during normal operation and during electrical system transients in medium-voltage cables can cause partial discharge, or corona, and electrical treeing to occur. These aging mechanisms can decrease dielectric strength over time and eventually can also lead to one of the power cable failure modes. Further details on electrical stressors and associated aging and degradation mechanisms can be found in Section 3.3 of NUREG/CR-6794, "Evaluation of Aging and Environment Qualification Practices for Power Cables Used in Nuclear Power Plants" [Ref. 3], and Section 4 of SAND96-0344, "Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations" [Ref. 2]. At 2-14

As seen in Table 2.2, the aging and degradation mechanisms affecting the polymer insulating materials used to construct and apply **cable splices** are similar to those affecting cables, and consequently over time, they can lead to one of the cable splice failure modes. When cable splices that are not qualified for wetted or continuous submersion are exposed to moisture or are submerged in water, they can be affected more rapidly and more severely than a cable with intact insulation in the same environment [Ref. 5]. Depending on the design of a splice, as the constituent materials degrade over time, multiple penetration pathways can develop that can introduce moisture into the interior of the splice. This can occur not only around the splice materials where they abut the surface of the cable insulation, but also through the interior of a cable via a damaged or cracked outer jacket or insulation. If these aging mechanisms progress on an environmentally qualified (EQ) electrical splice, it may shorten the qualified life of the cable splice and, as a consequence, the qualified life of the entire cable that contains the degraded EQ splice At 2-14

In addition to the insulation materials, the **connector that joins the electrical conductors within a splice** can be vulnerable to aging and degradation mechanisms such as vibration, mechanical stress, thermal and mechanical cycling, and electrical transients. These mechanisms can result in metal fatigue of the conductors and/or loosening of the connector. Intrusion of moisture into the interior can cause corrosion and formation of oxides at the connector joint of a splice at 2-14

Several examples of this type have been reported in Information Notice 2002-12, "Submerged Safety-Related Cables" [Ref. 7], and Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients" [Ref. 1]. In these incidents, medium-voltage power cables in inaccessible or underground cable ducts, cable trenches, or direct buried have been exposed to moisture or submergence for extended periods. **Cables exposed to water while energized are susceptible to a phenomenon called 'water treeing'** in which tree-like micro-cracks are formed in the insulation due to electrochemical reactions. Growth of water trees will increase with time under continued exposure to moisture and voltage stress eventually leading to complete electrical breakdown of the insulation [Ref. 3]. At 2-17

4.3.3 Monitoring Inaccessible/Underground Cable Circuits

Special consideration should be given by licensees to the problem of monitoring the operating environment for cable circuits routed through inaccessible underground cable ducts and conduits, covered cable distribution trenches, and manhole vaults. As discussed below, **underground cable ducts, conduits, and vaults have proven to be a persistent problem throughout the nuclear industry because they can frequently become flooded resulting in power and control cables operating in wetted and completely submerged conditions for extended periods of time.** Most electric cables used in nuclear power plants are designed to operate intermittently under high humidity or wetted conditions. However, the majority of these electric cables are not qualified to operate continuously in a fully submerged state unless the manufacturer has explicitly stated in the cable specification that they have been specifically designed, tested, and qualified for continuous submerged operation.
Since **most of these underground distribution systems are largely inaccessible, the wetted and flooding conditions remain undetected for extended periods of time. Eventually, power and control cables that are not designed to operate in the submerged state will experience early failures, often resulting in significant safety consequences.** Several of these incidents have been brought to the attention of licensees in NRC Information Notice 2002-12, "Submerged Safety-Related Cables" [Ref. 7] and, more recently, in NRC Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients" [Ref. 1]. **Generic Letter 2007-01 made the observation that cable insulation degradation due to continuous wetting or submergence could affect multiple underground power cable circuits at a plant site; should one of these medium-voltage cables fail, the resulting high-level fault currents and transient voltages would propagate onto the immediate power distribution system and potentially fail other systems with degraded power cable insulation.**
A similar set of circumstances can arise in above-ground conduits that are susceptible to water intrusion but lack sufficient drainage such that the cables routed within the conduits operate in a submerged condition for extended periods of time. Since the cable circuits within the conduit are inaccessible for visual inspection, the condition can go on unnoticed until early failure of the cable occurs. This variation of the submerged circuit's problem was brought to the attention of licensees in NRC Information Notice 89-63, "Possible Submergence of Electrical Circuits Located Above the Flood Level Because of Water Intrusion and Lack of Drainage," [Ref. 36].

