EPRI

Guideline for the Management of Adverse Localized Equipment Environments

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Guideline for the Management of Adverse Localized Equipment Environments

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REPORT SUMMARY

Most utilities have specified design basis environments for general areas and specific rooms within nuclear power plants. In most cases, the actual ambient environments are less severe than the design basis environments. However, in a limited number of localized areas, the actual environments may be more severe than the design basis environments. Equipment deterioration may be more rapid than expected. Identification of such areas has been the concern of both plant personnel and regulators. This guideline presents a systematic approach for identifying and managing localized adverse equipment environments at reasonable cost and effort.

Background

Some instances of localized environment-induced degradation or equipment failures have occurred at nuclear plants. When utilities identify an adverse localized equipment environment, they often determine that conditions in other areas must be evaluated to verify acceptability of the condition of the equipment in those areas. This guideline was developed to provide methods for utilities to proactively identify adverse localized equipment environments.

Objective

EPRI created this document in response to utility requests for guidance in the following areas:

- Developing a definition of adverse localized equipment environments
- Developing methods to identify and manage these environments
- Addressing regulatory concerns related to the effects of hot spots on environmentally qualified cables.

Approach

A Plant Support Engineering Task Group comprised of utility personnel and industry consultants was formed. Information from a survey of utilities, site visits, utility case studies, and Task Group meetings became the basis of this document. The Task Group

defined the term "adverse localized equipment environment" early in the project (see Section 1.2), which helped focus efforts on the types of environments intended to be within the scope of this guideline.

Results

A systematic approach has been developed that allows utilities maximum flexibility in deciding how best to complete the general steps, while not being overly prescriptive or requiring the implementation of new programs. It also allows utilities to gain maximum benefit from activities they have already completed and processes that are in place. The following conclusions were drawn from the research conducted for this guideline:

- For each plant, the number of areas with adverse localized equipment environments is minimal and manageable.
- Localized environments may be managed without implementing new programs.
- Thermal environments are the most significant type of adverse localized environment.
- Walkdowns and temperature monitoring are important tools in identifying and managing localized environments.
- With respect to cables, adverse localized environments are manageable.

EPRI Perspective

Although many plants have implemented temperature monitoring and radiation surveys, there appears to be wide variation in the scope of adverse localized environment initiatives. This guideline, developed to provide a systematic approach for identifying and managing these environments, offers a number of techniques that can be applied to all types of equipment, including cables. The two detailed case studies present different approaches used to provide reasonable assurance that the environments for large groupings of cables are satisfactory. While the techniques differ, the studies provide an excellent demonstration of how utilities can choose different techniques under the framework of the guidance presented here. This flexibility allows utilities to choose techniques that best fit their needs.

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INTRODUCTION

1.1 Purpose

EPRI created this document in response to requests from utility environmental qualification, license renewal, and cable-system engineers for guidance on management of adverse localized environments. The engineers were concerned with environments that could be consistently and significantly more severe than the surrounding ambient or bulk conditions. This guideline designates this type of environment as an "adverse localized equipment environment," which includes "hot spots." A full definition of the concept is provided in Section 1.2. "Equipment" has been included in the phrase because an adverse localized environment is of interest only when potentially susceptible equipment is within the localized environment.

Utilities specifically requested that the guideline assist in the following areas:

- Establishing the criteria that define an adverse localized environment
- Developing methods to identify and manage adverse localized equipment environments
- Addressing U. S. Nuclear Regulatory Commission (NRC) concerns relative to the effects of localized hot spots on environmentally qualified cables

This guideline will be of benefit to design, maintenance, license renewal, and environmental qualification engineers responsible for the following procedures:

- Verifying or enhancing design basis environmental and service conditions
- Establishing actual environmental conditions for use in evaluations of equipment aging susceptibility pursuant to License Renewal applications
- Implementing corrective actions in response to environmentally induced equipment problems
- Developing or specifying environmental service conditions

1.2 Definition

Adverse localized equipment environment—A condition in a limited plant area containing a piece or pieces of equipment, that is significantly more severe than the specified service condition for the equipment, the room in which the equipment is located, or the surrounding plant area. The service conditions of interest include normal, abnormal, and error-induced conditions, prior to the start of a design-basis accident or earthquake.

Equipment is included in the definition to indicate that the environment is specific to a piece of equipment or small groups of equipment. In reality, an adverse environment only is of interest when it could affect the aging or operability of equipment. Therefore, the scope of most identification and management efforts is limited to adverse environments that could affect equipment. Adverse environments in areas not containing susceptible equipment are not of interest. The word *equipment* designates discrete items from which a system is assembled. Examples include cables, switches, motors, power supplies, relays, solenoids, pipes, fittings, pumps, tanks, and valves.

The determination of whether the environment variation is significant is left to the user's discretion. The user could establish a quantitative definition of significance or evaluate each environment on a case-by-case basis. In general, an adverse variation in environment would be significant if it could appreciably increase the rate of aging of a component or have an immediate adverse effect on operability. An adverse environment would also only be significant if it were in excess of the conditions considered in the design basis for systems and components. Variations in environmental conditions are common within power plant volumes. For example, temperatures are higher in the vicinity of hot process lines and cooler a short distance away. However, the environment in the vicinity of the process line would not necessarily be considered an adverse localized equipment environment if the temperature remained within the design temperature for the overall volume or if no equipment were located within the adverse environment. If, on the other hand, the design-basis temperature were exceeded in the vicinity of the process line and susceptible equipment were located there, the area would have an adverse localized equipment environment and would be of concern.

1.3 Overview

Some instances of localized environment-induced degradation or equipment failures at nuclear plants have occurred over the past few decades. The NRC has raised localized environment concerns in several generic correspondence documents. The NRC has asked questions of applicants for license renewal and included "hot spots" as a concern in Environmental Qualification (EQ) Task Action Plan (TAP) [1] and associated ongoing research program.

This guideline was developed to provide methods to utilities that will allow adverse localized equipment environments to be systematically identified and documented so their effects can be evaluated and controlled. Most plants have identified equipment that has been affected by adverse-localized environments and have taken appropriate actions. However, fewer plants have systematically recorded the known instances and evaluated the plant to determine if additional areas with adverse-localized environments exist. This guide provides tools for gleaning known information concerning adverse localized equipment environments from plant personnel and documentation, and means for identifying such conditions within a plant.

Utilities do not necessarily need to implement new programs or processes to identify and manage adverse localized equipment environments. To some extent, all utilities already perform or have performed activities that provide assurance that their plants are not susceptible to common mode failures due to adverse localized equipment environments. However, utilities could benefit by implementing a systematic approach of capturing, crediting, and refining the tools and processes that are in place to identify and manage adverse localized equipment environments.

Possible reasons for deciding to systematically identify and evaluate adverse localized equipment environments include the following:

- Experiencing an equipment failure related to an adverse localized environment
- Identifying equipment with more severe deterioration than expected that is related to an adverse localized environment
- Receiving requests from NRC personnel concerning "hot spots" and their effects whether related to license renewal or other regulatory issues
- Verifying that environmentally qualified components are not exposed to environments more severe than those considered in the qualification basis
- Desiring more accurate characterization of actual environments in the vicinity of selected equipment (Determination of actual environments may also verify that conditions are more benign than design-basis conditions and provide relief with regard to periodicity of component replacement and refurbishment. However, such an effort may also identify adverse localized equipment environments.)
- Needing accurate service conditions to support aging analyses for equipment within the scope of license renewal, particularly long-lived passive equipment

A clear understanding of the reason for implementing the adverse localized equipment environment evaluation will help define the scope and depth of the evaluation. Section 3 provides some examples of scopes of review that may be considered.

One method that is particularly useful for identifying and managing adverse localized equipment environments is walkdowns. All utilities currently have some personnel who perform walkdowns, or tours of plant spaces. At most utilities, personnel from a number of plant organizations perform these tours. Although these tours may not be specifically focused on detecting adverse localized equipment environments, the personnel performing them could be trained to detect these environments with little increase in workload. Use of ongoing walkdown programs would give plants a method by which they frequently assess the condition of equipment in the plant and the environments that surround the equipment. If used effectively, walkdowns can be a tool for both identifying adverse localized equipment environments and providing feedback on the actual condition of equipment in the plant. Appendix A provides more detail on how to scope and conduct these walkdowns. Section 3 and Appendix B provide a number of photographs of the types of conditions that can be detected during these inspections.

Section 3 of this guideline presents a systematic approach to identifying and managing adverse localized equipment environments. The approach provides utilities with a method for maximizing the use of existing processes and resources without prescribing specific techniques that should be implemented. Following the general steps outlined in this guideline, a utility can develop a cohesive approach to the identification and management of adverse localized equipment environments by using a combination of existing programs and additional practices. Depending on the outcome of the adverse-environment evaluation, the utility may determine that additional work is or is not necessary. An ongoing process may be implemented to manage, adjust, and document activities that monitor localized-equipment environments and to provide further assurance that localized environments are recognized and that their effects are understood and documented.

1.4 Adverse Localized Environments and Cables

Cable aging has been the focus of substantial research and analysis by the industry and the NRC, particularly related to cables within the scope of the EQ Program or License Renewal Aging Management Reviews. One significant question that has been raised is "How are the effects on cables from localized elevated temperatures or 'hot spots' accounted for within the framework of an Aging Management Review or the EQ Program?" The methodology in this report may be used to answer such questions for cables.

Cables are emphasized in this guideline because they are included in all systems and are expected to last the entire plant life. Unlike other active equipment, periodic maintenance and surveillance is typically not performed because cables are passive, and cables in trays and conduits are often difficult to access. Cables are also exposed to multiple environments along the run, so inspection of the accessible portion of a cable at the end-devices may not provide a complete picture of the condition of the entire cable. These factors have led to the concern that cable degradation due to adverse localized environments could go undetected.

Although cable systems present some unique challenges, adverse localized environments potentially affecting cables can be identified and managed effectively. Several activities presented later in this guideline will be particularly valuable in identification of adverse environments near cables, including scoping analyses, interviews with plant personnel, walkdowns, temperature monitoring, and plant operating experience reviews. Employed in a systematic approach, implementation of selected activities can ensure that adverse localized environments are detected and managed.

1.5 Industry Research and Experience

The NRC has issued several generic communications discussing equipment problems caused by localized equipment environments. NRC Information Notices have been issued concerning identification of higher than expected temperature conditions, previously unrecognized radiation streaming conditions under normal operation, degradation of cable due to exposure to hydraulic fluids, and failure of components in electrical panels due to large temperature rises. Summaries of these Information Notices are provided in Appendix C.

EPRI has issued a number of reports that have dealt with localized equipment environments directly or peripherally. These documents include guidance on monitoring plant environments, use of thermography, evaluating the effects of adverse environments on components, and evaluating cable system longevity. A few of these reports are summarized in Appendix C along with a discussion of reports issued by other organizations.

In preparation for the development of this guide, a survey was performed to identify more clearly utility interests and practices regarding adverse localized equipment environments. Twenty-one utilities responded. The goals of the survey were to identify examples of utility practices for identifying and managing adverse environments, to gain an understanding of the industry's approach to the issue, and to obtain examples of the types and magnitude of problems that localized environments have caused.

The survey results indicate that most of the responding utilities perform or have performed inspections and temperature monitoring and that most have identified one or more areas with localized environments in excess of bulk area temperatures. The details of the survey and its results are presented in Appendix D. During the preparation of this guide, two utility evaluations of plant spaces for the existence of adverse localized equipment environments were identified. Summaries of these efforts are presented as case studies in Appendix E.

2

CAUSES AND RESULTS OF ADVERSE LOCALIZED EQUIPMENT ENVIRONMENTS

This chapter discusses some of the more common types of stressors that can cause adverse localized equipment environments. While the list of stressors discussed cannot be all-inclusive, the dominant stressors that could have an adverse effect on plant equipment are presented. A brief discussion of each stressor and related examples of the associated adverse environment are provided to help the reader relate to the types of situations that might be encountered in a plant. More detailed discussions of these stressors and the degradation they can cause are contained in the following publications:

- EPRI TR-1038415, Revision 1, "Low Voltage Environmentally Qualified Cable License Renewal Industry Report" [2].
- EPRI TR-106687, *Cable Aging Management Program for D. C. Cook Nuclear Plant Units 1 & 2* [3].
- U.S. Department of Energy (DOE) Aging Management Guidelines (AMGs), especially DOE Contractor Report SAND96-0344, "Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations" [4].

A key attribute of an adverse localized equipment environment is that it is more severe than the specified and analyzed design-basis service environment for the location. For example, if the design-basis temperature for a room were 40°C (104°F), and the temperature in the vicinity of a thermally sensitive piece of equipment were 50°C (122°F), the temperature at the piece of equipment would be an adverse localized equipment environment. However, if the actual peak bulk temperature in the same room were 30°C (86°F) and the localized temperature at the equipment were 35°C (95°F), the temperature at the equipment would not be an adverse localized environment because it is within the design-basis temperature for the room. A condition that is within the design basis for the equipment is not an adverse localized equipment environment.

The main concern related to adverse localized equipment environments is that they cause a faster than expected rate of aging of equipment. As a result, the equipment could fail in service or, in the case of environmentally qualified equipment, could be rendered more susceptible to failure under design basis accident conditions. Undetected or unevaluated adverse localized equipment environments in the vicinity of environmentally qualified equipment are not acceptable. By definition, environmentally qualified components must have defined replacement schedules or qualified lives that are based on the severity of environmental conditions. If an environmental condition at the location of a qualified component is more severe than the analyzed condition, the accumulated deterioration of the component during service may cause failure during a design basis event, should one occur. Therefore, either adverse localized equipment environments associated with environmentally qualified components must be corrected, or the qualified life must be adjusted to account for the severity of the condition and assure operability under accident conditions.

Detection and management of adverse localized equipment environments help eliminate the possibility of common mode failures during service or under accident conditions. If an adverse localized equipment environment only enveloped a single piece of equipment, there would be no concern related to common mode failure caused by the environment. The redundant system not affected by the localized environment would perform the function. However, by the nature of plant design and operation, it is likely that if an adverse localized environment exists for one piece of equipment, the redundant piece of equipment may have a very similar environment even if in a separate area. The designs for redundant systems and their environments are often replications or mirror images even though they are separated from one another. Therefore, if an adverse-environment is identified for one piece of equipment, the environment of the redundant piece should be evaluated as well. Other similar applications should be considered as well. Such efforts eliminate common mode failures resulting from adverse localized environments.

In the following paragraphs, many examples of adverse localized equipment environments are included after a discussion of the stressors. The examples are not intended to discuss all the possible locations where adverse localized equipment environments can occur or all the possible ways they can occur. They are included to help the reader gain perspective on the issue and broaden the understanding of the sources and results of the adverse environments. This awareness, combined with plant-specific knowledge, should equip the reader with a good foundation for developing a plan to manage adverse localized equipment environments.

2.1 Temperature

The most common adverse localized equipment environments are those created by elevated temperature. Elevated temperature can cause equipment to age prematurely, particularly equipment containing organic materials and lubricants. The effects of elevated temperature can be quite dramatic. A rough approximation of the effect can be gained by use of the 10°C rule, which estimates that an organic material's life is halved for each 10°C (18°F) increase in temperature. For example, a component operating in a 45°C (113°F) environment would have approximately 1/4 of the thermal life of the same component in a 25°C (77°F) environment. Accordingly, it is important to know when localized temperatures exceed the specified operating temperature.

The following types of areas are prone to high temperatures:

- Areas with high temperature process fluid piping and vessels
- Areas with equipment that operate at high temperature
- Areas with limited ventilation

Some examples of high temperature areas and affected applications are described in the following paragraphs.

2.1.1 Areas with High Temperature Process Fluid Piping

Equipment near Main Steam Isolation Valves (MSIVs). Many utilities have found that limit switches installed on MSIVs experience temperatures in excess of the bulk ambient temperature. Environmental qualification requirements may limit the lives of these switches to two to six years depending on the severity of the temperature. A few utilities indicated that other types of equipment near the MSIVs are exposed to temperatures higher than the bulk room temperature.

Equipment in Pressurizer Compartments. Many PWRs have discovered that temperatures inside the pressurizer compartments exceed the bulk containment ambient temperatures. The limited ventilation in these compartments is another contributor to higher temperatures.

Main Steam Pipe Tunnels. Some utilities have experienced higher than originally predicted temperatures in main steam pipe tunnels or piping penetration rooms. Limited ventilation in these areas sometimes also contributes to the elevated localized temperatures.

Compartments under Turbines in BWRs. The area under the turbine of a BWR has many high-temperature steam lines and a by-pass header. This area may have limited ventilation and resulting high temperature conditions. Depending on plant design, cables and valve operators in these areas may have limited life.

Equipment Adjacent to Uninsulated Process Piping. RC Information Notice 86-49 [5] discusses a failure of medium-voltage cable due to installation near an uninsulated feedwater line. The thermal insulation had been removed from the line during repairs and had not been replaced.

2.1.2 Areas with High Temperature Equipment

Electrical Cabinets. Some utilities have experienced failures of energized equipment in electrical cabinets. NRC Information Notice 89-30, Supplement 1 [6] discusses the failure of a static exciter in a diesel generator control cabinet. NRC Information Notice 85-89 [7] discusses erratic instrumentation readings during a loss of control room ventilation. Both of these incidents resulted from elevated temperature due to a combination of energized equipment and limited ventilation. Temperature rises in non-ventilated cabinets can be significant.

2.1.3 Areas with Limited Ventilation

Upper Drywell or Containment Regions. Some plants have noted higher temperatures in upper drywell and containment regions. NRC Information Notices 89-30 [8] and 87-65 [9] also alerted utilities of this issue.

2.1.4 Miscellaneous Causes of Localized High Temperature Environments

Steam Leaks and Valve Packing Leaks. Some utilities noted instances of system leaks causing adjacent equipment to experience elevated temperatures. These conditions are usually corrected when discovered. Equipment in the vicinity of steam and valve packing leaks experience a combined adverse environment of elevated temperature and condensation. Immediate action should be taken to protect exposed equipment when a leak is identified, and the impact on equipment operability and service life should be evaluated as part of the utility's corrective action process.

Inadequate or Improperly Installed Thermal Insulation. Significant problems can occur when process line insulation is damaged, inadvertently not reinstalled, or improperly installed after maintenance. Exposed pipe flanges and pipes supports can conduct large amounts of heat. Additional insulation may be needed in areas where equipment is located close to high temperature piping or related supports.

One measure to take in evaluating the potential for adverse localized environments is to confirm the adequacy of post-maintenance verification of the condition of thermal insulation. Area walkdowns should include identification of equipment located adjacent to exposed process line supports and flanges.

Additionally, thermal problems can occur when components are inadvertently enclosed within thermal insulation so that they experience temperatures approaching process temperatures rather than temperatures approximating ambient conditions. Components such as the heads of thermocouples and RTDs, solenoid operated valves, and pneumatic operators can be subject to being partially contained within the process equipment thermal insulation and, thereby, be exposed to undesirably high temperatures.

Some utilities reported cases where elevated equipment temperatures were caused by improperly installed thermal insulation. Examples include cables wrapped within the insulation blanket next to high temperature piping, thermal insulation blankets not tied tightly enough causing radiant "shine" from the small exposed portion of piping, and pipe flanges or pipe supports left uninsulated following maintenance.

Abnormal Ventilation System Configurations or Balancing. Equipment relying on direct ventilation to keep it within specified operating conditions may experience high temperatures when ventilation systems are not in normal configurations or are balanced improperly. At many plants, specific short-term operating conditions are specified in areas with nonsafety-related ventilation, such as during Station Blackout. It is important that all operating conditions are considered when designing and installing equipment.

Proximity to High Power Incandescent Lighting. Incandescent lamps can give off up to 95% of their energy as heat. Equipment installed directly adjacent to these lights may experience premature aging. One utility found a faded cable near an incandescent light during electrical equipment walkdowns (see Figure 3-3).

2.1.5 Other Temperature Considerations

Inordinately cold temperatures can also cause adverse localized equipment environments in some plant areas. While cold temperature does not cause aging per se, it can cause equipment or system failures. Cold weather extremes should be accounted for in the design of the plant based on local weather histories. Extreme cold can be an immediate operational problem, such as freezing of water filled instrument lines, and must be promptly managed.

Cycling between temperature extremes can also cause equipment degradation. Equipment malfunctions, such as nitrogen system leakage, can also cause localized cold temperatures. Degradation caused by cycling between temperature extremes or localized cold temperatures caused by equipment malfunctions can also be identified and managed by the methods discussed in this guideline.

2.2 Radiation

Exposure to elevated radiation doses can also cause premature degradation of organic materials by changing the molecular structure of the material through cross-linking and scission of long-chain molecules. Depending on which process is dominant and the severity of the dose, radiation can cause improvement or deterioration of a polymer's engineering properties. The types of property changes possible include hardening (embrittlement), cracking, crazing, and softening. More information on the effects of radiation on materials can be found in EPRI NP-2129, *Radiation Effects on Organic Materials in Nuclear Power Plants* [10]; EPRI NP 4172-M and NP-4172-SP, *Radiation Data for Design and Qualification of Nuclear Plant Equipment* [11]; and EPRI NP-4735, *Radiation Effects on Lubricants* [12].

The radiation levels most equipment experience during normal service have little degrading effect on most materials. Design-basis calculations or evaluations that determine or bound the expected radiation doses should be available for all plant areas. These evaluations should account for additional doses seen in these areas due to infrequent operational line-ups. However, some localized areas may experience higher than expected radiation conditions.