If the underground cable circuit includes a **cable splice**, long-term submergence of the splice can also result in unexpectedly early failure of the cable system if the splice is not specifically qualified for continuous submerged operation. If a splice is not installed correctly, failure could occur even more quickly in the presence of moisture or standing water. NUREG/CR-6788, At 4-16

"Evaluation of Aging and Qualification Practices for Cable Splices Used in Nuclear Power Plants," [Ref. 5] describes numerous incidents of moisture and water intrusion-related splice failures in nuclear power plant applications. The report also provides an informative discussion of the common stressors and failure mechanisms that can lead to splice failures.

The **chief failure mechanisms affecting power cables operating in the submerged state over extended periods of time** are described in NUREG/CR-6794, "Evaluation of Aging and Environmental Qualification Practices for Power Cables Used in Nuclear Power Plants," [Ref. 3[5]] as follows:

> "Exposure to moisture can also degrade power cables. This can occur for cables installed below grade in ducts or conduits that are susceptible to water intrusion, or for cables buried directly in the ground. Cables exposed to water while energized are susceptible to a phenomenon called 'water treeing' in which tree-like micro-cracks are formed in the insulation due to electrochemical reactions. The reactions are caused by the presence of water and the relatively high electrical stress on the insulation at local imperfections within the insulating material, such as voids and contaminant sites that effectively increase the voltage stress at that point in the insulation." Figure 4.2 shows an illustration of a water tree formation in the insulation of a cable.
>
> "The occurrence of water treeing is well known in XLPE, however, it also is known to occur in other insulating materials, such as EPR, polypropylene, and PVC [Ref. 37]. Water trees increase in length with time and voltage level, and can eventually result in complete electrical breakdown of the cable insulation. Discharges leading to micro-cracks can also occur at voids and contaminants in the insulation without the presence of water. This is known as "electrical treeing" in which discharges occur due to ionization of the air or gas in voids, and the energy of the discharge causes breakdown of the insulation and the formation of micro-cracks also resembling trees."
>
> "Moisture can also cause corrosion of the various metallic components in the cable, such as metallic shields or the conductor. In some applications where moisture intrusion is to be mitigated, cables with a lead sheath will be used. The lead sheath makes the cable impervious to moisture, provided it is properly sealed at splices and terminations. If such cable is installed in concrete ducts, free lime from the concrete can be a concern since it will form an alkaline environment which can corrode the lead sheath [Ref. 38]."

In **GL 2007-01, licensees were requested to provide failure history information for power cables within the scope of 10 CFR 50.65 (the Maintenance Rule) and a description of inspection, testing, and monitoring programs to detect degradation of inaccessible or underground cables supporting systems within the scope of 10 CFR 50.65.** The licensee responses to the requested information were analyzed and described by the NRC in a summary report [Ref. 8[6]]. The summary report indicated that 93% of the cable failures analyzed occurred on normally energized power cables. More than 46% of the failures were reported to have occurred while the cable was in service and more than 42% were identified as "testing failures" in which cables failed to meet testing or inspection acceptance criteria. **The failure data showed a trend toward early failure, the majority occurring in the range of 11-20 years of service and 21-30 years of service; this is shorter than the plants' original 40-year licensing period.**

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[5] NUREG/CR-6794, "Evaluation of Aging and Environmental Qualification Practices for Power Cables Used in Nuclear Power Plants," Brookhaven National Laboratory, January 2003

[6] Memorandum from G.A. Wilson, Chief, Electrical Engineering Branch to P. Hiland, Director, Division of Engineering, "Generic Letter 2007-01, Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients: Summary Report," U.S. Nuclear Regulatory Commission, November 12, 2008.