Typical areas prone to elevated radiation levels include areas near primary reactor-coolant- system piping or the reactor-pressure vessel; areas near waste processing systems and equipment (e.g., gaseous-waste system, reactor-purification system, reactor-water-cleanup system, and spent-fuel-pool cooling and cleanup systems); and areas subject to radiation streaming.

NRC Information Notice 93-39 [13] alerts utilities of narrow, intense beams of radiation that can stream through the gaps around process and instrumentation lines at biological shield penetrations, potentially exposing environmentally qualified (EQ) equipment to high levels of radiation.

2.3 Chemicals and Contaminants

Chemicals and contaminants can cause equipment degradation. However, they are usually found only at discrete locations. Contaminants themselves can be visually detected, whereas temperature and radiation cannot. Because superior housekeeping is demanded at nuclear power plants, contaminants should not be widespread and would have little probability of causing failures of multiple trains or systems of equipment.

However, equipment and cables in rooms containing reactor water chemical treatment and boration systems may be exposed to chemical contamination. Hydraulic fluids and lubricating oils may also adversely affect cable jackets and insulations if leaks or spills occur. NRC Circular 77-06 describes cable damage due to a leak in the electro-hydraulic control (EHC) system at a plant (see Appendix C).

Cleaning and repainting of power plant areas can contaminate the inside of electrical panels if not properly controlled. Cabinet vents must be sealed or protected in some manner from dust and dirt generated by sandblasting surfaces and from paint and epoxy mist caused by refinishing walls, floors, or equipment in the vicinity. Otherwise, components within the cabinets can be directly effected chemically, or heat transfer may be impaired due to surface coating or clogged ventilation filters.

The visual inspection techniques discussed in this guideline and housekeeping processes already in place at utilities should provide reasonable assurance that degradation caused by chemicals and contaminants is adequately managed.

2.4 Moisture

Moisture can cause deterioration of equipment by corrosion of metals including housings, subcomponents, and electrical connections and contacts; and by reactions with some organic materials. Surface insulation properties of components such as terminal blocks may also be affected when wet. Moisture, generally in combination with elevated temperature and/or radiation, can cause certain cable insulation and jacket systems to swell. Moisture can cause cracking of Kapton insulation at tight bends when moisture or caustics and elevated temperature are present (see NRC Information Notice IN 88-89 [14]).

NRC Information Notice IN 84-57 [15] discusses 53 events related to moisture intrusion that occurred in a four-year period. The Information Notice cites the following three mechanisms for moisture intrusion:

- Loss of environmental protection boundary due to maintenance activities
- Inadequate protective boundary design
- Steam and moisture entering unsealed conduit systems at higher elevations

In IN 84-57, the NRC recommends that licensees consider performing routine surveillance to assure that equipment environmental parameters are within design limits.

2.5 Vibration

Excessive vibration can cause damage and degradation to the equipment that is the source of the vibration as well as to adjacent equipment. Electrical connections, especially if improperly supported, are susceptible to vibration induced failures. Vibration in piping systems can cause failures of connections and damage pipe-supported equipment.

Information Notices 85-47 [16], 83-70 [17], and 83-55 [18] discuss damage to valve internals due to excessive vibration that resulted in failures. These types of failures or equipment degradation would be detected by functional and performance testing of the valves.

Information Notice 89-07 [19] discusses failures of small diameter tubing of diesel generator support systems due to vibration. The vibration may have been detectable by observation of the tubing system during diesel operation. The failure of the tubing would be detectable during functional and performance testing of the diesel system.

2.6 Ultraviolet Radiation

Ultraviolet light can come from sunlight or lighting fixtures. Equipment vendors often specify storage requirements to protect material from ultraviolet radiation.

Ultraviolet light is only a potential threat to exposed non-metallic materials. Page 3-4-3 of EPRI Report TR-106687 [3] describes cracking of high-density polyethylene insulation on control room cables that was attributed to ultraviolet radiation damage. Most power plant cables containing carbon black and cables that are qualified for radiation conditions will not be susceptible to ultraviolet radiation damage. However, some nonsafety-related specialty cables may be susceptible.

3

METHODOLOGY FOR MANAGEMENT OF ADVERSE LOCALIZED EQUIPMENT ENVIRONMENTS

This section presents a systematic approach to managing adverse localized equipment environments. The ultimate goal of this approach is to provide reasonable assurance that adverse localized equipment environments do not pose a significant threat to safe and reliable operation. General steps are discussed to help utilities form an optimal approach to managing adverse localized equipment environments for their individual situations. Through this process a utility can optimize existing activities and design supporting activities that best match the utility's specific needs.

Figure 3-1 provides a flowchart of the adverse localized equipment environment (ALEE) evaluation and management process. The following are basic actions to be performed:

1. Determination of the concern driving the adverse localized equipment environment evaluation.
2. Determination of the constraints of the evaluation
3. Definition of the scope and depth of the evaluation
4. Identification of the existing data and knowledge
5. Evaluation of existing information and data
6. Determination of the need for supplemental activities
7. Performance of supplemental activities and evaluation of results
8. Determination of the need for ongoing activities
9. Implementation of ongoing activities as needed
10. Verification that adverse localized equipment environments are managed
11. Implementation of actions for adverse localized equipment environments that were not previously managed.
12. Documentation of activities and results

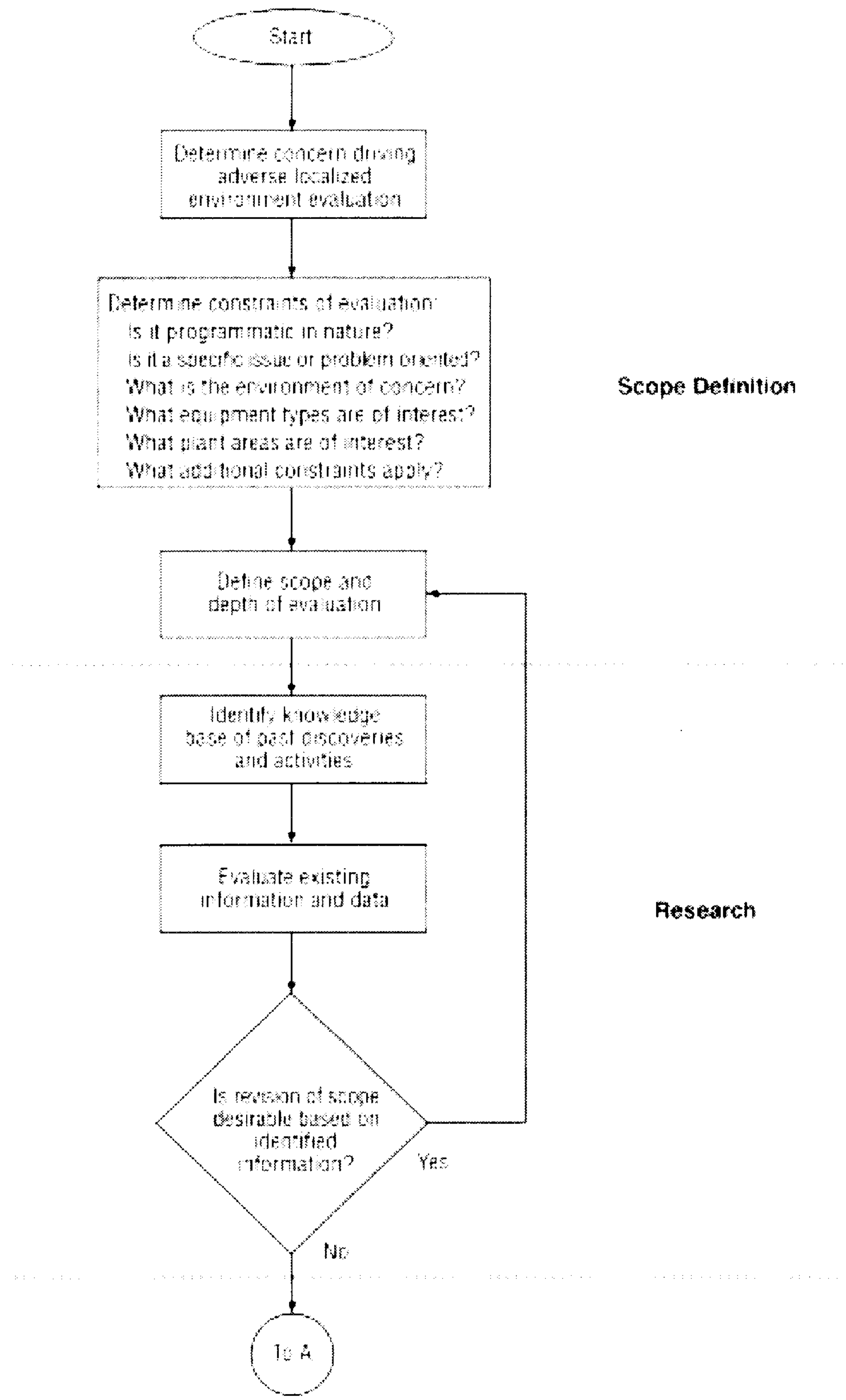
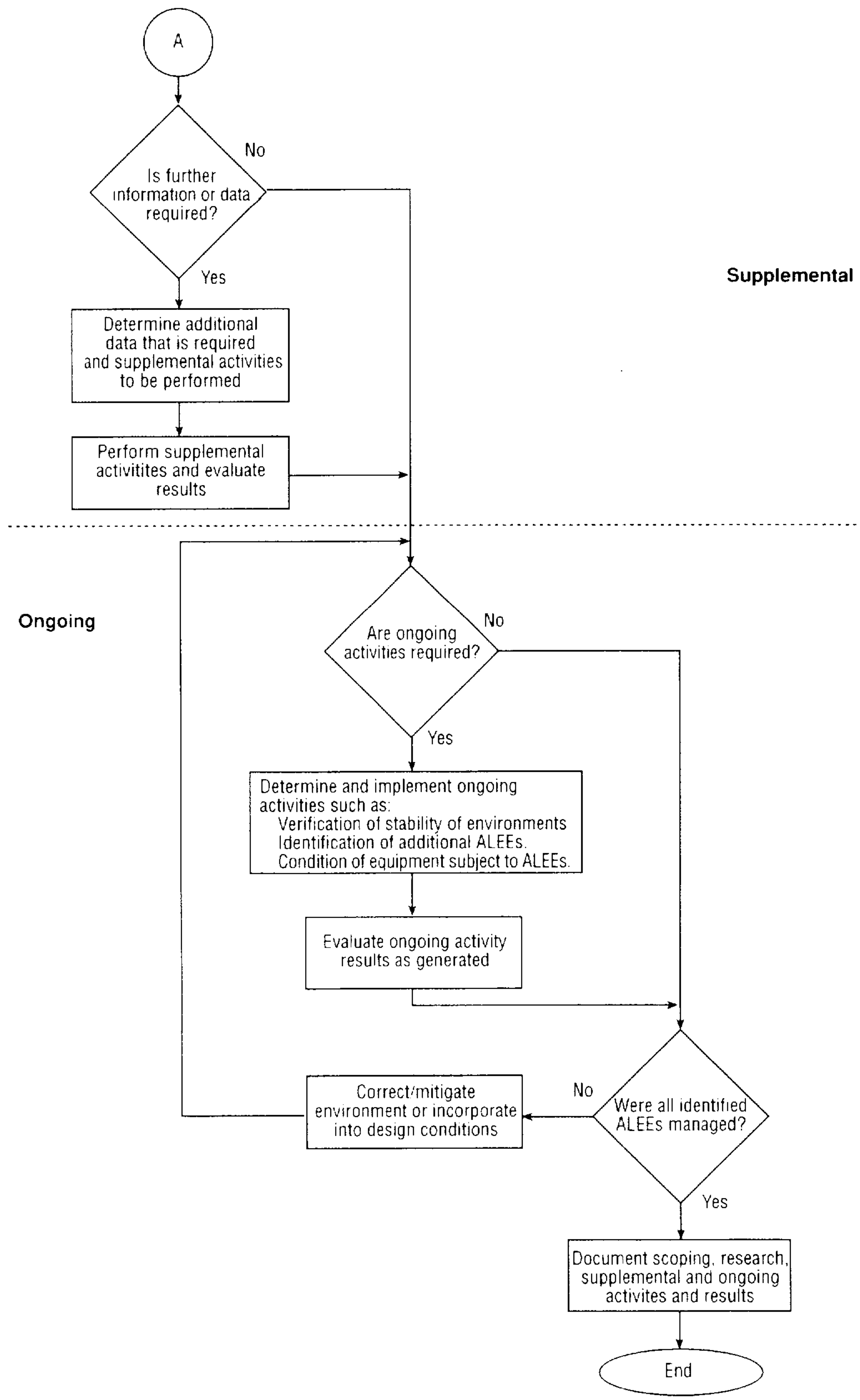


Figure 3-1
Flowchart for Management of Adverse Localized Equipment Environments



Flowchart for Management of Adverse Localized Equipment Environments (continued)

These activities can be grouped into one of the following four phases:

- Scope Definition
- Research
- Supplemental Activities
- Ongoing Activities

In the Scope Definition phase, the reasons for implementing an evaluation of adverse localized equipment environments are explored. Once they are understood, the scope of the program and the depth of the evaluation are determined. In the Research phase, past information concerning adverse localized equipment environments is identified and evaluated. The Research phase entails interviewing personnel and reviewing plant documentation to identify past discoveries and resolutions of adverse localized equipment environments. This effort also identifies programs and activities that may provide partial or entire solutions to the identification of these localized environments.

In the Supplemental Activities phase the data from the Research phase is evaluated to determine those activities necessary to complete the current identification of adverse localized environments. Once this phase is completed, the overall status of the environments for the given scope will have been identified. Thereafter, the need for ongoing activities is examined. The Ongoing Activities phase may include periodic verification of the temperatures or radiation dose rates to confirm that conditions have remained stable, or reviews of plant areas to verify that new adverse environments have not been created through plant modifications. This phase also includes actions taken to change, mitigate, or control the effects of the adverse environment. While documentation of the efforts is shown at the completion of the flowchart, documentation of activities should be performed throughout the process as actions are completed. These steps are described further in the following subsections.

This systematic approach results in the management of adverse localized equipment environments. Once discovered, the environment is either corrected or mitigated or the environment becomes part of the specified service conditions.

3.1 Scope Determination

Reasons for initiating an identification and management effort related to adverse localized equipment environments include the following:

- One or more equipment failures have occurred that were attributed to adverse localized environments.

- Equipment has been identified that has been significantly degraded by an adverse localized environment.

- Environmental monitoring programs identified plant areas with conditions in excess of evaluated design basis conditions.

- A program such as environmental qualification or license renewal needs data concerning localized environments and their control.

- Regulators have requested information on how "hot spots" are identified and resolved either with regard to license renewal or current operations.

Other reasons may exist for a concern to arise. However, understanding the reason for the concern and the nature of the condition initiating the concern help define the scope and the level of effort necessary.

While the scope could be to search for all adverse localized equipment environments of any kind, most utilities would not choose such a wide scope without some impetus to do so, such as identification of multiple failures related to a number of types of adverse environments.

During the course of any adverse localized equipment environment evaluation, additional adverse environments beyond those within the original scope may be identified. The scope and nature of the review may expand during the course of the effort, especially as the review of past experience and the knowledge of plant personnel is explored.

Once the impetus for the review is understood, the scope of the effort can be defined. A utility may choose to include or exclude certain groups of equipment and areas based on the goals of the effort. For example, License Renewal may be the impetus for reviewing the environments assumed in assigning equipment service lives. In this case, the utility may choose to limit the scope of activities to License Renewal systems, structures, and components.

A utility may also decide that for certain equipment types, it may be easier to include all of the equipment of that type than to determine which equipment is within a limited scope and which equipment is not.

Scope may also be limited if a utility is using an area-based approach. (Inspection approaches are discussed in Appendix A.) The utility can limit its scope to include only areas prone to adverse localized equipment environments.

Considerations for determining the scope of review are detailed in the following paragraphs.

3.1.1 License Renewal Equipment

This group of equipment, defined in 10 CFR 54.4 [20], includes the following:

- Safety-related equipment relied upon to remain functional during and following design-basis events
- Nonsafety-related equipment whose failure could prevent safety-related equipment from performing their safety function
- Other equipment within the scope of some specific NRC regulations

A utility may choose to focus on License Renewal equipment to help support time-limited aging analyses. Alternatively, a utility may wish to include only equipment within the scope of an adverse localized equipment environment review that is subject to aging management review to fulfill License Renewal Rule requirements. In either case, activities undertaken to manage adverse localized equipment environments may also be credited for fulfilling License Renewal Rule requirements.

3.1.2 Environmentally Qualified Equipment

Environmentally Qualified (EQ) equipment, as defined in 10 CFR 50.49 [21], must be capable of performing safety-related functions before, during, and after a Design Basis Event (DBE). One of the dangers of adverse localized equipment environments is that they may cause degradation of equipment that, while not significant enough to cause failure during normal operation, may render the equipment incapable of functioning properly during or after an accident. A utility may choose EQ equipment as its scope for the localized environments evaluation to ensure that service condition assumptions supporting its EQ program remain valid.

3.1.3 Maintenance Rule Equipment

This group of equipment, defined in 10 CFR 50.65 [22], contains much of the License Renewal equipment. It also includes equipment whose failure could cause a reactor scram or safety system actuation and equipment used during implementation of Emergency Operating Procedures. Utilities may choose to include Maintenance Rule equipment group in the scope of its review because this equipment is important to plant reliability as well as plant safety.

3.1.4 Operationally Important Equipment

A utility may choose to include equipment in the scope of review that are vital to reliability and availability of the plant. This set of equipment may include nonsafety-related equipment whose failure could cause a plant trip or without which the plant cannot continue to operate. For example, supply breakers and cabling to safety-related busses from the station power system are often classified as nonsafety-related. Other examples of equipment that might be classified as nonsafety-related, but are vital to plant operation, include main-turbine controls, and feedwater pump and feedwater regulation valve controls.

3.1.5 Specific Issue or Problem

In some cases, an evaluation of adverse localized equipment environments may result from a plant occurrence or problem. The scope of this effort may be focused on other applications or situations for which similar problems or occurrences could be expected, particularly if no plant actions were taken. Examples of specific issues include identification of cabinets with high temperature rise, discovery of inadequately installed thermal insulation following maintenance, and identification of components subject to radiation streaming.

3.2 Research

To some extent, all utilities have performed some activities that can be credited for identification and management of adverse localized equipment environments. Sources through which information about these activities can be identified include the following:

- Corrective action documents
- Environmental service condition manuals or drawings
- Interviews of plant personnel
- Licensee Event Reports
- Maintenance history and trending files
- Plant operating experience files
- Related plant programs

In addition, interviews of personnel knowledgeable of past activities and programs can provide rapid insights into the types of conditions that exist and the location of information concerning adverse localized equipment environments and their management.

Each of these is discussed in more detail on the following pages.

3.2.1 Corrective Action Documents

Quite often corrective action documents contain descriptions of previously identified adverse localized equipment environments. Searches of corrective action databases may reveal environmentally induced equipment failures, areas of elevated temperatures, fluid spills, temperature excursions, and other events involving adverse localized environments. Review of the actions taken in response to the events identified in the corrective action document may reveal additional activities that can be credited in managing adverse localized equipment environments. This review can also identify candidate areas for supplemental actions.

3.2.2 Environmental Service Condition Manuals or Drawings

Some plants have developed consolidated environmental service condition manuals. These manuals combine data originally documented in numerous sources, such as architect engineer calculations, design calculations, equipment specifications, Safety Analysis Reports, Safety Evaluation Reports, and licensing correspondence. In addition to a listing of the environmental parameters, these manuals may have text sections that explain the derivation of the parameters. This text portion may discuss efforts that determined or verified the parameters by environmental monitoring. These manuals and the personnel who developed them often can provide insights for identifying adverse localized equipment environments.

3.2.3 Interviews of Plant Personnel

Interviews with plant personnel can assist in identifying past or present existence of adverse localized environments and actions taken to detect, correct, or mitigate the effects of adverse localized environments. Personnel having wide and frequent exposure to plant conditions—such as operators, maintenance technicians, maintenance planners, system engineers, and health physics personnel—are excellent candidates for personnel to interview. Many plants also have a specialized, multi-disciplined maintenance team to resolve day-to-day emergent equipment problems, sometimes called Fix-It-Now (FIN) or Work-It-Now (WIN) Teams. Members of these teams are also good interview candidates. EPRI Report TR-110089 and NUREG/CR-5424 report describe the interview process for eliciting experienced-based information [35,36].

3.2.4 Licensee Event Reports

A utility may have implemented inspections or other monitoring programs in response to events reported to the NRC via Licensee Event Reports (LERs). A review of LER files, available electronically at many utilities, may reveal processes that a utility has implemented to preclude recurrence of environmentally induced degradation of equipment.

3.2.5 Maintenance History and Trending Files

Maintenance history and trending files often provide insights to adverse localized equipment environments. Some utilities require that failure analyses be entered into corrective maintenance work orders. Some maintenance databases provide keyword search capabilities. Searches of these files for words such as "temperature," "thermal aging," "premature failure," and "age-related" may reveal equipment that has been exposed to adverse localized equipment environments. Increasing failure rates may also reveal equipment exposed to adverse environments.

3.2.6 Plant Operating Experience Files

Utilities have performed inspections for localized environments in response to NRC generic correspondence. A list of relevant correspondence is included in Table C-1 of Appendix C. Reviewing the correspondence files for these generic communications may identify activities that were completed to detect adverse localized equipment environments. Interviews with personnel associated with these activities and review of the resulting reports or files identify the scope and its basis, results, and any ongoing activities. Review of Institute of Nuclear Power Operations (INPO) Significant Operating Experience Reports (SOERs) for the plant may also reveal activities that can be credited for identifying and managing adverse localized equipment environments.