The NRC staff noted in its conclusions that "...**the predominant factor contributing to cable failures at nuclear power plants appears to be the presence of water/moisture or exposure to submerged conditions**." At 4-18

The data in Reference 8 also showed that more than 36% of the reported failures occurred on power cables of 2000Vac or less. These data indicate that long-term submergence in water and moisture intrusion can drive insulation degradation mechanisms that **can affect the dielectric strength of insulation materials in both low- and medium-voltage cables, even when they are normally deenergized.**
In the summary report of licensee responses to GL 2007-01 [Ref. 8], the NRC further concluded and recommended that:

"Licensees have identified failed cables and declining insulation resistance properties through current testing practices; however, licensees have also reported that some failures may have occurred before the failed condition was discovered. Although the majority of in-service and testing failures have occurred on cables that are normally energized, the **staff is concerned that additional cable failures have not been identified for cables that are not normally energized or tested.** The NRC staff recommends that the licensees should also include normally deenergized cables in a cable testing program. It appears that **no manufacturer or insulation type is immune from failure**. In addition, licensees have identified failures and/or declining performance capability of both shielded and unshielded cables."

Clearly, underground cable environments needed to be monitored for the presence of moisture or standing water. However, due to the inaccessibility of these cable circuits, **indirect methods for inspection and measurement must be considered.** Visual inspection for moisture or standing water, or the signs of flooding, such as accumulations of sand, mud, and silt or flooding high water marks, could be performed at accessible manhole vaults or cable pull boxes along the length of an underground duct bank. Site survey data on the elevations of the manhole vaults along the underground cable duct bank can then be used to determine whether manhole flooding has affected connected cable ducts. If available, site hydrological data on water table depth and how the water table is affected by site precipitation or the water surface level in nearby bodies of water can also be used to determine where underground cable flooding may be occurring. Illuminated borescopes, such as those used for internal inspection of pipelines,
4-18

can be routed down into underground duct banks or conduits to visually inspect for standing water or the signs of flooding, such as accumulations of sand, mud, and silt. Cable conduits that are above flood level elevation, but are susceptible to moisture intrusion, such as described in Information Notice 89-63 [Ref. 36[7]], can be checked for water accumulation using ultrasonic inspection at low points.
Some of the condition monitoring tests for cables performed for implementation of element 7 of the cable CM program, described in subsection 4.7, can be used to detect and locate the presence of water along the length of an electric cable. Time domain reflectometry (TDR), the ECAD inspection system, and the newer line resonance analysis (LIRA) technique, which are described in Section 3 of this report, may be able to accomplish this.

The results of electrical property measurement CM tests from program element 7 that can detect water treeing or the degradation of insulation dielectric strength resulting from water treeing could be reviewed

[7] US NRC Information Notice 89-63, "Possible Submergence of Electrical Circuits Located Above the Flood Level Because of Water Intrusion and Lack of Drainage," U.S. Nuclear Regulatory Commission, September 5, 1989.

as another indirect method for determining whether it is or has been operating in a submerged condition. CM measurement techniques such as insulation resistance/polarization index testing, dc high potential testing, and VLF withstand testing, can be used to check the condition of cables that may be exposed to water. Test results indicating weakened dielectric strength, or trends of unusually rapid deterioration of dielectric strength between successive testing periods, could be an indication of power cables operating in a submerged condition over extended periods of time. At 4-19

The output results of the CM program element 3 monitoring of cable operating environment activities will be periodic environmental measurements, data, and inspection results for global and local cable operating environments for those cables selected for monitoring in the CM program. The periodic environmental monitoring information for each cable circuit is documented in the CM program database. These data, together with the baseline environmental characterization information, and will be available for review by the cable engineer under CM program element 9, in order to make decisions on managing cable operating environments. At 4-19