3.2.7 Related Plant Programs

Existing plant programs should be reviewed to identify any programs that can detect or minimize equipment susceptibility to localized environments, and to familiarize the personnel performing the review with activities and practices already implemented at the plant. This review can identify candidate programs for detecting or minimizing susceptibility to localized environments without significant expenditure of resources. Programs may exist that would only need minor alterations to allow ongoing detection, documentation, and resolution of adverse localized equipment environments. A few examples of these programs follow.

Temperature Monitoring Programs. Many plants have implemented temperature-monitoring programs. Quite often these programs were evolutionary. Personnel involved with implementing or maintaining these programs can often provide insight as to why temperature monitoring equipment and locations were chosen, especially for areas with more severe temperatures.

Environmental Qualification (EQ). This program establishes equipment qualified lives based on environmental conditions. Many EQ programs include extensive reviews of environmental service conditions to maximize qualified lives and reduce equipment replacement costs.

Sometimes EQ files contain field inspection sections that provide a description or measurement of the environmental conditions at the equipment. Walkdown information for EQ components may also provide insights regarding localized conditions and their effects.

Maintenance Rule/System Management. The Maintenance Rule (10 CFR 50.65 [22]) requires that appropriate corrective action be taken when the performance or condition of a structure, system, or component does not meet established goals. Most utilities monitor equipment for the maintenance rule on a system basis. Systems outside the Maintenance Rule scope often have the same techniques applied to them. Monitoring and failure analyses performed under these programs may provide useful insight into the existence of adverse localized equipment environments. Old system report cards can also document environmentally induced problems.

License Renewal. If a utility is preparing or applying for License Renewal, the License Renewal Group may have already performed or committed to activities that can be used to manage adverse localized equipment environments. License Renewal organizations are often excellent candidates for sharing resources for aging management techniques. Also, when implementing new aging management techniques, utilities will want to ensure that the needs of License Renewal organizations are considered.

Performance and Reliability Engineering/Life Cycle Management. These programs review equipment and system failures. Often, the scope of equipment evaluated includes additional equipment that is vital to the reliability of the plant but excluded from other programs. Personnel working in these programs may be aware of equipment problems caused by adverse localized equipment environments.

Other plant programs that may be involved with system management or development of operating conditions include the following.

- Barrier Control
- Design Basis Documents
- Fire Protection / Appendix R

Since the primary concern associated with adverse localized equipment environments is equipment degradation, information and techniques used in these programs can aid in the management of adverse localized equipment environments. Reviewing these programs can provide insight into how information from the programs can be melded to comprehensively identify and manage adverse localized equipment environments.

3.3 Selection of Supplemental and Ongoing Activities

Once the scope and desired level of detail have been defined (Section 3.1), the available information (Section 3.2) must be evaluated to determine supplemental efforts necessary to fully determine and document the current status of adverse localized equipment environments. If the identified information fulfills the scope, the remaining activity is to document the findings. However, the existing information may not be sufficient to define the current status of adverse localized equipment environments. Supplemental activities may be needed to complete the review for the entire scope of environments and equipment of interest.

Once the supplemental activities are completed, the current status of adverse localized equipment environments can be determined and documented. After completion of the supplemental activities, the need for ongoing activities can be assessed.

Ongoing activities may be implemented to detect changes to existing environments and identify new adverse localized equipment environments. If a review of activities reveals a weakness in the long-term ability of a plant to detect these changes, a utility should consider the areas of the plant that may be likely to experience changes in equipment environments and how those changes would be likely to occur. Then, ongoing activities to detect such changes can be developed and implemented.

When selecting either supplemental or ongoing activities, the following items may be considered:

Length and periodicity of monitoring. The depth and duration of previous and ongoing environmental monitoring activities are important to consider. Past actions may have been sufficient to determine that susceptibility to localized environments in a certain plant area or for a specific equipment type is minimal. A one-time inspection or monitoring for a specific period may be performed to determine that conditions warrant no further actions. Alternatively, frequent inspections may require less rigorous inspection criteria because the area will be revisited often enough to verify that no significant changes are occurring. While inspection times and frequencies can easily be changed as new information dictates, knowing the intended inspection duration and frequency in advance help in choosing techniques and the level of depth of the inspections.

Personnel Resources. Opportunities should be taken to use personnel who can perform any desired additional inspections without a significant change to their existing workload. Frequently, existing personnel already routinely inspect the area or equipment type under consideration.

Integration of the inspection technique with existing plant programs and processes. Before techniques to detect adverse localized equipment environments are selected, the programs reviewed in the research phase should be evaluated as potential resources for implementing the new or modified techniques. Techniques should be chosen that maximize benefits to as many organizations as possible. For example, if temperature monitoring is one of the techniques chosen, the research phase may identify multiple organizations interested in temperature data for different reasons. These organizations can then share resources to develop a temperature-monitoring program that fulfills the needs of all interested organizations. Also, if some organizations already perform one of the chosen activities, such as visual inspections, those organizations may be willing and able to complete the add-on activity with little or no additional resources.

Training. The personnel and organizations chosen to implement activities to manage localized equipment environments must be trained to support those activities. Appendix A includes a discussion of training personnel for visual inspections.

Table 3-1 provides a summary of programs and organizations that can support the management of adverse localized environments.

Table 3-1
Programs and Organizations Related to the Management of Adverse Localized Equipment Environments

Program or Organization	Activity	Examples and Criteria
Component Engineering, EQ Engineering, Operations, Maintenance, Maintenance Engineering, Radiation Monitoring, System Engineering	Visual Inspections	Any organization that periodically performs walkdowns of equipment. These personnel may need training on how to detect environmentally induced damage.
Radiation Monitoring (Health Physics)	Radiation Hot Spot Detection	These personnel are aware of radiation hot spots and changing radiation conditions.
Component Engineering, EQ Engineering, Fire & Safety (Heat Stress Evaluators), License Renewal Engineering, Maintenance Rule Engineering, Operations, Predictive Maintenance, System Engineering	Temperature Monitoring	Temperature monitoring can be performed programmatically or as discrete observations. All can be credited for verifying actual temperatures in the plant.
Component Engineering, EQ Engineering, Maintenance Engineering, Materials Engineering, Reliability Engineering, System Engineering, Operating Experience Specialists, Corrective Actions Specialists	Trending	These organizations may systematically review maintenance orders to identify trends in equipment failures. Equipment failing faster than predicted may be indicative of an adverse localized environment.

3.4 Inspection and Investigative Techniques

Inspection and investigative techniques available to help manage adverse localized equipment environments include the following:

- Visual inspection
- Temperature monitoring
- Radiation monitoring
- Plant data log reviews

While the scope of this guideline is not focused on monitoring of equipment environments, important elements of some of the techniques are discussed below. These techniques can all be used in either the supplemental or ongoing phases of managing adverse localized equipment environments. Examples are presented at the end of each section describing the technique.

3.4.1 Visual Inspections

Utilities and the NRC recognize visual inspections as one of the most powerful tools for managing localized equipment environments. In Information Notice 86-49, "Age/Environment Induced Electrical Cable Failures" [5], the NRC stated, "Another important facet of the periodic maintenance and testing program for cable circuits is the walkdown inspection to identify actual or potential environmental conditions (heat, water, chemicals, etc.) in the immediate vicinity of the cables that could adversely affect the cable conditions."

Walkdowns provide the opportunity to detect environmental conditions that could cause equipment to degrade prematurely and provide the opportunity to detect signs of equipment degradation. Visual inspections do not need to include expensive equipment or complicated processes. They only require personnel knowledgeable in detecting signs of degradation and causes of adverse localized equipment environments.

The effectiveness of walkdowns can be improved as an aging management tool by providing training in detection of environmentally induced damage and by adjusting the focus of walkdowns already occurring in the plant. Visual inspections should be a part of every utility's activities to manage adverse localized equipment environments.

Examples of the types of situations that visual inspections can discover are included in Figures 3-2, 3-3, and 3-4. Additional photographs of items that could be identified are included in Appendix B.

Performing visual inspections may have additional benefits, such as discovery and corrections of problems not related to adverse localized equipment environments.

Examples of walkdown checklists and walkdown organization techniques are included in Appendix A.

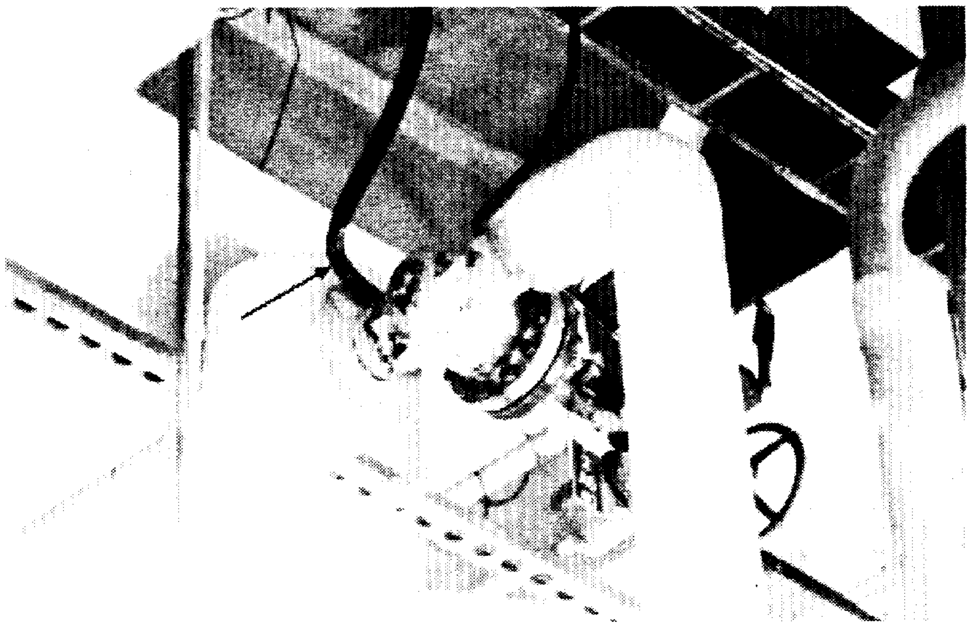


Figure 3-2
Example of an Installation That Could Create an Adverse Localized Equipment Environment–A Cable Installed near an Uninsulated Valve on a High Temperature Process Line

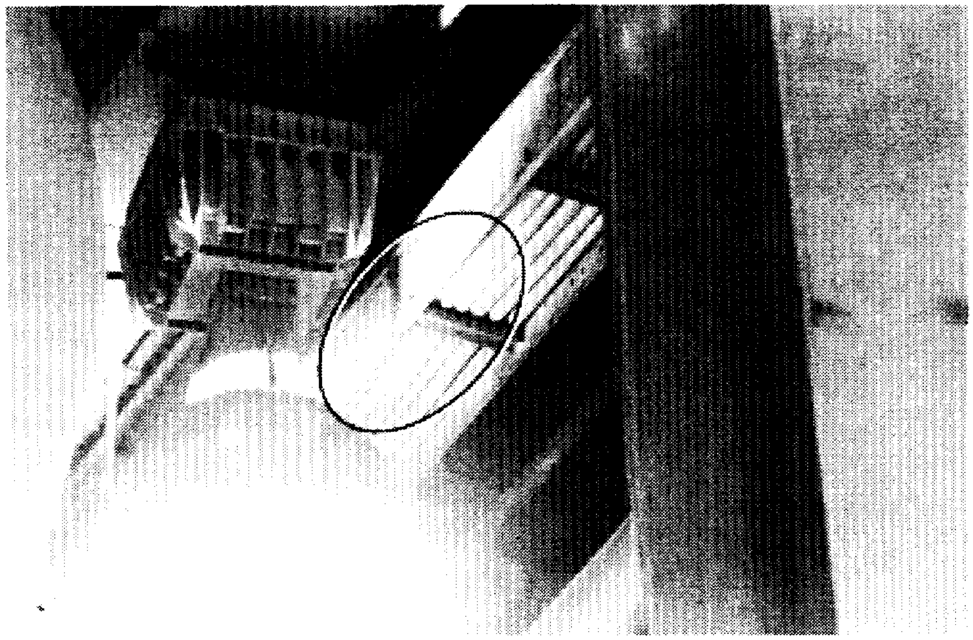


Figure 3-3
Example of Degradation Potentially Caused by an Adverse Localized Equipment Environment–Faded Cable Insulation Caused by a Localized Hot Area near an Incandescent Light Fixture

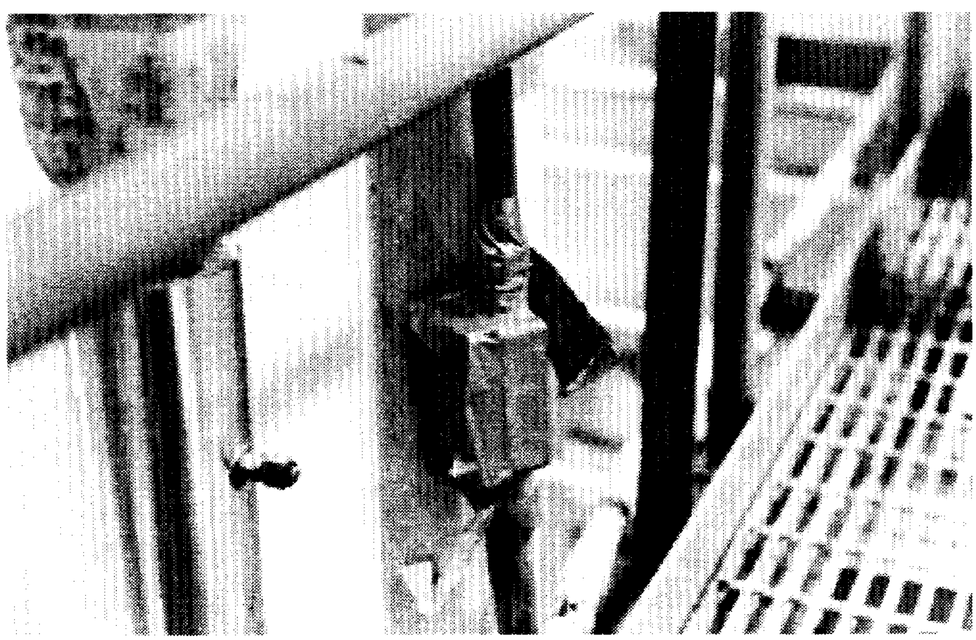


Figure 3-4
Example of an Installation That Could Create a Different Environment Than Assumed In Equipment Design–A Conduit Fitting with Duct Tape Rather Than Correct Cover and Seal, Which Could be Susceptible to Moisture Intrusion

3.4.1.1 Utility Examples–Visual Inspections

The project investigation identified one utility that has implemented all of the following periodic walkdown activities:

1. System engineers are required by procedure to walk down their systems at regular intervals, typically monthly. These inspections specifically target the following localized conditions:

    - Leaks from valve packing, pump seals, air lines, and steam or hydraulic lines
    - Improperly installed insulation
    - Adequacy of cooling and ventilation
    - Equipment operating temperatures
    - SSC [System, Structure or Component] stress or abuse (The procedure that governs system walkdowns defines this as "Thermal insulation damage, bent or broken hangers, excess piping motion or vibration, and damaged tubing or flex conduits are examples of potential stress or abuse to the system. Excessive vibrations, unusual noises, excessive temperatures, discolored fluids, relay chatter, indications of flow through closed valves, external leakage of fluids, corona discharges, or arc paths are some examples of potential equipment stress. The purpose of this objective is to assess the condition of SSCs.")

2. Personnel assigned ownership of plant spaces are required to conduct periodic inspections of their assigned spaces by a procedure different from the procedure governing system walkdowns. (The procedure for this activity also requires all site personnel to report material deficiencies that they observe through the site corrective action process.) These inspections include a review for the following material deficiencies that could be indicative of adverse localized equipment environments:

    - Leaks–water, steam, oil or air from valves, pumps and piping
    - Drains/drain holes–clogged, full, or plugged, or have missing screens or grating
    - Lines/pipes–loose, unsupported, or having missing insulation
    - Panels–covers missing, open or loose
    - Packing–bottomed-out adjustments or rusted glands
    - Cables/leads–unsecured, worn or frayed insulation, and improper terminations

- Motors/generators–broken brush-rigging pigtails, loose or missing ground straps, and excessive noise or vibration
- Preservation–rust, corrosion, or inadequate paint
- Pipe supports–cracked welds, missing or loose hardware
- Structure–cracked concrete, water leaks through concrete or expansion joints, or missing or deteriorated expansion joint material

In addition to walkdowns conducted as systems are returned to service, a specific post-outage walkdown verifies that thermal insulation is properly installed. A signoff on the pre-startup check off certifies that this walkdown has been conducted.

While these walkdowns were not initiated specifically to identify adverse localized environments, they obviously provide a significant amount of information about potential and actual adverse localized environments.

3.4.2. Temperature Monitoring

Almost all utilities have implemented some level of temperature monitoring at their nuclear plants. Often, temperature monitoring is implemented to determine a more accurate service temperature or temperature profile to allow a refined determination of qualified life for environmentally qualified components. Sometimes, temperature monitoring is implemented to verify that equipment temperatures are within design limits.

Many utilities have turned to temperature monitoring as the primary method for ensuring equipment does not degrade faster than predicted. Temperature monitoring is a valuable tool in managing adverse localized equipment environments because it can quantify the equipment's thermal environment and allow determination of the need for changing the periodicity of maintenance and replacement.

Many different techniques and monitoring devices have been used to monitor equipment temperatures, some of which are discussed in detail in EPRI Report NP-7399, *Guide for Monitoring Equipment Environments during Nuclear Plant Operation* [23]. Many utilities have successfully used infrared (IR) thermography as a screening tool. More guidance on IR thermography can be found in EPRI Report NP-6973-R2, *Infrared Thermography Guide* [24].

3.4.2.1 Utility Examples–Temperature Monitoring

Many utilities have used temperature-sensitive film, or "temperature dots," as a screening tool for determining locations of potential thermal hot spots. These devices are inexpensive and require little labor to install. However, at least one utility has noticed that the results recorded on some films can change if they are removed and stored for long periods of time. Therefore, the peak temperatures indicated by these films should be recorded shortly after they are removed from the monitoring application.

EPRI Report TR-106687, *Cable Aging Management Program for D. C. Cook Nuclear Plant Units 1 & 2*, [3] discusses an extensive analysis of cable life using seven-years of temperature monitoring data.

Another utility used temperature monitoring to determine operating temperatures for cables that could not be shown on an analytical basis to be operating at less than the temperature that would allow a 60-year service life. This utility used a combination of walkdown inspections and calculations to establish a ranking of areas most likely to exceed the 60-year service life temperature. Then, monitoring of these locations was performed. Further details of this example are provided in Case Study 1 in Appendix E.

One utility used a multi-faceted approach to determine susceptibility to thermal hot spots on cables. The effort included infrared thermography screening, installation of 32 temperature monitoring devices, evaluation of hourly measurements inside the building and site temperatures, and evaluation of outage schedules and equipment lineups. Further details of this approach are presented in Case Study 2 in Appendix E.

3.4.3 Radiation Monitoring

Very few cases of in-service equipment degrading faster than expected due to localized radiation fields were identified in the course of this effort. However, a review of plant radiation surveys could be conducted to determine areas of the plant that might be exposed to long-term radiation doses in excess of assumed values. Dose or dose-rate measuring devices could be installed in these areas to determine actual doses received by equipment. If the measured dose is in excess of design values, then the area should be included in the adverse localized equipment environment review process.

3.4.3.1 Utility Examples–Radiation Monitoring

One utility reviewed radiation surveys to determine the susceptibility of equipment, specifically cables, to radiation-induced deterioration. The review revealed only five locations where the contact reading resulted in a 60-year dose in excess of the cable insulation radiation threshold for the most susceptible cable type. The utility was able to conclude that radiation hot spots were not an aging concern for its plant.

One PWR installed five Westinghouse Lifetime® Monitors in response to uncertainties in certain equipment calculated doses and Information Notice 93-39 [13]. After one cycle of operation, the utility determined that all equipment-specific doses were lower than those predicted by calculation and that containment general area doses were slightly higher than predicted. The temperatures measured were also used to confirm location-specific temperatures. The following specific areas were monitored:

- Inside the control element drive motor (CEDM) cooling shroud, near connectors for the reactor vessel level monitoring system (RVLMS)
- Near reactor coolant system (RCS) hot leg piping (one monitor on each of 2 loops), near RCS temperature elements
- Near RCS cold leg piping
- Near the letdown isolation valves

3.4.4 Plant Data Log Reviews

Review of plant data logs can provide valuable insight into localized temperature and radiation environments. However, reviewing logs is probably more labor intensive than either interviewing personnel that frequently tour plant areas or perform surveys, or taking some measurements of suspect areas. The cost and level of effort required to extract data from existing logs should be compared to the cost of obtaining data from other methods.

3.5 Evaluation of the Data

Data must be evaluated after it is collected. Evaluation can occur in the following forms:

- Evaluation for a specific condition or set of conditions
- Additional reviews for similar conditions
- Periodic review for worsening conditions
- Periodic review for increased frequency of problems

Evaluation of a specific condition. Occasionally, a condition is identified that requires immediate evaluation. A typical example is when a piece of equipment is severely degraded due to a localized environment. This type of evaluation should be performed using the site's corrective action procedures. Equipment operability, event reportability, the extent of the concern, and likelihood of recurrence must be evaluated. The evaluation should also determine if the equipment's environment is properly specified. If the equipment's service conditions need to be refined, then the evaluation should determine the new environmental service parameters and the ability of the equipment to operate in that environment.

Additional reviews for similar conditions. Once an adverse localized environment is identified, a review may be performed to determine if similar localized environment problems or conditions are occurring at other similar locations or in similar applications in the plant. The following are examples of conditions to look for:

- Failures or degradation of identical equipment on the opposite train or unit
- Failures or degradation of identical or similar equipment in different locations
- Similar conditions noted on different systems
- Multiple problems with different equipment types in close proximity to the original or similar applications

Periodic review for worsening conditions. A periodic review may be implemented to determine if conditions are worsening. Such reviews would be implemented to identify the following:

- Changes in the range of recorded temperatures
- Changes in conditions noted in walkdown inspections
- Decreases in availability of systems or components

Periodic review for increased frequency of problems. An increasing failure rate is an indication that the severity of the environment may be increasing. This type of review may require gathering data for relatively long periods to enable detection of increased frequency of problems. For example, five or more years may be required to determine that a component with a six-year replacement frequency is failing earlier than expected and may require replacement every four years instead.

3.6 Management of Adverse Localized Equipment Environments

Once an adverse localized equipment environment is discovered, a management strategy must be chosen. Available choices include the following:

- Incorporate the environment into design conditions.
- Replace the equipment or part with more durable components.
- Eliminate or lessen the cause of the adverse environment.

- Shield the equipment from the environment.
- Move the equipment away from the environment.

Examples of some of these preventive and mitigative actions are discussed below.

Incorporate the environment into design conditions. This option is based on the capability of the equipment to operate in the newly identified environment. Neither the equipment nor the environment of the equipment is changed. Evaluation may determine that equipment has a shorter service and must be replaced or refurbished more frequently. Incorporating the environments into design conditions ensures that other equipment installed in the same area is also evaluated, designed, and maintained for the more severe condition.

A number of utilities have effectively used temperature monitoring to more accurately specify equipment and sub-component temperatures of equipment installed in areas with localized-high temperatures. Some utilities have also measured surface temperatures at different locations on the equipment to determine sub-component temperatures.

Replace equipment or part with more durable components. This option does not change the environment. Instead, the equipment is modified to allow the equipment to operate in the more severe environment. For example, sub-components that are more resistant to radiation or elevated temperatures may be installed.

Eliminate or lessen the cause of the environment. This option lessens the environment by correcting the cause. If the cause is heat, the heat source is removed, improved cooling is provided, or thermal insulation is improved. If the cause is moisture or contaminants, the source is removed. For example, a leaking valve or pipe could be repaired.

One utility with a PWR replaced the solid concrete roof on the pressurizer compartment with steel grating, allowing free circulation of cooler air. This modification reduced the temperature of certain components by 40°F with no appreciable change in general containment temperatures. As a result, the qualified life of components in the compartment doubled.

Shield the equipment from the environment. Different types of shields may be used to reduce the impact of the adverse environment. Reflective shields can be installed to protect the equipment from radiant heat. Local lead shielding can be installed to reduce radiation exposures at equipment. Drip shields or improved sealing can be installed to protect the equipment from moisture. Ultraviolet light shields or barriers can be installed.

One utility installed heat dissipation fins on the limit switches on the main steam isolation valves (MSIVs). Due to high temperatures experienced by the limit switches (184°F) and the mounting brackets (200-215°F), the qualified life of the MSIV limit switches was approximately 1.2 years (less than a refueling cycle). Heat was being transmitted from the valve body to the yoke and then to the limit switch mounting brackets. An alternate mounting bracket consisting of a series of plates or fins utilizing a heat shield material to aid in the dissipation of the heat was designed to mount the limit switches. This modification was designed to reduce the temperatures of the limit switches by at least 18°F, which would increase the life to approximately 2.6 years. Additional temperature monitoring of the newly designed mounting bracket after installation showed an actual 28°F temperature drop with a resultant 4.1 year life. This modification not only resolved the problem of having to replace the switches during operation, but also allowed the switches to be replaced during every other refueling outage.

Move the equipment away from the environment. The option does not change the local environment, but does change the conditions experienced by the equipment.

One utility found damaged cable in a conduit during a modification for the main steam-line radiation monitors. The cables were breaking when the maintenance personnel pulled the cable from the existing conduit. The breaks occurred where the cables crossed over main steam piping and at areas where the cables were routed in close proximity to the main steam lines. These cables had been in service for 10-15 years. Temperatures in the vicinity of the cables were measured at 130°F to 150°F on a day when the outside air temperature was about 45°F. Past temperature monitoring efforts showed that temperatures in this room rose with outside air temperature. Instead of using the existing conduit as planned, the modification package was revised to route the conduit further away from the steam line.

3.7 Documentation

An important aspect of any effort to manage adverse localized equipment environments is documentation. All activity in the area should be documented in a form that is retrievable. Consistent use of keywords and coding can greatly enhance electronic retrievability of information. Many utilities have done numerous focused activities to address specific adverse localized environments; however, the ability to retrieve this information could be improved in some cases. A documented summary of past efforts would be a valuable tool in ensuring the transfer of knowledge as new personnel become involved. Many of the same programs, files, and documents discussed in Section 3.2 can be used to document activities relating to localized environments:

Environmental service conditions manual or drawings. Many utilities maintain a consolidated environmental service conditions manual or drawings. This can be an excellent location to document identified adverse localized equipment environments.

This living document may serve as a single source of environmental information, including (1) the environmental service conditions, (2) records of the efforts taken to determine locations where the localized environments may differ from the general area or bulk environment, and (3) documentation of activities performed to validate the specified environmental service conditions.

Corrective action documents. If a utility has identified a localized-equipment environment as a condition potentially adverse to quality, then it can use its corrective action system as the means to store documentation of actions taken to properly manage these environments. Alternatively, if no previous corrective action document has been written to identify problems with localized equipment environments, then the utility may choose to write one. Since these quality assurance records are kept for the life of the plant, a corrective active document would provide permanent documentation of efforts taken to reduce susceptibility to adverse localized equipment environments.

EQ file field inspection sections. EQ files may be a good location to document localized-adverse environments if the scope of the effort is limited to EQ equipment and the plant had previously documented equipment environmental service conditions for that equipment in the files.

NRC generic correspondence files. Additional information can be appended to the file to document efforts taken since the original response was made to the NRC or the initial evaluation was performed. Using the file from the original NRC correspondence provides a long-term storage location for documenting different activities completed by different organizations to minimize a plant's susceptibility to adverse localized environments. One drawback of using NRC generic correspondence files is that they usually have a specific focus. This makes it difficult to select one correspondence file in which to store documentation of activities taken to detect or correct many types of adverse localized equipment environments. However, if a plant limits its efforts to a specific type of environment or equipment (e.g., thermal hot spots), then a related generic NRC correspondence file may be an acceptable choice for storing documentation of efforts in that area.

Self-assessment reports. Performing a self assessment to determine a plant's performance related to identification and mitigation of adverse localized environments would help develop an approach to managing adverse localized equipment environments. Since these reports are often kept for the life of the plant, the self-assessment report would provide long-term documentation of previous efforts.

System files. Some plants and many system engineers maintain a historical file for each system. These files can provide records of inspection activities, general observations, failures, and basis for decisions on how to operate equipment that may be relevant to understanding environmental service conditions. Many utilities have implemented system report cards as a method of complying with the Maintenance Rule. System report cards are another candidate location for documenting adverse environment evaluations.

4

CONCLUSIONS

Five major conclusions can be drawn from the research conducted in the development of this guideline. They are discussed in the following subsections.

The Number of Adverse Localized Equipment Environments Is Minimal and Manageable

Based upon the site visits, surveys, and research conducted as part of the development of this guideline, it is evident that adverse localized equipment environments occur only at a limited number of discrete locations at each plant. Using the process and techniques discussed in this guideline, these adverse localized environments can be managed effectively to preclude impacts on plant safety, reliability, and operating costs.

Localized Environments Can Be Managed Without Implementing New Programs

To some extent, all utilities perform or have performed some efforts to determine susceptibility of equipment to damage from adverse localized environments. Utility corrective action programs and Maintenance Rule programs, both mandated by NRC regulations, provide ongoing processes that help to ensure that adverse localized equipment environments do not impact plant safety or reliability. Many other utility-specific programs include activities that reduce the likelihood of equipment problems caused by adverse localized environments. By using the process in Section 3 of this guideline, utilities can determine what additional effort is needed to ensure adverse localized equipment environments do not impact continued safe and reliable operation of their plants. The approach presented in Section 3 also helps utilities decide which existing programs or processes are best suited for implementing new or refined activities.

Because many utility processes and programs already address much of what is needed to effectively manage adverse localized equipment environments, utilities can implement relatively minor adjustments to these processes and programs more efficiently than implementing a new program to specifically address adverse localized equipment environments. This conclusion is supported by recent plant operating experience.

Localized Elevated Temperature Is the Most Significant Type of Adverse Localized Environment

While the overall number of existing adverse localized equipment environments within nuclear power plants is small, localized elevated temperature is the most common type of adverse localized equipment environment. Plant operating experience, including NRC generic correspondence, clearly supports this conclusion. The number and diversity of sources of elevated temperature in a nuclear power plant are greater than for any other stressor. High temperature process lines, equipment self-heating, and limited ventilation may produce environments in limited locations that could cause accelerated degradation of plant equipment in close proximity. It is important to note that elevated temperatures may occur in these limited areas even while plant HVAC systems are operating properly and bulk or general area temperatures remain well within the design basis conditions.

Elevated thermal environments may also occur as a result of equipment problems (e.g., steam leaks, or damaged or inadequate thermal insulation) or location-specific configurations that usually are not part of the plant design basis.

Areas with radiation dose rates high enough to affect equipment are confined to a relatively small portion of the plant, and many components are not affected by the doses that would occur during normal plant life. Often, the areas with higher dose rates are also areas with high temperature, where temperature is still the dominant stressor. Few areas have the potential for chemical contamination.

Because localized elevated temperatures are more common and have potential to affect more equipment than other types of adverse environments, elevated temperature is more significant to plant operations than other stressors.

Walkdowns and Temperature Monitoring Are Important Tools in Identifying and Managing Localized Environments

Walkdowns are an important tool for identifying and managing adverse localized equipment environments for the following reasons:

- Walkdowns allow detection of the effects and relative severity of all types of adverse localized equipment environments.
- They familiarize plant personnel with expected environmental conditions in plant areas.
- They can be used as a tool for identifying adverse localized equipment environments with little or no expenditure of additional resources.

Walkdowns can also be credited as an ongoing condition monitoring activity and provide an ongoing affirmation that the plant is operated within its design bases.

Temperature monitoring also provides many benefits in the management of adverse localized environments. A temperature-monitoring program can do the following:

- Quantify thermal environments at discrete locations and for bulk areas
- Accumulate data over long periods of time once a monitor is installed and require little personnel interaction beyond periodic evaluation of the resulting data
- Detect changes in environments over time
- Employ inexpensive screening activities, such as use of temperature dots or infrared thermography, to identify areas where further monitoring is warranted
- Produce information to support evaluation of maintenance, refurbishment, and replacement frequencies
- Provide indication of the effectiveness of current HVAC systems configurations

While monitoring other stressors in specific areas may be appropriate, the number of components affected is much smaller, and the severity of the effect on the components under non-accident conditions is generally within tolerable limits.

Adverse Localized Thermal Environments for Cables Are Also Manageable

The majority of cables will not be adversely impacted by thermal conditions during the life of a plant. The case studies in Appendix E support this conclusion. Severe elevated temperatures may have an impact on a limited number of cables at a nuclear power plant.

Operating experience reviews suggest that a few locations of concern have been identified at most plants. These limited areas are being identified at the plants through activities discussed in this guideline. The basic walkdown guidance presented in Appendix A can successfully identify adverse localized environments and their effects on cables as shown by the walkdown photographs provided in Appendix B. As these adverse environments are identified, they are managed by such activities as periodic replacement, relocation of the cable, addition of thermal insulation, or improvements to HVAC.

Case studies presented in Appendix E provide examples of some activities that were successfully employed by utilities in characterizing thermal environments for cables. Techniques applied to confirm the actual effects on cables are also discussed. In the case studies, different methods were used to show that the actual plant conditions were not as severe as predicted by plant calculations, and that a 60-year service life could be expected. In both case studies, the utilities presented reasonable assurance that all cables would be capable of operation for 60 years with reasonable resource expenditures and within a reasonable time period. The different approaches these utilities used to reach the same conclusion demonstrate that multiple options exist to manage cable thermal environments.

The results of the utility survey, case studies, and photographic exhibits presented in the Appendices all indicate that adverse localized environments affecting cables are relatively few in number and can be identified and managed.

5

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A

WALKDOWN GUIDANCE

Approach

There are two primary methods for approaching walkdown inspections for localized equipment environments: the general area approach and the focused approach. In the general area approach, inspectors investigate an entire area of the plant without limiting the inspection to a specific group of equipment or discrete area. In the focused approach, a specific type of equipment or specific location in the plant is selected for inspection. Valid reasons to use each approach exist.

General Area Approach

The general area approach selects an area of the plant to be inspected. This approach requires the least amount of prior planning as to which equipment will be inspected. However, it does require some prior planning, especially when the area or zone to be inspected is a subset of a larger area.

Walkdowns using the general area approach require a clearly defined set of boundaries for the area or zone to be inspected. Inspectors need to use discipline in staying within the defined boundaries and covering the entire area within the boundary. When inspecting for potential localized environments, inspectors are often looking in remote or hidden places. By staying within the prescribed boundaries, it is easier to locate the potential adverse localized equipment environments when returning to the area to evaluate the condition during subsequent inspections. If the inspections are being performed one area at a time as part of a larger inspection, it is often tempting for inspectors to follow their senses to areas most likely to contain adverse localized environments rather than covering the assigned area. Applying discipline to inspecting specific areas also makes it easier to adhere to a schedule. The inspection boundaries are best determined by dividing the plant into small areas defined by structural members, such as distinct rooms, or quadrants defined by row and column numbers. Radiation survey maps are often a good tool for defining areas, especially in locations with little structural definition to the area. Fire hazard and boundary drawings are other tools that can be used for organizing area-based inspections. Figures A-1 through A-3 provide examples of the drawings that can be used for planning walkdowns.