5.1 Conclusions

A **cable condition monitoring program is needed for the following reasons**:

The 10 CFR Part 50 regulations require licensees to assess the condition of their components, to monitor the performance or condition of SSCs in a manner sufficient to provide reasonable assurance that they are capable of fulfilling their intended functions, and to establish a test program to ensure that all testing required to demonstrate that components will perform satisfactorily in service is identified and performed. Recent incidents involving early failures of electric cables and cable failures leading to multiple equipment failures, as cited in IN 2002-12, "Submerged Safety-Related Cables" [Ref. 7[8]], and Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients" [Ref. 1[9]], may indicate that licensee approaches to cable testing, such as in-service testing, surveillance testing, preventive maintenance, maintenance rule, etc., do not fully characterize the status of cable insulation condition nor provide information on the extent of the aging and degradation mechanisms that can lead to cable failure.

The polymer materials used for the insulation and jacket materials for electric cables, cable splices, and terminations are susceptible to aging and degradation mechanisms caused by exposure to many of the stressors encountered in nuclear power plant service. Portions of a cable circuit may pass through areas experiencing more harsh environmental conditions, such as high temperature, high radiation, high humidity, or flooding of underground cables. There has been concern that **such local adverse environmental stressors can cause excessive aging and degradation in the exposed sections of a cable that could significantly shorten its qualified life and cause unexpected early failures**.

In-service testing of safety-related systems and components can demonstrate the integrity and function of associated electric cables under test conditions. However, in-service tests do not provide assurance that cables will continue to perform successfully when they are called upon to operate fully loaded for extended periods as they would under normal service operating conditions or under design basis

[8] US NRC Information Notice 2002-12, "Submerged Safety-Related Electrical Cables," U.S. Nuclear Regulatory Commission, March 21, 2002.

[9] US NRC Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients," U.S. Nuclear Regulatory Commission, February 7, 2007.

conditions. In-service testing of systems and components does not provide specific information on the status of cable aging degradation processes and the physical integrity and dielectric strength of its insulation and jacket materials.

Analysis of the summary of licensee responses to GL 2007-01 [Ref. 8[10]] inquiries on licensees' experiences regarding cable failures and cable CM activities, revealed wide variations to the approaches and comprehensiveness of cable testing activities. Analysis of the reported cable failures also indicated a trend toward early cable failures occurring prior to the end of the original 40-year license period. These data prompted the NRC to consider whether "...licensees should have a program for using available diagnostic cable testing methods to assess cable condition." At 5-1

5.2 Recommendations

Special consideration should be given the problem of monitoring the operating environment for cable circuits routed through inaccessible underground cable ducts and conduits, covered cable distribution trenches, and manhole vaults because they can frequently become flooded resulting in power and control cables operating in wetted and completely submerged conditions for extended periods of time. Unless the installed cables have been procured specifically for continuous submerged or submarine operation, the licensees should ensure that cables installed in duct banks, manholes, bunkers and direct burial applications, are provided with proper drains, sumps, alarms and other protective measures and inspection activities to ensure that they are monitored and maintained in a dry environment.

Definitions at B-5

Submergence/Submerged (environment) - an operating environment in which an electric cable is submerged in water continuously or for extended periods of time
Water Treeing - a phenomenon in which tree-like micro-cracks are formed in electric cable insulation due to electrochemical reactions caused by the presence of water and the relatively high electrical stress on the insulation at local imperfections within the insulating material, such as voids and contaminant sites, that effectively increase the voltage stress at that point in the insulation [Refs. B7 & B8]
Wetting/Wetted (environment) - an operating environment in which an electric cable is exposed to moisture and high humidity for limited periods of time

Respectfully submitted,

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[10] Memorandum from G.A. Wilson, Chief, Electrical Engineering Branch to P. Hiland, Director, Division of Engineering, "Generic Letter 2007-01, Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients: Summary Report," U.S. Nuclear Regulatory Commission, November 12, 2008.