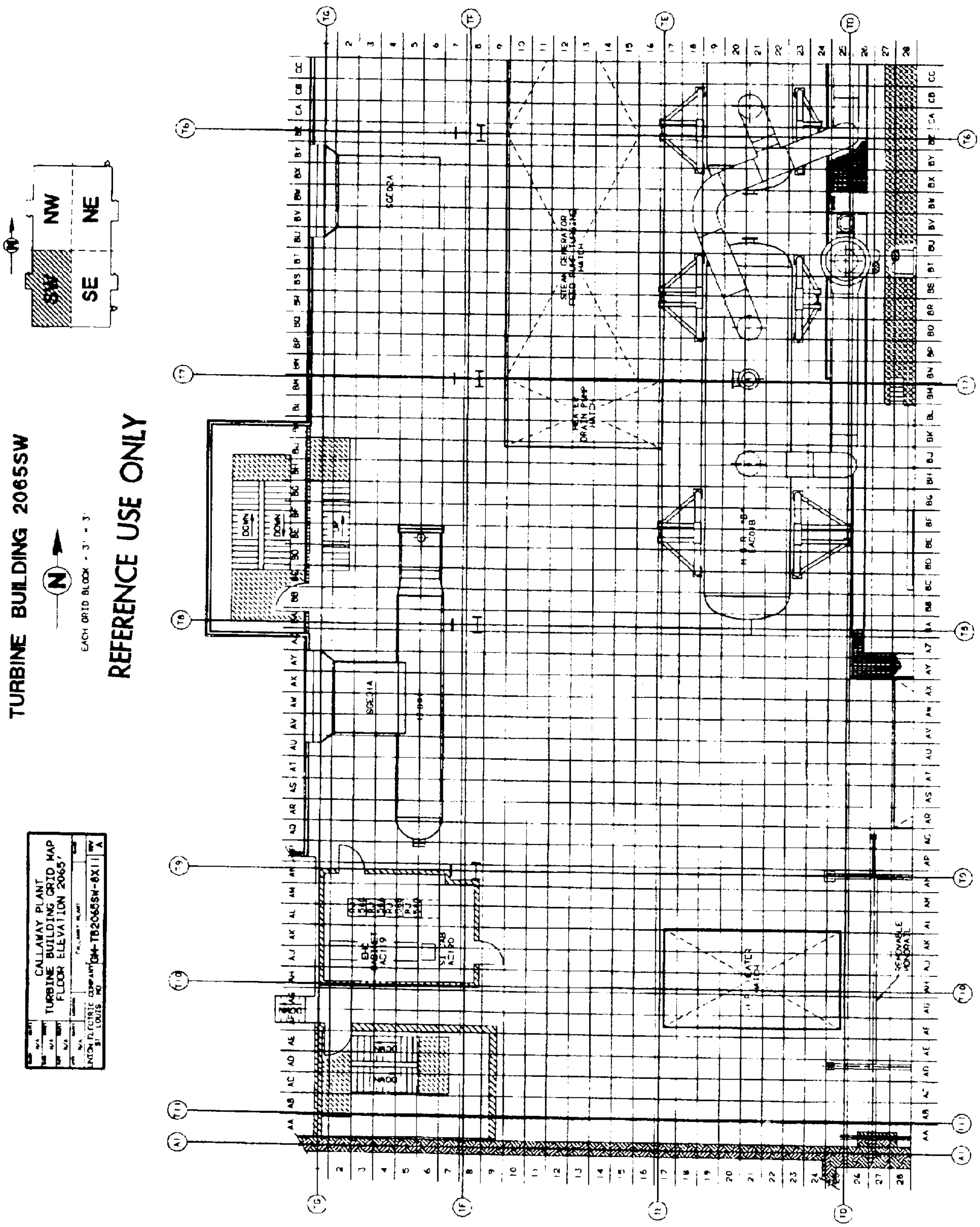


Figure A-1
Grid Layout for a Turbine Building

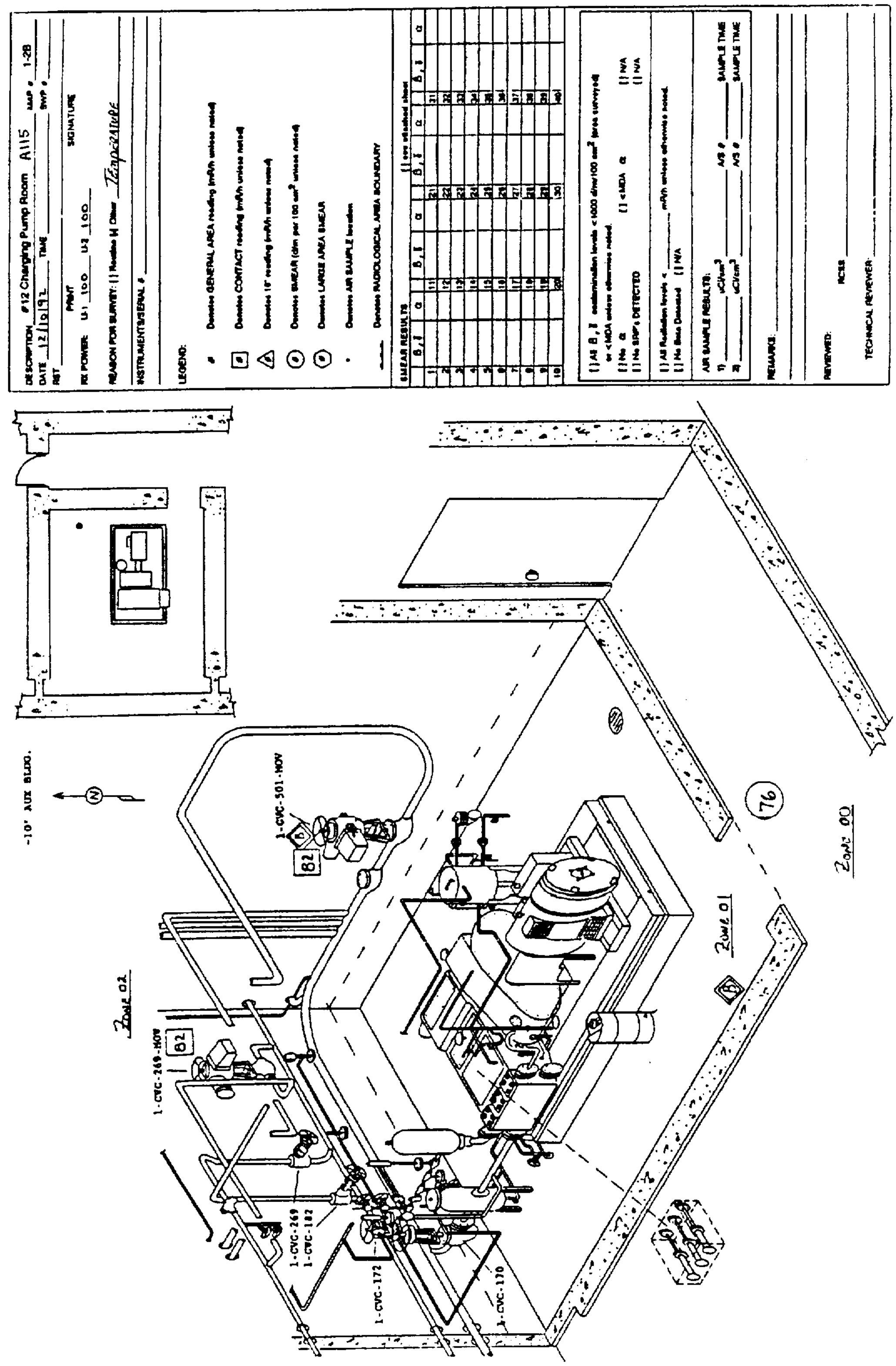
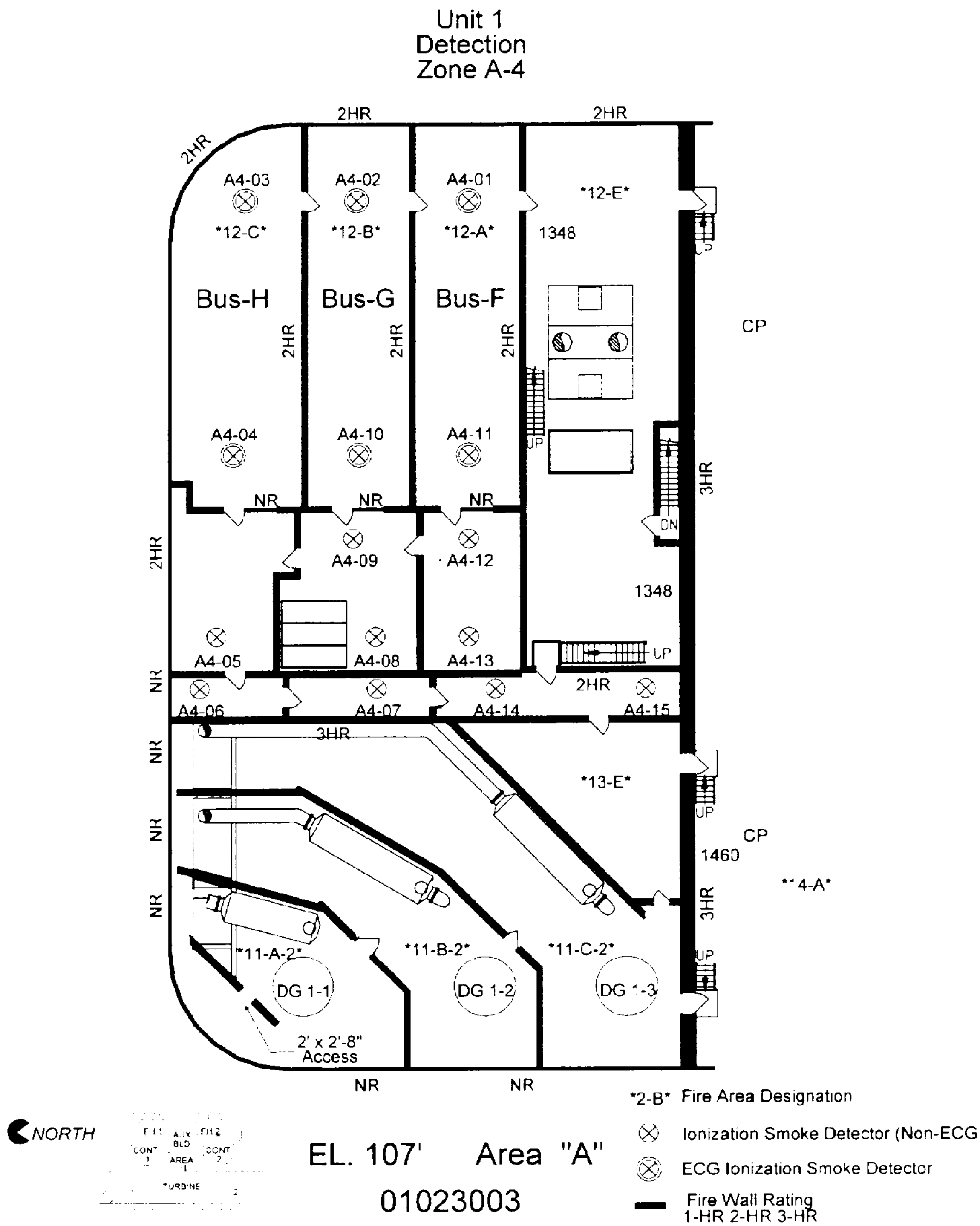


Figure A-2
Radiation Survey Map



01023012.DOC 02 45 0605.0216

Figure A-3
Fire Hazards and Boundary Drawing

The general area approach is best suited for the following types of inspections:

- Inspections of the entire plant or large sections of the plant, whether on a one-time or periodic basis.
- Inspections performed by personnel with area-based responsibilities.
- Inspections performed by a small number of persons. Use of a small team for an entire general area inspection allows ease of training for the task and sharing of results and ongoing refinements of the inspection process.

Focused Approach

The focused approach is used when large portions of a particular plant area or a large subset of an equipment type can be eliminated from the inspection scope through evaluation of susceptibility to adverse localized equipment environments. For example, a room may have only one significant heat source. Rather than the whole room, only the area in the immediate vicinity of the heat source would be inspected.

The focused approach is well suited for the following types of inspection:

- Inspections of the plant where access is limited. For example, access to certain areas may be limited to outage periods, or time in the area may be limited due to dose concerns.
- Inspections performed by personnel with equipment or system-based responsibilities.
- Inspections of specific equipment types. Often a large quantity of a particular equipment type (e.g., cables) can be determined to have low likelihood of being exposed to an adverse localized equipment environment. Cable inspections could be limited to those areas where analytical techniques have been unable to demonstrate that the cable is exposed to temperatures low enough to allow satisfactory operation for the life of the plant.
- Screening inspections. A utility may determine that a certain group of equipment is susceptible to deterioration if exposed to an adverse environment. Rather than inspecting all of the susceptible equipment, the utility may choose a smaller number of components that represent the worst case. The need to perform further inspections would then be based on the results of the inspections of the worst case applications.
- Inspections in response to specific problems or generic correspondence.

One important consideration in using the focused approach is the basis for exclusion of certain areas or equipment from evaluation. The goal is not to eliminate entirely the need to perform walkdown inspections, but to limit and focus the walkdown on key areas of concern or equipment. While inspections of many plant areas can be justifiably eliminated, a sound basis for excluding areas from walkdown inspections is necessary. Also, general area inspections can be used as the basis for scoping future focused inspections and vice versa.

Inspection Guidance

What to Inspect

When performing an inspection for adverse localized equipment environments, inspectors are looking for two things: (1) signs of degradation and (2) installations that could cause adverse localized environments. The photographs in Section 3 and Appendix B provide examples of situations that could be encountered. They may be used as training aids for inspectors. Each utility may supplement these photographs with photographs of situations discovered during inspections at their sites.

In addition to looking for degradation or questionable installations, inspectors should also be aware of environmental conditions on a larger scale. They should document the general environmental conditions in the area, such as the following:

- Temperature
- Air flow
- Odors
- Sounds
- Evolutions in progress

Documentation of these conditions provides good baseline information and may be helpful in future evaluations. Documenting external weather conditions at the time of the inspection may also be helpful. Sometimes it may be helpful to document plant and system conditions such as process fluid temperatures, or which equipment is running. The date and time of the inspection should also be noted.

Inspectors should focus on detecting any visible change to equipment from its new condition. Degradation can appear as crazing, cracking, fading, textural changes, or discoloration of materials. Unusual noises, deposits of foreign substances, stains from systems leaks, and corrosion may also be indicators of adverse localized environments. Not all changes in appearance of equipment indicate an adverse localized equipment environment. However, looking for these signs helps the inspector identify areas where they may exist.

Where to Look

All accessible areas within the inspection boundaries should be thoroughly inspected. In addition to the examples provided in Section 3, inspectors should be alert for other locations susceptible to localized environmental conditions. The following are examples of these locations:

- Areas exposed to environmental extremes (e.g., large temperature swings)
- Areas exposed to unusual lighting (e.g., direct sunlight or close proximity to artificial lighting)
- Near moving or vibrating equipment
- Equipment interfaces
- Near high-energy piping
- Near fluid systems that tend to leak (Health physics personnel are often a good source for identifying locations prone to leaks.)
- Near tanks and piping systems containing caustic or petroleum-based fluids

Tools to Use

The size of the inspection team limits the number of tools that can be carried during the inspection. Description of these tools and considerations for using them are provided below.

Visual Inspection Tools

Several visual inspection tools should be standard items for the inspection team. High intensity flashlights, mirrors, and cameras should be part of almost every inspection. Cameras equipped with zoom lenses are helpful. The pictures provided in Section 3 and Appendix B were taken with a 35 mm camera using high-speed black and white film. Digital cameras and video cameras have also been used successfully. Detailed records should be kept for each picture taken. For extensive inspection efforts, a log with locations and dates of photographs taken can be helpful. If digital cameras and storage media are being used, an electronic log can be used or the date and location can be imbedded in the file name. Binoculars or spotting scopes can also be useful for viewing areas difficult to access.

Recording Tools

Some method of recording the inspection must exist. Notes, datasheets, tape recorders, still or video cameras, or any combination of these may be used. When using tape recorders, inspectors should perform a playback test early in the inspection to ensure background noises are not too loud. Voice-activated tape recorders work best in this type of inspection.

Monitoring Tools

Some method of measuring temperatures should be available to the inspection team. Infrared temperature sensors are portable and can detect temperatures of distant objects. Hand-held thermometers and contact pyrometers may also be useful.

It is important that the inspector be familiar with the capabilities and limitations of the monitoring tools being used. The inspector should be familiar with the accuracy and response time of each sensor, operational techniques, and interferences that can affect the data being recorded. It is helpful to test thermometers and infrared equipment under known conditions before using them to measure field temperatures.

Datasheets

Datasheets are useful. The sample datasheet in Figure A-4 was designed for recording walkdowns of multiple areas on a single sheet. This datasheet allows inspectors to minimize the amount of radioactive waste that could potentially be created when inspecting radiologically controlled areas. The datasheet could also be easily loaded into a palm computer or digital assistant.

The sample datasheet includes spaces for items that help organize and compare data from separate walkdowns, while allowing a free-form text area for the walkdown participant to record pertinent comments. Locations of any observations that might require re-inspections must be described accurately. One utility noted that when using a similar datasheet, personnel performing re-inspections occasionally had difficulty finding the observed condition even though they were standing in the correct spot.

Figure A-5 provides a sample of a system-based walkdown datasheet. A utility may wish to model a datasheet after this example if System Engineers are the primary inspectors for ongoing detection of adverse localized equipment environments.

Localized Environment Walkdown Datasheet No. ___

Building/Level: ______________________ Date/Time: ______________

W/D Participants: ____________, ____________, ____________, ____________

Unit: ____ Operating Mode: ________ Room/Column Block: ______________

Recording Devices ______________________________

Photo/Tape Numbers: ______________________________

Potential Thermal Hot Spot? **Yes No** Potential Other Localized Environment? **Yes No** Type: __________

Details: *(Detail location & description of components involved along with any other adverse conditions)* __________

____

____

____

____

____

____

______________________________ Continued? **Yes No**

Photo/Tape Numbers: ______________________________

Potential Thermal Hot Spot? **Yes No** Potential Other Localized Environment? **Yes No** Type: __________

Details: *(Detail location & description of components involved along with any other adverse conditions)* __________

____

____

____

____

____

____

______________________________ Continued? **Yes No**

Photo/Tape Numbers: ______________________________

Potential Thermal Hot Spot? **Yes No** Potential Other Localized Environment? **Yes No** Type: __________

Details: *(Detail location & description of components involved along with any other adverse conditions)* __________

____

____

____

____

____

______________________________ Continued? **Yes No**

Figure A-4
Generic or Area-Based Walkdown Datasheet

MECHANICAL SYSTEM WALKDOWN REPORT

NAME: ______________________ DATE: ____/____/____

SYSTEM: ______________________

U1 MODE: 1 2 3 4 5 D U2 MODE: 1 2 3 4 5 D

N/A N/I INSP	DESCRIPTION	SPECIFIC FINDINGS/ACTION TAKEN (IR / MO NUMBERS)
1.0	**VALVES**	**NOTES**
	• Installed in proper flow direction?	
	• In correct position for current mode?	
	• Properly labeled?	
	• Any unusual packing leakage?	
	• Bent stem or missing hand wheel?	
	• Stem threads properly lubricated?	
	• Any air, steam, or hydraulic leaks noted?	
2.0	**PUMPS**	**NOTES**
	• Any unusual noises noted?	
	• Properly labeled?	
	• Properly lubricated?	
	• Unusual packing or seal leakage?	
	• Motor amperage normal?	
	• Discharge pressure normal?	
3.0	**CONDUIT AND PIPE SUPPORTS**	**NOTES**
	• Spring cans bottomed/topped out?	
	• Proper eyebolt engagement on sway strut?	
	• Good bearing surface contact on base plates?	
	• Snubbers have sufficient fluid in reservoir?	
	• Structural concrete spalling/damage?	
	• Binding? Proper alignment? Too loose?	
	• Are supports painted?	
	• Vent/drain lines properly supported?	
4.0	**INSTRUMENTATION AND BREAKERS**	**NOTES**
	• Properly installed and functional?	
	• Leaking fittings?	
	• Any missing components on tubing supports?	
	• Components properly labeled?	
	• Breakers in proper position?	
5.0	**TEMPORARY ALTERATIONS**	**NOTES**
	• Are existing temp alts properly posted?	
	• Are there any unauthorized temp alts? (Unevaluated installation, removal, or modification of plant configuration)	
6.0	**GENERAL**	**NOTES**
	• Insulation properly installed?	
	• Heat tracing installed and operational?	
	• Significant process parameter values consistent with current mode?	
	• Components/room adequately cooled/ventilated?	
	• Operator aids, signs, temp notes, and label plates correctly posted and logged?	
	• IR tags in the field still appropriate?	
	• General housekeeping within set standards?	
	• Any safety concerns?	
	• Coatings applied and intact?	

N/A: Not Applicable
N/I: Not Inspectable
INSP: Inspected

AREA OF WALKDOWN: ______________________

SHEET ____ OF ____

Figure A-5
System-Based Walkdown Datasheet

Training of Inspectors

Training of inspectors should not be overly complicated. Inspectors need to know the conditions they are trying to find and how to operate any equipment they will be using.

Inspectors need sufficient training on the measuring equipment that they use to ensure erroneous readings are not taken. They should be instructed on what can induce errors in measuring equipment. For example, if using infrared temperature measuring devices, inspectors need to know how reflective properties of equipment and proximity to other heat sources can effect readings.

Inspectors need to know what settings to use with their recording devices to ensure desired data is not lost. For example, they should know the camera settings to use in different lighting levels or at different distances. Special settings for voice recorders, such as background noise filters, should be understood. Inspectors should also know the limits of batteries or data storage systems so data is not lost or overwritten.

On-the-job training is an excellent training method for walkdown team members. Pairing of more experienced personnel with new team members can be effective. Specific situations can be discussed in on-the-job training that might not necessarily be included in classroom training. Job notebooks and turnover logs also provide a means to share learned information as larger-scale walkdown efforts proceed. In addition to the photographs in Section 3 and Appendix B of this guideline, on-the-job training is an excellent method for teaching the types of conditions that can be discovered. The Westinghouse Owner's Group (WOG) Aging Assessment Field Guides [25, 26, 27, and 28] also provide pictures and information that may be useful in training inspectors. Utility and plant-specific examples of previously identified adverse environments may also be an important part of the inspector training.

If a utility is undertaking a larger-scale walkdown effort, at the beginning of the effort, emphasis should be placed on recording all questionable items. As the walkdown effort progresses, the team will understand more clearly the types of conditions that need to be recorded and the types of conditions that are acceptable and do not need to be mentioned. The walkdown team needs to have a method of documenting and disseminating decisions to all walkdown team members throughout the walkdown effort.

B

PHOTOGRAPHS OF POTENTIAL ADVERSE LOCALIZED EQUIPMENT ENVIRONMENTS

Examples of installations that could create adverse localized equipment environments are included in Figures B-1 through B-10.

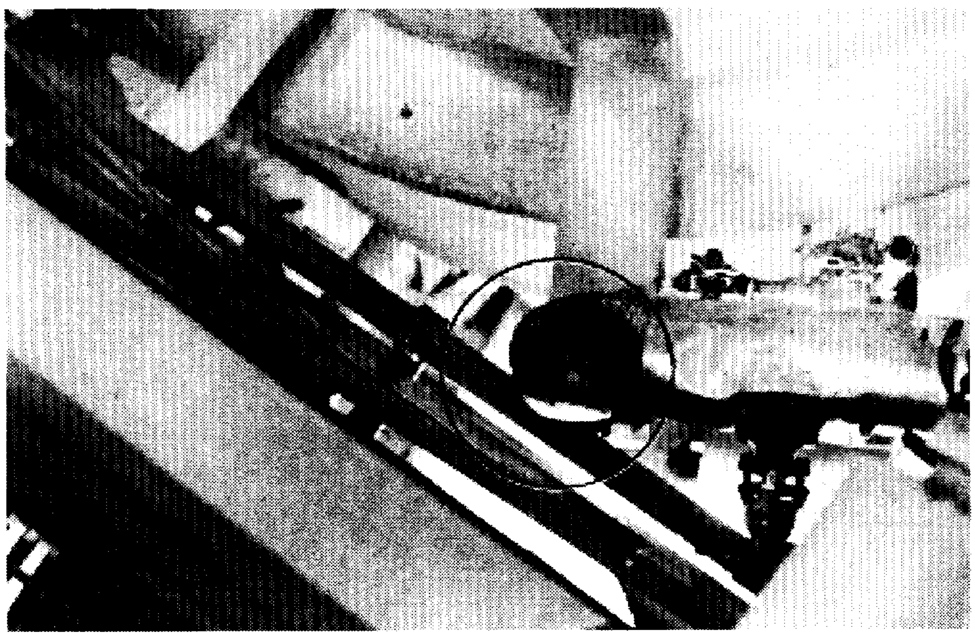


Figure B-1
Pipe Insulation Partially Enveloping an Electrical Conduit

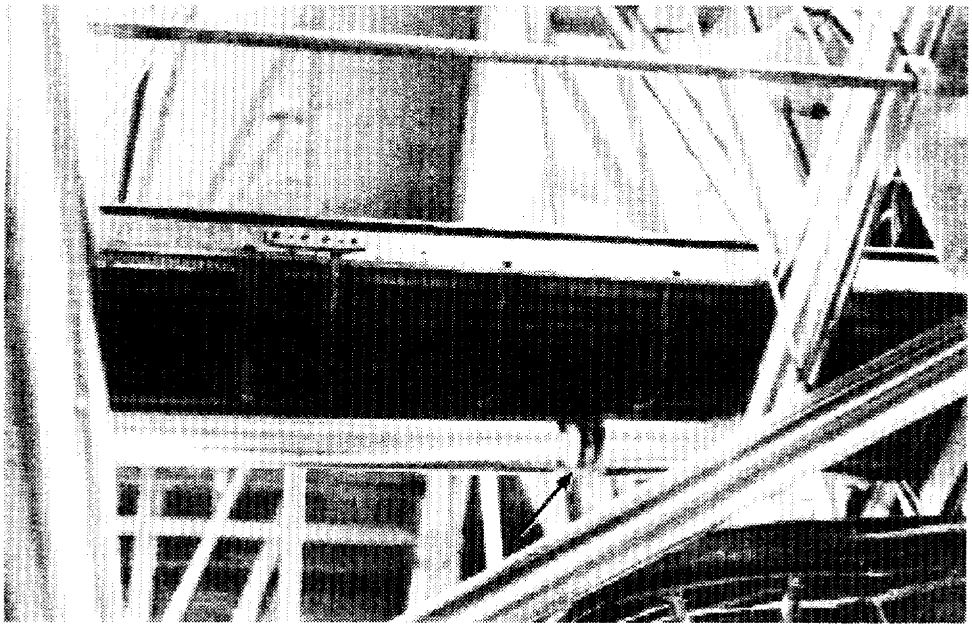


Figure B-2
Cable Tray Installed near an Uninsulated Pipe Flange

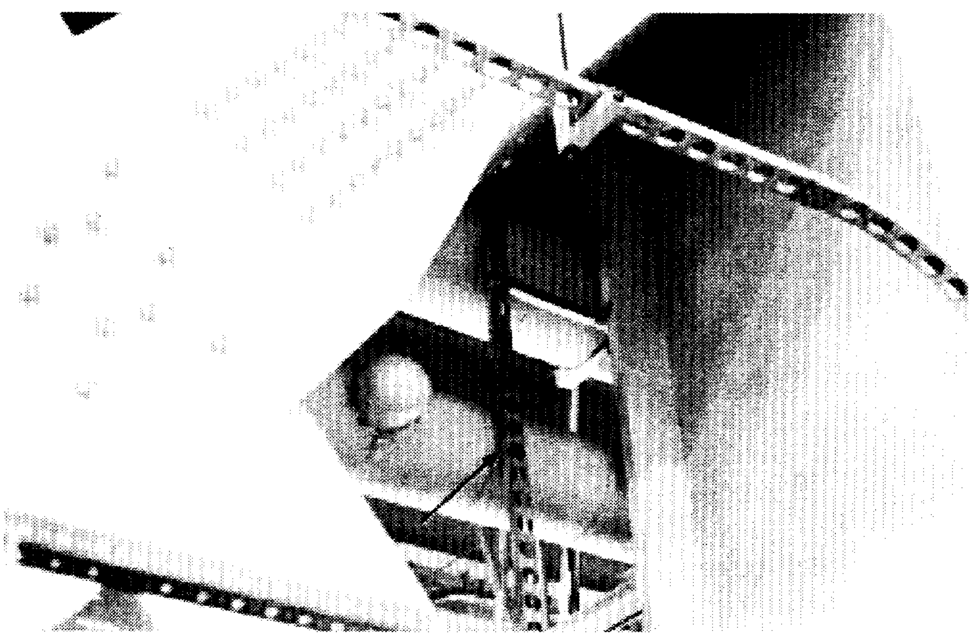


Figure B-3
Cable Tray in Contact with Pipe Insulation

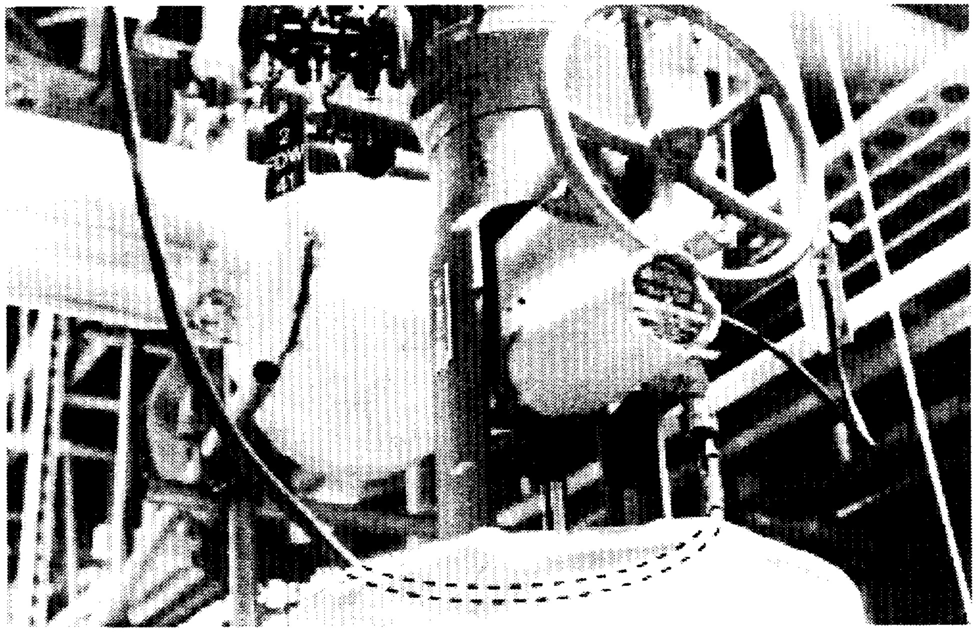


Figure B-4
Cable Installed Underneath Thermal Insulation Surrounding a Hot Component

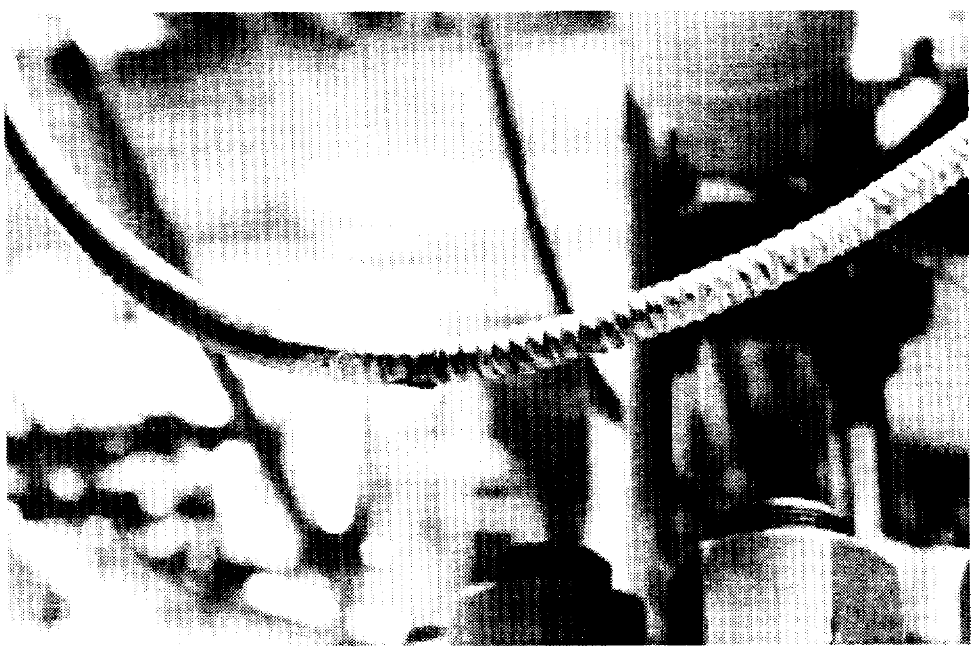


Figure B-5
Evidence of Degradation of the Cable Shown in Figure B-4 Following Removal of the Thermal Insulation

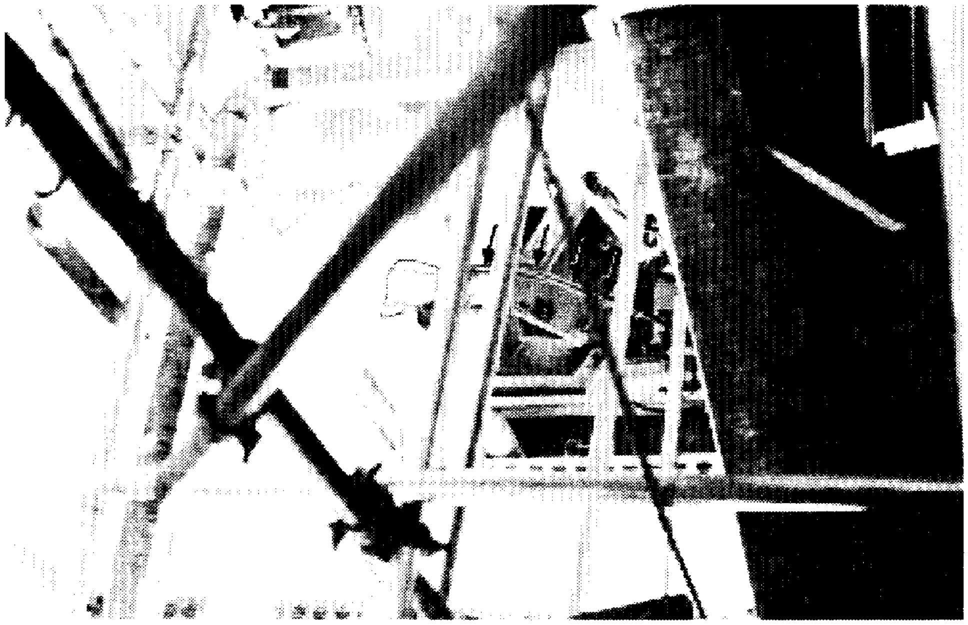


Figure B-6
Cable Draped Across an Uninsulated Valve Body

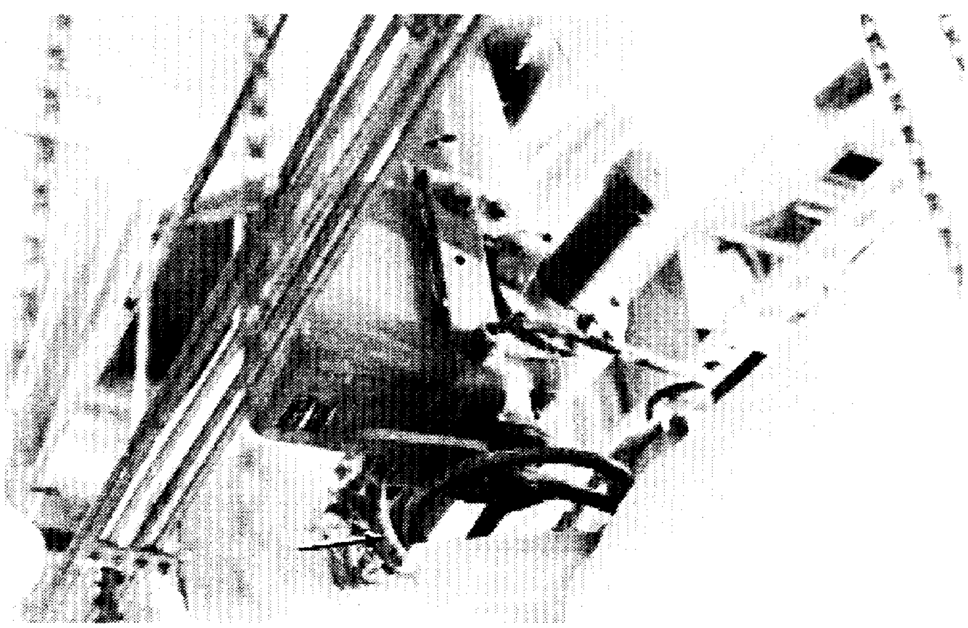


Figure B-7
Cable Installed near a Hot Valve (Infrared Thermography indicated 150°F at cable surface.)

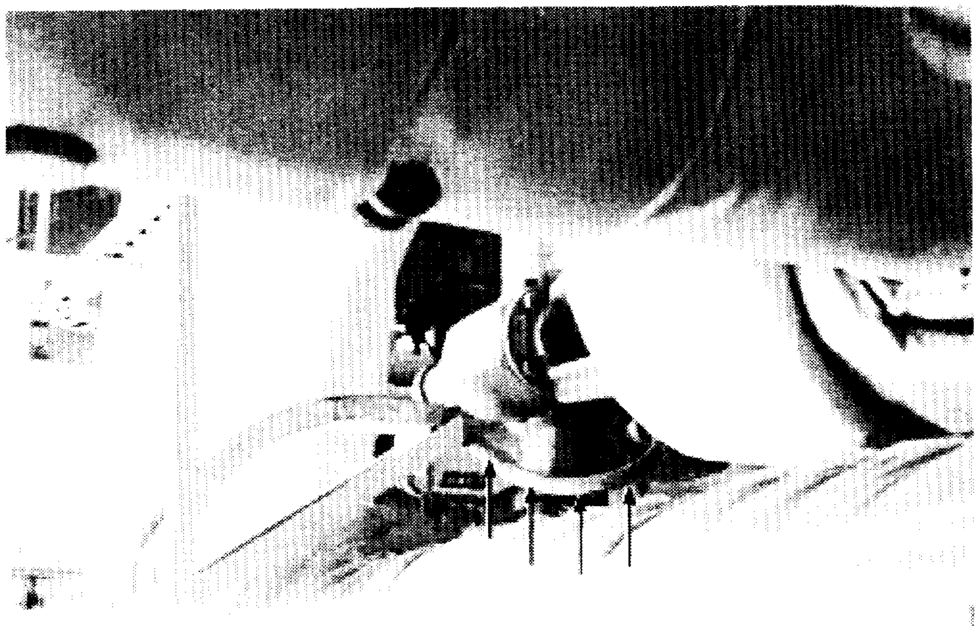


Figure B-8
Opposite Side View of Installation in Figure B-7

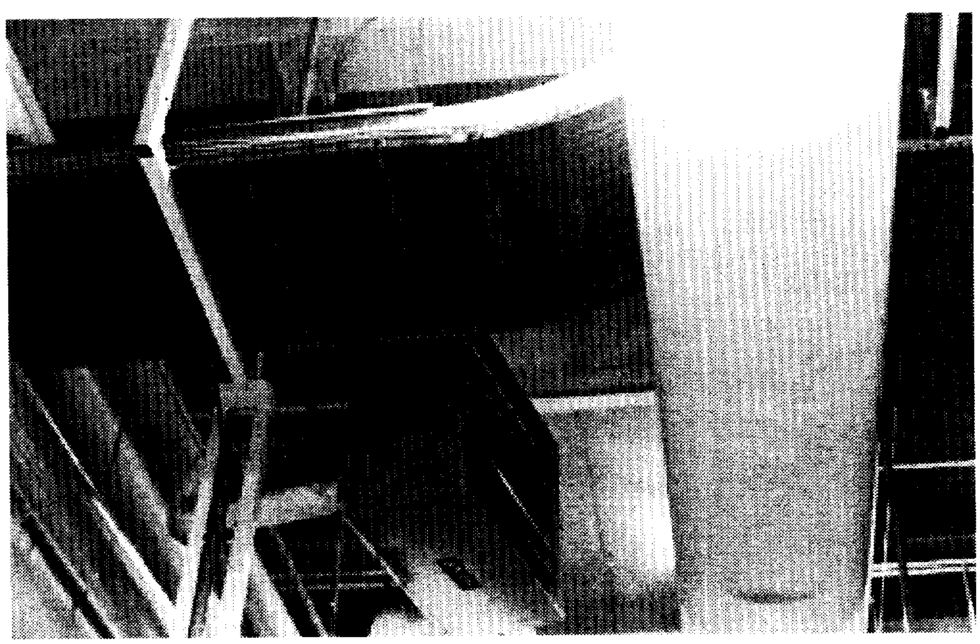


Figure B-9
Heater Aligned to Discharge Towards a Cable Tray (This particular arrangement did not cause an adverse localized environment.)

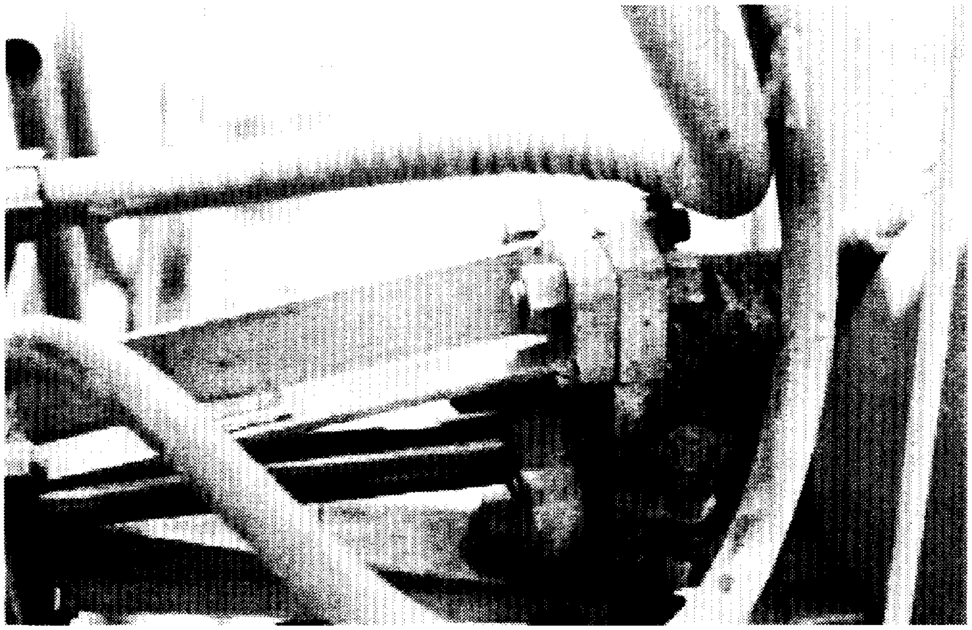


Figure B-10
Evidence of Water Inside a Flexible Conduit

Examples of degradation potentially caused by adverse localized equipment environments are shown in Figures B-11 through B-17.

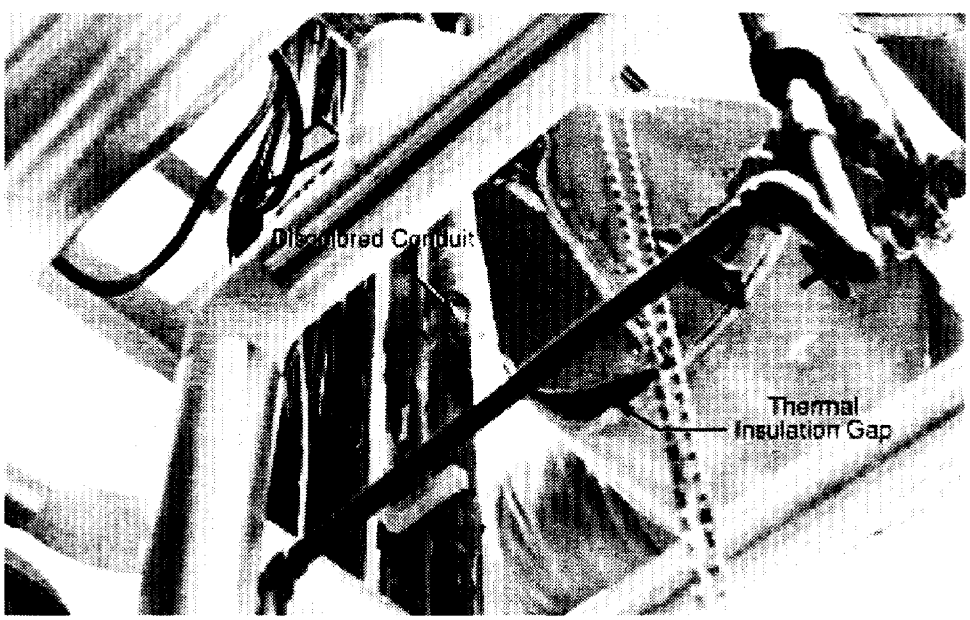


Figure B-11
Scorched Conduit Located near a Valve with Improperly Installed Insulation

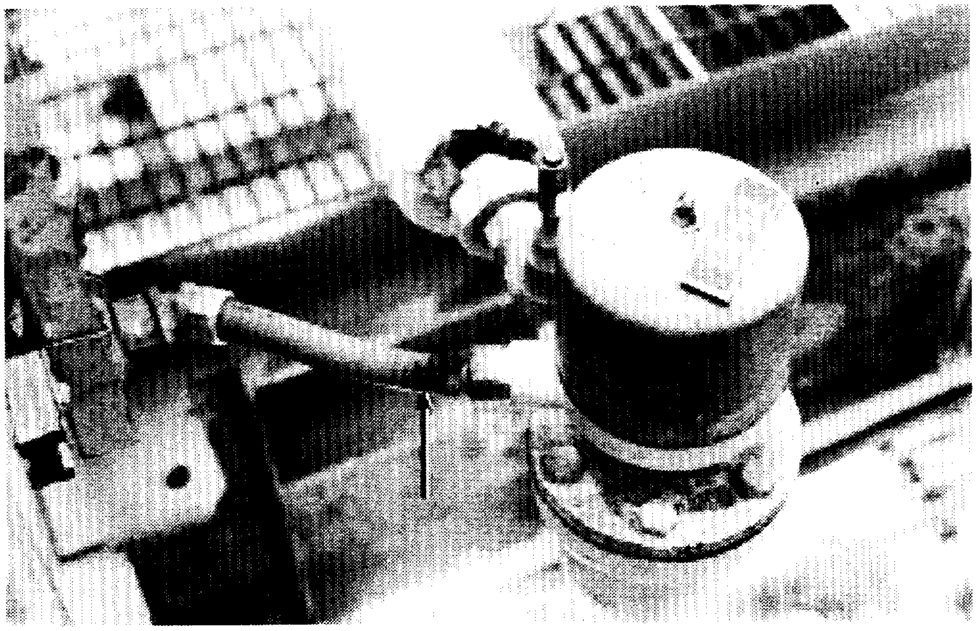


Figure B-12
Flex Conduit Exhibiting Heat Damage

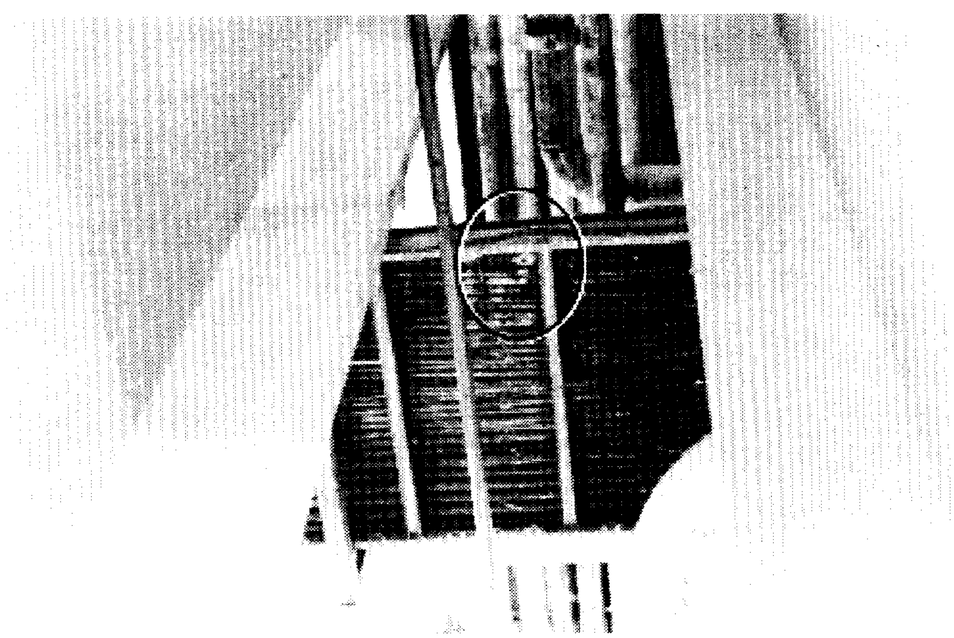


Figure B-13
Cables in a Tray Covered with White Crystallized Particles

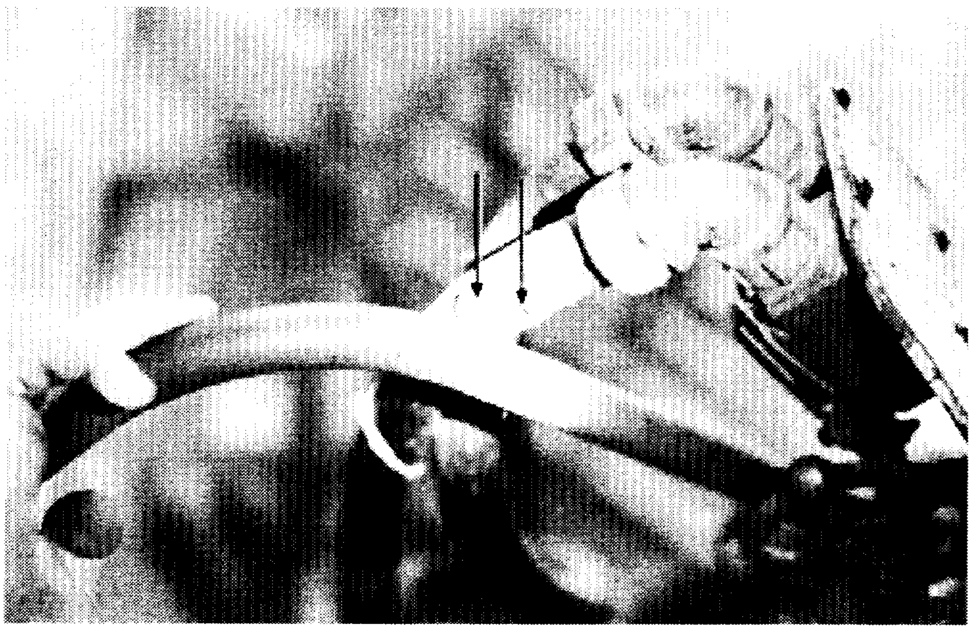


Figure B-14
Vibration-Induced Damage to a Flex Conduit

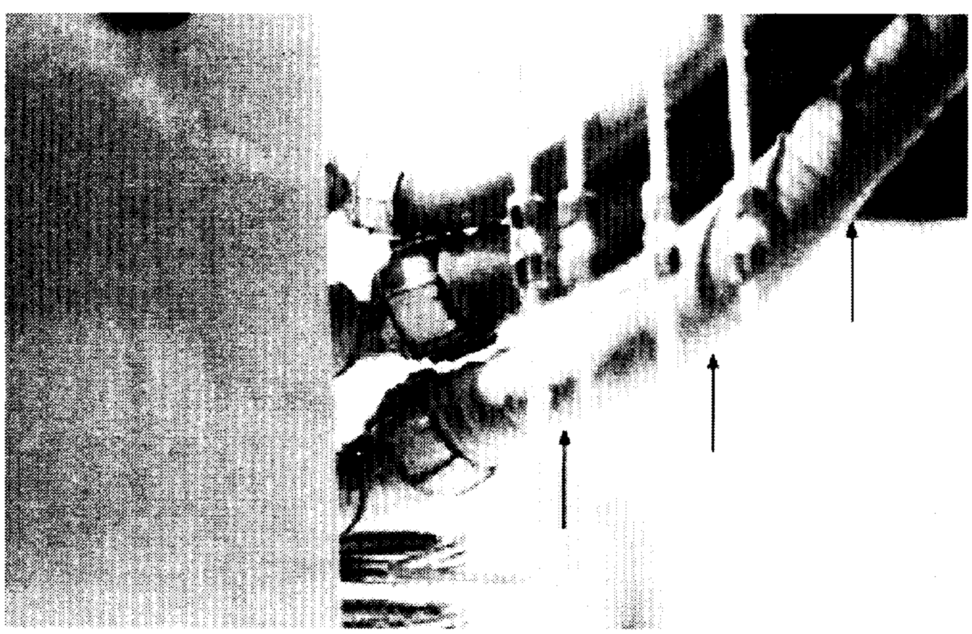


Figure B-15
Damaged Cable Jacket near Hydraulic Fluid Lines

Figure B-16
Cable Jacket Showing Scaling or "Alligator" Look

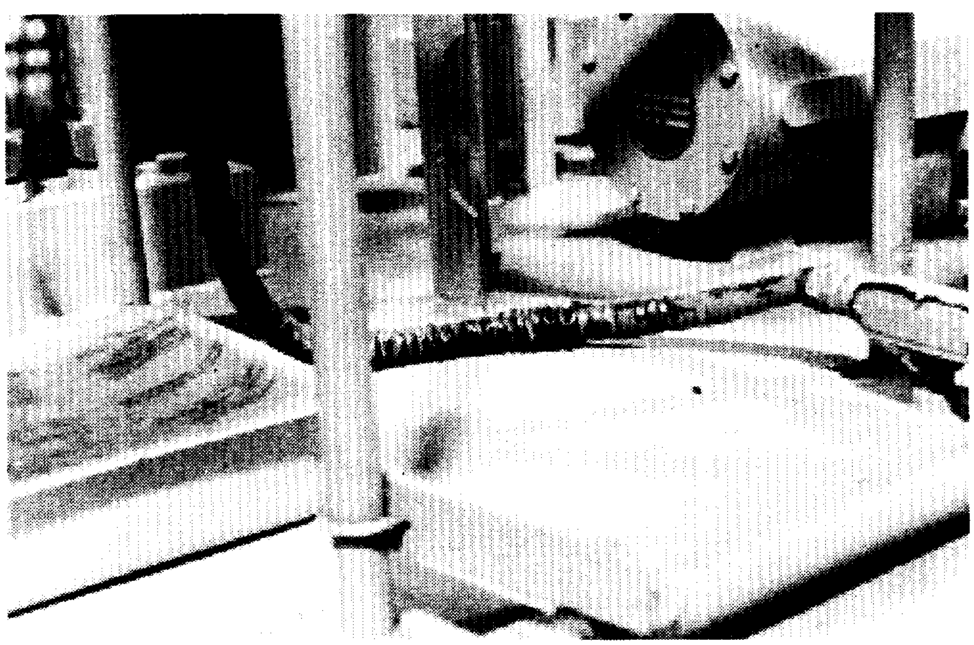


Figure B-17
Cable Jacket Wrinkling near Hydraulic Oil Tank

Examples of equipment problems that may cause equipment failure, but are not necessarily indicative of localized environment problems are included in Figures B-18 through B-22.

Figure B-18
Damaged Cable for a Heater

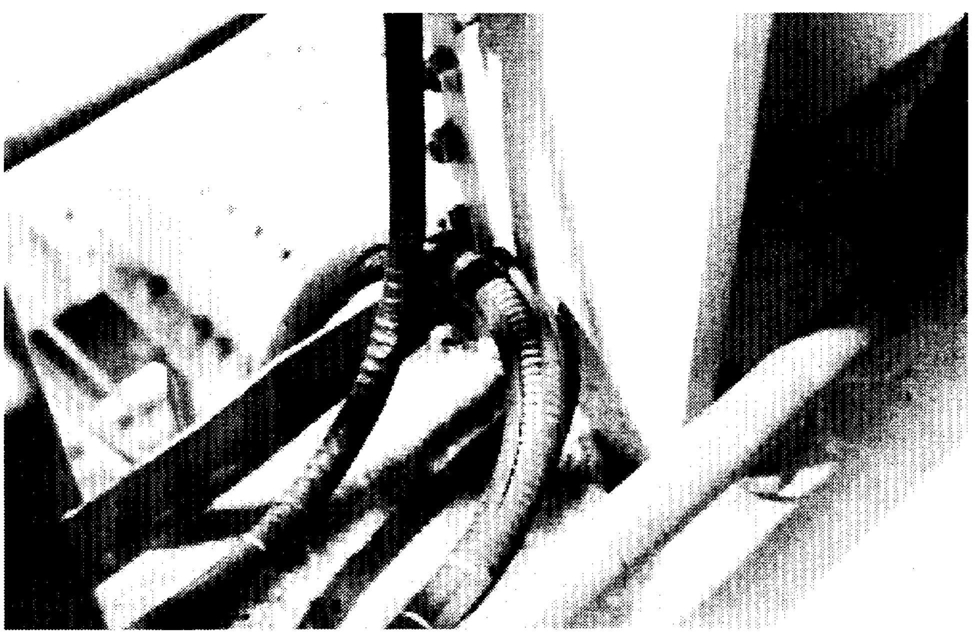


Figure B-19
Cable Jacket Splitting Due to Exceeding Allowable Bend Radius

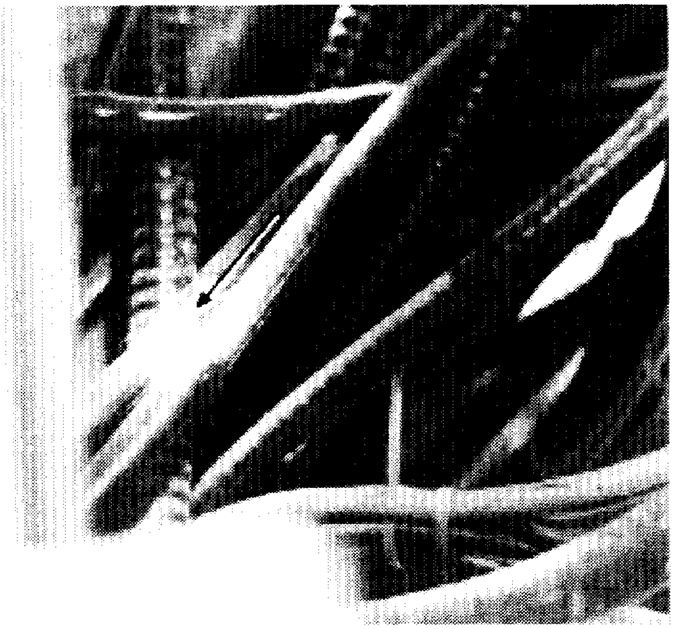


Figure B-20
Cable Damage Apparently Caused During Installation

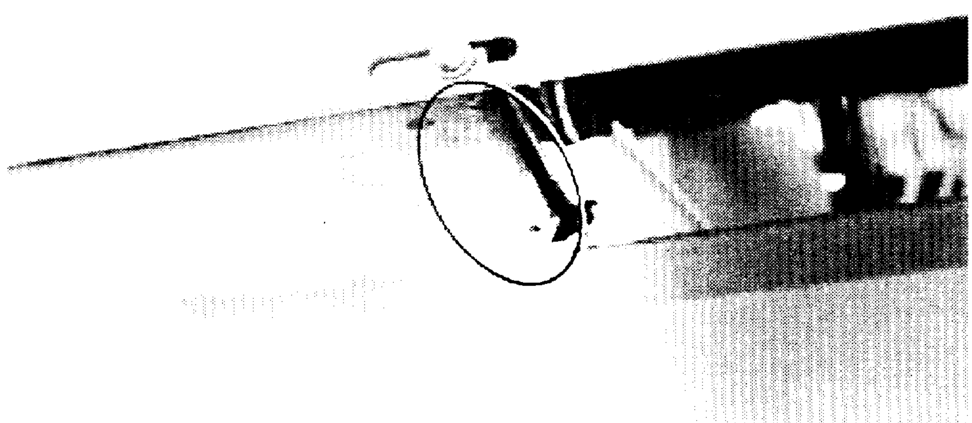


Figure B-21
Water Seeping from a Cable Tray (Adjacent trays had weep holes and did not exhibit seeping.)

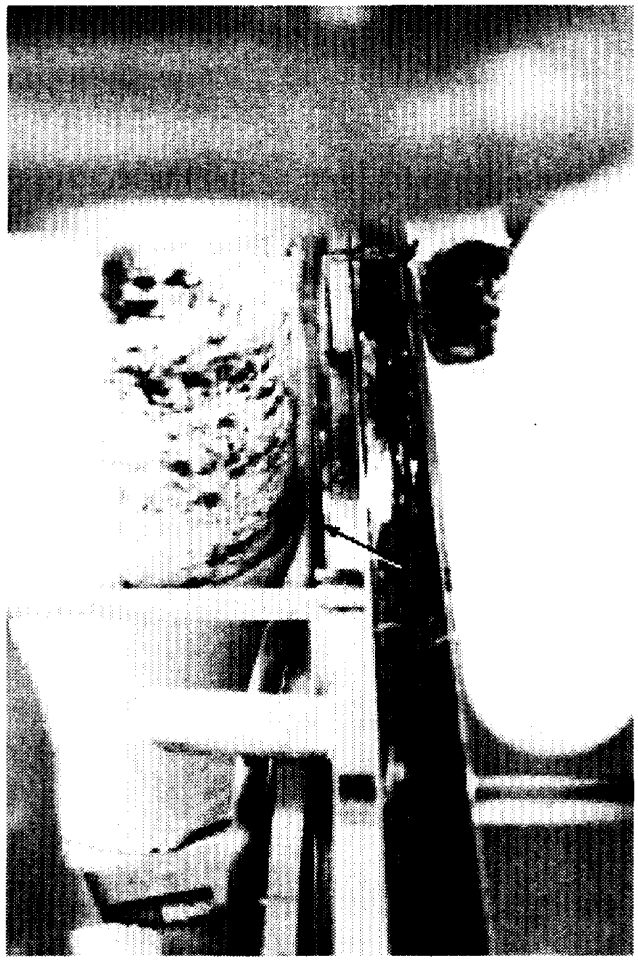


Figure B-22
Cable Apparently Pinched Between a Pipe and a Structural Column

C

SUMMARY OF INDUSTRY DOCUMENTS

The tables at the end of this section provide listings and summaries of documents pertinent to the identification and management of adverse localized equipment environments. Table C-1 lists NRC generic communications that describe adverse localized environments and their effects. Table C-2 lists EPRI reports that may be useful in preparing and implementing an adverse localized environment program.

In addition to the documents listed in the tables, other documents may be of use. The Department of Energy has produced several Aging Management Guidelines (AMGs). These guidelines provide recommended methods for effective detection and mitigation of age-related degradation mechanisms in various types of nuclear power plant equipment. The intent of the guidelines is to assist plant maintenance and operations personnel in maximizing the safe, useful life of these components. The AMGs also support the documentation of effective aging management reviews required under the License Renewal Rule, 10 CFR Part 54 [20]. Some of the equipment types covered are electrical cable and terminations (SAND96-0344, September 1996); motor control centers (SAND93-7069, February 1994); power and distribution transformers; battery chargers, inverters, and uninterruptible power supplies (SAND93-7046, February 1994); heat exchangers; and station batteries.

The Westinghouse Owner's Group (WOG) produced an Aging Assessment Field Guide for cables and connectors [25]. This guide includes an overview of cable and connector design, degradation mechanisms, and methods for evaluating cables and performing failure analyses. It contains a section on walkdown inspections (including a checklist for performing inspections) and photographs of plant equipment exhibiting signs of degradation. The WOG is also producing field guides for other equipment. Each of the field guides prepared by the WOG has a corresponding Implementation Guide, Workshop, and video recording of the workshop. Non-WOG member plants can obtain these guides from the Westinghouse Owner's Group.

Institute of Electrical and Electronics Engineers (IEEE) Standard 1205-1993, "IEEE Guide for Assessing, Monitoring, and Mitigating Aging Affects on Class 1E Equipment Used in Nuclear Power Generating Stations" [29], provides methods for managing degradation of equipment due to aging. The IEEE Guide includes brief discussions of many of the same topics discussed in this report. A discussion of stressors and aging mechanisms is included along with tables of aging effects for polymers, lubricants, and metals. Annex B to Standard 1205, monitoring of environments, and Annex C, equipment and system examples, may provide additional insight for personnel implementing adverse localized environment monitoring activities.

Table C-1
NRC Localized Environment Related Generic Correspondence

Document	Title	Synopsis
IN 93-39	Radiation Beams from Power Reactor Biological Shields	This Notice alerts addressees to narrow, intense beams of radiation that can stream into accessible areas of a drywell through penetrations in the biological shield of a boiling-water reactor (BWR), potentially exposing environmentally qualified (EQ) equipment located in a drywell to high levels of radiation.
IN 92-77	Questionable Selection and Review to Determine Suitability of Electro-pneumatic Relays for Certain Applications	This Notice discusses the possibility of time delay relay drift that is affected by temperature changes within electrical panels.
IN 89-30, Supplement 1	High Temperature Environments at Nuclear Power Plants	This Notice identifies numerous occasions where localized temperature inside electrical cabinets can lead to equipment failure.
IN 89-30	High Temperature Environments at Nuclear Power Plants	This Notice discusses containment temperatures at three BWRs being higher than assumed in EQ specifications. The Notice specifically discusses the possibility of local equipment temperatures being higher that specified even when bulk area temperatures are within normal range. It also discusses the potential generic application to BWRs and PWRs.
IN 88-89	Degradation of Kapton Electrical Insulation	The Notice discusses failures of Kapton insulation due to physical abuse and from environmental effects coupled with mechanical strain.
IN 87-65	Plant Operations Beyond Analyzed Conditions	This Notice discusses two cases where plants were operated beyond the temperature limits assumed in their accident analysis.
IN 86-49	Age/Environment Induced Electrical Cable Failures	This Notice discusses failure of a safety-related cable. The most likely cause of the failure was heat damage from an uninsulated feedwater line and pipe flange. The thermal insulation had not been replaced after feedwater line repairs. The Notice specifically discusses walkdown inspections as a method of cable condition monitoring.

Document	Title	Synopsis
IN 85-89	Potential Loss of Solid-State Instrumentation Following Failure of Control Room Cooling	This Notice discusses failure of solid state equipment inside electrical cabinets during loss of control room ventilation.
IN 85-11	Licensee Programs for Inspection of Electrical Raceway and Cable Installations	While no environmental concerns were discussed in this document, inadequate physical separation problems were noted at eight different sites. In response to this Notice, plants may have performed inspections that could have also inspected for proximity to heat sources.
IN 84-57	Operating Experience Related to Moisture Intrusion in Safety-Related Electrical Equipment at Commercial Power Plants	This Notice states that 53 moisture intrusion events occurred in a four-year period. It summarizes the types of events that occurred and provides five recommendations for preventing moisture intrusion events.
IN-83-70	Vibration-Induced Valve Failures	Vibration caused loosening of set screws that caused anti-rotation pins to drop out, allowing the valve stems to rotate. These problems caused valves to be mispositioned or damaged.
CIRCULAR 77-06	Effects of Hydraulic Fluid on Electrical Cables	The Circular discusses the puffing and plasticization of electrical cables caused by contact with EHC hydraulic fluid.

Table C-2
EPRI Documents Related to Localized Environments

Document Number	Title	Description
NP-6973-R2	Infrared Thermography Guide (Revision 2)	This report describes use of infrared thermography for evaluation of temperatures within power plants.
NP-7399	Guide for Monitoring Equipment Environments During Nuclear Plant Operation	This report provides a description of the considerations that need to be made when developing and implementing an environmental monitoring program. It gives advantages, disadvantages, and costs of various methods and monitoring devices. The guide also includes 20 technical papers presented at an environmental monitoring workshop.
TR-100516	Nuclear Power Plant Equipment Qualification Reference Manual	This manual provides information on determining, monitoring, and specifying environmental service conditions.
TR-103841, Revision 1	Low Voltage Environmentally Qualified Cable License Renewal Industry Report	This report provides an in-depth study of the age-related degradation mechanisms of EQ cables. It also includes an operational experience section.
TR-106687	Cable Aging Management Program for D. C. Cook Nuclear Plant Units 1 & 2	This report describes a cable-aging management program at D. C. Cook. It includes a review of aging stressors, operational experience, and condition monitoring methods and evaluates the capability of cables installed at D. C. Cook to operate up to 60 years.
TR-102399	Proceedings: 1993 EPRI Workshop on Power Plant Cable Condition Monitoring	This report presents the proceedings from one of a number of workshops on cable condition monitoring. This workshop included a breakout session on thermal and radiation hot spots.
TR-104514	How to Conduct Material Condition Inspections	This guide could be used to assist in the development of more specific guidance for localized equipment environment inspections.
TR-110089	Experienced Based Interview Process for Power Plant Management	This publication describes and demonstrates techniques for retrieving knowledge of plant conditions through interviews.

D

UTILITY SURVEY RESULTS

The Adverse Localized Environment Task Group issued a utility survey in the initial stages of this project. The questionnaire was designed to achieve the following goals:

- Identify utilities that had good practices that warranted further research.
- Gain a better understanding of how the industry as a whole was approaching the adverse localized environment issue.
- Obtain an idea of the types and magnitude of problems adverse localized environments were creating.

The answers to the questionnaire are summarized and presented in Tables D-2 through D-15. Answers are given as provided by the responding utility. When the answer for a given utility is blank, no answer was provided. Table D-1 identifies the plant types for the responding utilities. Engineering personnel from 21 utilities responded to the survey.

Table D-1
Plant Code Key

Code	Plant Description
A	PWR
B	PWR
C	BWR
D	PWR
E	PWR
F	BWR
G	PWR & BWR
H	PWR
I	PWR
J	PWR
K	PWR
L	PWR
M	PWR
N	BWR
O	PWR
P	PWR & BWR
Q	BWR
R	BWR
S	PWR
T	BWR
U	PWR

Response to Generic Correspondence

Which of the following best describes the inspections or monitoring of plant equipment or environments your plant conducted in response to the following NRC generic correspondence?

- Information Notice IN 89-30, High Temperature Environments at Nuclear Power Plants
- IN 86-49, Age/Environment Induced Electrical Cable Failures

- Circular 77-06, Effects of Hydraulic Fluid on Electrical Cables
- NRC 50.54f request on adequacy and availability of design basis information, especially item (c) "Rationale for concluding that system, structure, and component configuration and performance are consistent with design bases"

Table D-2
Inspections and Monitoring Performed in Response to Listed NRC Generic Correspondence

Code	No Inspections/ Monitoring Activity	One-time Inspections/ Monitoring Activity	Short or medium-term Inspections/ Monitoring Activity or suspended long term Inspections/ Monitoring Activity	Ongoing Inspections/ Monitoring Activity
A				X
B				X
C				X
D				X
E				X
F	X			
G				X
H			X	
I			X	
J	X			
K				X
L	X			
M			X	
N		X	X	X
O				X
P	X			
Q				
R			X	
S	X			
T				X
U			X	
Total	5	1	6	10

A few plants provided additional details concerning inspection or monitoring activities. These responses are provided in Table D-3.

Table D-3
Additional Details of Inspection and Monitoring Activities

Plant Code	Response
B	Dataloggers used extensively for EQ equipment. Some non-EQ equipment temperature monitoring. Some generic plant equipment walkdowns have been performed.
C	Ambient area temperature monitoring is performed.
D	We had walked down all the components in the EQ Program and identified the equipment and areas of concern (temperature, hot spots, etc.).
L	Localized temperature monitoring on pressurizer area.
M	Temperature and radiation monitoring in the Reactor Head Area.
P	Medium voltage cable test program. This was being done prior to any of the referenced documents being published. Nothing has been done directly as a result of the Bulletins/Notices.

Local Environment Induced Failures

Has your plant ever experienced failures or malfunctions as a result of localized environmental conditions? (Check all that apply)

- ❑ No
- ❑ Yes. Localized environment caused by improper installation (e.g., equipment installed closer to heat source than allowed by design, poor insulation installation, protective covering not properly installed).
- ❑ Yes. Localized environment caused by inadequate design (Insufficient insulation in design, approved equipment location too close to heat source).
- ❑ Yes. Localized environment caused by equipment malfunction (e.g., leaks, loose connection).
- ❑ Yes. Localized environment still exists, but has been incorporated into design conditions (e.g., special environmental zone established).
- ❑ Yes. Plant conducted inspections to determine extent of condition. Describe inspections.

Table D-4
Local Environment Induced Failures

Code	No	Yes. Improper Installation	Yes. Inadequate design	Yes. Equipment Malfunction	Yes. Incorporated into Design Conditions	Yes. Plant conducted inspections to determine extent of condition. Describe inspections.
A			X			X
B				X		
C	X					
D	X					
E			X		X	
F			X	X		X
G			X			
H			X			
I	X					
J	X					
K			X			
L			X			
M				X		
N		X				X
O			X			
P			X			
Q		X				
R		X		X		
S	X					
T			X	X		X
U			X		X	
Total	5	3	11	5	2	4

The following notes were supplied in support of the response to the environment-induced failure question.

Table D-5
Additional Descriptions of Localized Environment Induced Failures and Extent of Condition Inspections

Code	Response
A	A walkdown of turbine building and parts of auxiliary building was performed to look for equipment installed too close to heat sources, i.e., uninsulated pipes, steam leaks, etc.
B	Pipe leak into Limitorques on essential service water system
D	No, but we have found severely degraded power cable to MOVs where the cable were in close contact with a hot pipe. The cable was replaced and reconfigured away from the source. Again, a walkdown was performed to verify if other similar configuration existed. If found, the configuration was corrected. If these cables had not been replaced, there may have been a failure or malfunction.
F	Safety related raceways in high temperature environments (≥130°F) inspected for spatial clearance from potential heat sources.
G	Failures have occurred in mild environment panels due to temperature rise and poor ventilation. Failures have also occurred on Okonite cable in harsh environment with normal operating temperatures of 185°F.
K	CR 120A relay failures. Diesel generator static exciter failure (Described in NRC Information Notice 89-30, Supplement 1)
L	We have installed Westinghouse Lifetime Monitors in the vicinity of EQ components in the drywell to determine if the replacement frequency was adequate or excessive. This is ongoing. First cycle of monitoring provided temperatures lower than the bulk temperature that was being used for aging.
Q	Steam Tunnel was running above Technical Specification limit. We had to install additional room coolers.
T	Corrective actions included thermography, daily operator rounds, modifications to selected alarm panels.

Condition Monitoring Checklists

Which of the following best describes your plant's use of condition monitoring checklists?

Table D-6
Condition Monitoring Checklist Usage

Code	Used on EQ Equipment only	Used on Safety-Related Equipment	Used on All Classes of Equipment
A			
B		S	S
C			S
D	N	N	N
E	N	N	N
F	N	N	N
G		S	
H	N		
I	N		
J	N	N	N
K			S
L	N	N	N
M	F	N	N
N			
O	S	S	F
P	N	N	N
Q	N	N	N
R	S		
S	F	F	N
T		S	
U	S	N	N

Legend
S=Still in Use, F=Formerly Used, N=Never Used

Have the checklists ever identified a localized severe environment? If yes, describe.

Table D-7
Localized Environments Discovered Using Condition Monitoring Checklists

Code	Response
A	We do not have a condition monitoring "checklist" per se. We have instructions in procedures for inspection of equipment when being worked on. We also try to have people be aware of plant conditions and report any problems they may see. These are applicable to all equipment. This general awareness has identified several localized-severe environments as follows: cable too close to steam generator sample line, cable too close to an uninsulated feedwater line, and a direct steam leak onto a limit switch.
B	We do not use checklists to identify localized severe environments. We did not expect to have localized severe environments.
C	As part of a review of corrective maintenance work requests, we address aging effects due to adverse equipment conditions.
D	We do not use conditioning monitoring checklists for any equipment, at least not a formal list.
E	
F	
G	Condition monitoring checklists are used for cable inside containment (Okonite, Kerite, Rockbestos & Eaton) and cable in the MSIV area (Okonite) in hot spots.
H	
I	
J	
K	Checklists identified problems in hydrogen monitor cabinets
L	
M	No.
N	I'm not sure what you mean by "checklists." We use environmental monitoring on all classes.
O	Localized hot spots (temperature) were identified and have been monitored by a number of methods since. Currently using portable data loggers.
P	
Q	
R	No.
S	No.
T	No
U	

Inspections and Monitoring

Describe the inspection of plant areas conducted at your plant other than those performed by plant operators during their rounds.

Table D-8
Plant Inspections Summary

Code	Cleanliness Inspections by Plant Management and Supervision	Space or Area Inspections Conducted by Personnel Assigned Ownership of Plant Area	System Engineer/ System Manager Walkdowns	Housekeeping Inspections Conducted as Part of Self-Assessments (INPO Style, Periodic, Etc.)	Other
A	X	X	X	X	Plant inspection by Component and System Engineers just prior to closing up containment at end of outage.
B	X	X	X	X	
C	X	X	X	X	
D			X		Radiation Protection, Fire Protection, EQ Engineer. See detailed description.
E		X			
F	X	X	X	X	
G	X	X	X	X	Area temperature monitoring outside containment. Daily rounds verify temperatures are below design in areas without Class 1E HVAC.
H	X		X		Temperature monitoring
I	X				
J			X	X	Walkdowns for temperature monitoring program

Code	Cleanliness Inspections by Plant Management and Supervision	Space or Area Inspections Conducted by Personnel Assigned Ownership of Plant Area	System Engineer/ System Manager Walkdowns	Housekeeping Inspections Conducted as Part of Self-Assessments (INPO Style, Periodic, Etc.)	Other
K	X	X	X	X	
L		X	X		EQ walkdowns performed as part of component replacement.
M	X	X	X	X	
N	X	X	X	X	Post outage/startup walkdowns by System Engineers, routine comments from any staff.
O	X	X	X	X	EQ walkdowns after maintenance and after and during outages.
P	X	X	X		
Q		X	X	X	
R	X	X	X	X	Thermography
S			X	X	
T	X	X	X		
U	X	X	X	X	Inspection performed as part of equipment installation and field verification process.

Table D-9
Detailed Description of Inspections

Code	Response
D	Periodic walkdowns are mainly performed by system engineers. Other inspections by different groups such as Radiation Protection, Fire Protection, etc. No localized severe environments have been encountered. We have temperature recorders installed in those areas previously identified as experiencing elevated temperatures. These are downloaded every three months. We had already surveyed the plant several times over the last six years to determine the areas of concern. If this would change, then it would be noticed during walkdowns. No additional areas have been found. The areas of the plant having elevated temperatures have been narrowed down to the top of the pressurizer vault and the area in the Auxiliary Building near the MSIVs. The pressurizer vault temperatures remain fairly constant so we have assigned a worst case temperature and no further monitoring is required. Due to changes in the ventilation lineups, seasonal responses, and equipment performance of the nonsafety-related room coolers, the areas surrounding the MSIVs are monitored by the temperature recorders previously mentioned. EQ equipment qualified life is based upon the worst case elevated temperature.

Have any of these inspections revealed localized severe environments? (Yes/No) Describe condition discovered.

Table D-10
Types of Environments Discovered by Inspections and Monitoring

Code	Response
A	Missing thermal insulation, cable not secured properly, and in contact with hot pipe.
B	Have had pipe leaks cause environment changes. Radios tripped various equipment.
C	There were times when an area cooler was performing poorly and localized hot spots were created. This is monitored and corrected when discovered.
D	No additional areas have been found.
E	No.
F	No.
G	No.
H	
I	Yes. Walkdown inspection for the temperature monitoring program revealed that some components around the MSIVs and the ADVs were very hot. For example, the Namco limit switches around the ADVs were experiencing temperatures about 190°F during the month of July.
J	
K	
L	No.
M	
N	Yes. Localized hot spots, moisture leakage, lack of proper ventilation.
O	Yes. Hot or overheating terminations/splices on electrical equipment such as containment fan cooling unit motors.
P	
Q	No.
R	
S	
T	No.
U	Yes. Equipment close to high temperature process piping.

Indicate which of the following best describes temperature monitoring at your plant.

Table D-11
Areas Where Temperature Monitoring Is Performed

Code	Monitoring Performed Only in Areas Suspected of Exceeding Design Conditions	Monitoring Performed Throughout the Plant, Including Areas Suspected of Exceeding Design Conditions	Monitoring Performed Only in Areas Suspected of Being Substantially Less Than Design Conditions
A		X	
B		X	
C		X	
D			
E		X	
F		X	
G	X		
H		X	
I		X	
J	X		
K	X		
L	X		
M			X
N		X	
O	X	Initially, but discontinued	X
P			
Q			X
R		X	X
S	X		
T		X	
U	X		

Has temperature monitoring ever revealed additional high temperature areas not previously suspected of exceeding design conditions? (Yes/No)

Table D-12
High Temperature Areas Revealed by Temperature Monitoring

Code	Response
A	
B	No
C	
D	
E	No
F	
G	No
H	Yes
I	Yes
J	Yes, in a couple of instances during the hottest part of the year.
K	Yes
L	No
M	
N	Yes
O	Yes, 1-FCV-95
P	There is no continuous monitoring activity, other than described above, that has been initiated beyond original plant design.
Q	No
R	Yes
S	No
T	Yes
U	Yes

Describe the areas of your plant identified as having temperatures exceeding bulk area or general design temperatures (excluding internal equipment temperatures).

Table D-13
Areas with Temperatures Exceeding Bulk Area or General Design Temperatures

Code	RCP Bays	PZR Compt.	Near MSIVs	Inside EPs	Main Steam Pipe Tunnels	Pen. Rooms	Upper DW or CTMT	Cable Trays	Other
A									See Table D-14
B		X	X	X	X				
C				X			X		
D		X	X						
E			X				X		
F				X					
G		X	X	X					ARVs
H		X	X		X				
I		X				X			
J									See Table D-14
K				X					
L		X (1)	X	X					(1) Pressurizer Area Make-up (HPI) and Decay Heat (DH) pump rooms
M	X	X	X						
N									RWCU Pump Room
O		X	X		X				
P							X		Suppression Pool Air Space
Q									
R				X	X				
S		X		X					
T									Isophase duct work (only during operation)
U			X				X		Auxiliary Feedwater Doghouse

Legend
RCP Bays=Reactor Coolant Pump Bays
PZR Compt.=Pressurizer Compartment
Near MSIVs=Near Main Steam Isolation Valves
Inside Eps=Equipment Inside Electrical Panels
Pen. Rooms=Penetration Rooms
Upper DW or CTMT=Upper Drywell or Containment Regions

Please indicate any additional areas with elevated temperatures of which you are aware.

Table D-14
Other High Temperature Areas

Code	Response
A	Inside containment ventilation fan rooms/dead air spaces above heat exchangers.
J	Main Steam Support Structures. Only during the summer months when the outside temperature is about 115°F.

Aging Management

Does your plant have plans for implementing aging management methods during license renewal that will aid in detection of localized severe environments? If so, describe the method and degree to which the method has been implemented.

Table D-15
Aging Management Methods That Will Aid in the Detection of Localized Environments

Code	Response
A	Temperature monitoring has been installed in containment and turbine building. Penetration room monitoring is on the drawing board.
B	Have yet to commit to License Renewal. We will definitely be looking at cable monitoring.
C	None beyond those already in place.
D	At this time, no. But then again, those areas have been identified contain EQ components.
E	
F	Not aware of any.
G	Temperature monitoring has demonstrated that bulk room temperatures are 10 to 20°F below design values.
H	No.
I	No. We are not that far along in the license renewal process at this time.
J	No.
K	Yes. We belong to EPRI I&C Upgrade Project. We are looking at aging and obsolescence on I&C Systems. We have temperature monitoring programs for EQ equipment areas.
L	Unknown—no discussions at this time.
M	No.
N	Yes. We already have temperature monitoring in place in many areas of the plant. We have performed radiation monitoring via survey and have installed dosimetry. If so, we use thermography to identify hot spots.
O	Yes. Numerous procedures have been implemented for condition monitoring and temperature monitoring. Both are used as a basis for extending qualified lives of various EQ devices.
P	No. Currently, we have not decided on seeking license renewal.
Q	No.
R	Yes.
S	No.
T	Yes. Tracking of cycles, i.e. scrams, heatup/cooldown rates.
U	No.

E

CASE STUDIES

The two case studies discussed in this Appendix provide detailed examples of how adverse localized environments can be managed. Both of these examples are from plants pursuing license renewal. The utilities performed these tasks to demonstrate that aging of cables was being sufficiently managed. As part of this demonstration, the utilities addressed the actual environments to which cables are exposed. The verification and determination of the actual environments are excellent examples of activities that could be performed to help manage adverse localized equipment environments. While these examples are expected to be useful to utilities, they are not intended as requirements for monitoring activities.

Both case studies are presented using the same outline. Although the activities performed before the systematic approach discussed in this guideline was developed, the outline identifies elements of the systematic approach that were used by the utilities.

Case Study 1—Evaluation of Cable Temperatures in Random-Filled (Unspaced) Cable Trays

Type of Localized Equipment Environment of Concern: Elevated temperature

Potential Cause: Joule (Ohmic) heating, proximity to heat sources, or both

Type of Equipment Affected: Non-EQ power cables in mixed and random-filled (unspaced) cable trays

Challenge Presented by Localized Environment: The plant was pursuing license renewal, but could not analytically demonstrate that all cables would be operating below the 60-year service limiting temperature.

Solution: Demonstrate by a combination of analysis and temperature surveys that all cable will be below its 60-year service limiting temperature.

Definition

Sixty-year service limiting temperature–The temperature above which thermal aging would limit continued use of the cable. The cable insulation may experience dielectric failure if exposed to temperatures above this limit for 60 years.

Systematic Approach Elements Used

1. Determine Concern Driving the Evaluation–The utility was performing an aging management review of cables to support its License Renewal application

2. Determine Constraints and Define Scope of Evaluation–The study was limited to non-EQ power cables in mixed and randomly filled cable trays.

3. Determine Supplemental Activities to Be Performed–The project team analytically determined which cables were most likely to be near or above 60-year service limiting temperatures. These cables were then selected for screening temperature measurements and walkdowns.

4. Perform Supplemental Activities and Evaluate Results–After inspecting and measuring temperatures of the cables in the screening population, the project team reviewed the data and selected cables for longer term monitoring.

5. Determine Ongoing Activities–Since the maximum recorded temperatures of the cables most likely to exceed their 60-year service temperature were all at least 9°F less than the 60 year service temperature, the project team determined that no ongoing activities were needed.

Details

The following methodology was used to determine cable service temperatures:

1. A thermal model was developed for the cable mass in an open cable tray.[1] This model incorporates tray dimensions, tray fill, cable heat generation, and ambient temperature in relationships that predict the maximum cable temperature within the cable mass. This fundamental thermal model was then extended to provide quantitative predictions of maximum cable temperatures in trays with covers, fire stops, and fire wrap.

2. A screening process for initially selecting trays for temperature recording was developed. The thermal model was implemented in a spreadsheet to calculate temperatures in the center of the cable mass for over 4,000 cable trays. The calculated temperatures were used to identify trays with the highest expected cable temperatures for further investigation.

3. The screening process, plant data bases, plant drawings, and similar information were then used to select trays for physical inspections (walkdowns). Two groups of trays were selected. Group 1 contained trays where the primary influences on cable temperatures were Joule heating and high ambient temperatures. Group 2 contained trays where the primary influence on cable temperature was indirect heating via neighboring high-temperature piping, vessels, and equipment.

4. The most promising trays and plant locations were physically inspected to determine final tray selections and identify locations for placing monitoring equipment. A hand held digital thermometer and thermal imaging equipment were used during the physical inspections to identity the highest temperature locations and tray sections.

5. The devices used for recording cable jacket temperatures were checked for functionality and accuracy prior to installation, using a water bath and a high-accuracy digital thermometer.

6. Temperature recording devices were installed and activated. These recording devices were set to record 1800 temperatures over a time span of 360 days, so that seasonal temperature extremes and daily profiles were captured. Visual inspections were performed of cables at monitoring locations to identify discoloration, cracks, and other signs of elastomer deterioration.

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1 The basic thermal model used the ICEA-P-54-440 [30] methodology for determining cable ampacities in open cable trays. The basic model was then extended to account for tray covers and fire barriers by increasing the heat generated in the cable mass by the square of the reciprocal of the appropriate derating factors given in IEEE Standard 666-1991 [31].

7. The recording devices were removed at the end of the recording period, their data was downloaded into spreadsheet files, and analysis of the data was performed.

8. The recording devices were again checked for functionality and accuracy using a water bath and a high accuracy digital thermometer.

The screening process yielded 32 candidate trays for temperature monitoring (Three of these turned out to actually be wireways). These trays were then inspected visually and using infrared thermography. Six trays were selected for temperature monitoring. Five of these trays had cable surface temperatures greater than 20°F above the ambient temperature (The temperatures were determined using an AGEMA Model AG 470 color thermal imaging device). The remaining tray was especially susceptible to indirect heating. The trays selected are described below:

- A tray in a series with four other trays that had a difference of 30°F between ambient and the surface temperature. Of the five trays in series, this tray had the largest difference between ambient and surface temperatures.
- A partially covered tray, 75% full, with a difference of 23°F between surface and ambient.
- A tray with a metal cover its entire length, 75% full, with a surface to ambient temperature difference of 25°F.
- A tray, 100% full, subject to severe radiant heating from a main-steam-pipe restraint with an ambient-to-surface temperature difference of 34°F.
- A tray, 50% full, with an ambient-to-surface temperature difference of 26°F located directly above a hot pipe.
- An 85% full tray over potentially hot pipes. The ambient-to-surface temperature difference could not be meaningfully determined since the unit was shut down.

Twelve Omega Engineering Model RD-TEMP-XT single channel data loggers were installed in each of the trays selected. Ten recorders monitored temperatures in the cable mass. Two recorders monitored ambient temperature. Locations within the cable mass were selected based on the hottest locations found using an Omega Model HH41 digital thermometer equipped with an Omega 400-Series tubular stainless steel thermistor probe. Prior to installation, tests were run to determine the effects of elevated temperature and magnetic fields on the data logger leads. Both exposing the leads to the magnetic field of a welding cable and immersing the leads in boiling water had less than a 1°F effect on the data loggers. While installing the temperature recorders the cables were inspected for discoloration, cracks or other signs of deterioration. No signs of deterioration were found.

After 360 days of recording, none of the measured peak service temperatures was within 9.9°F of the 60-year service limiting temperature for any of the insulation types used at this plant. The Arrhenius equivalent temperatures of the recorded data (calculated using the formulas from Section A5.2 of EPRI's EQ Reference Manual [32]) were at least 35°F below the 60-year service limiting temperature. The highest temperature recorded was 156.93°F in the tray that was 100% full in close proximity to a main steam-piping support.

From this data, the plant was able to conclude that non-EQ power cables in mixed and random fill cable trays are all operating below the 60-year service limiting temperature.

Additional Information

EQ cables were excluded from this study because the plant is crediting its EQ Program as an aging management program. EQ cables are replaced based upon their qualified life.

The 60-year service limiting temperatures were derived using Arrhenius data from Fulcrum Group, Inc.'s System 1000 database. Typically 50% elongation was used as an endpoint, but endpoints as low as 20% elongation were used. This was justified because the cables being reviewed were not required to operate when subjected to a harsh design basis accident environment, and research has shown that degradation of insulation material mechanical properties precedes any degradation of electrical properties.

Case Study 2—Evaluation of Turbine Building Cable Temperatures

Type of Localized Equipment Environment of Concern: Elevated temperature

Potential Cause: Ventilation using outside air, proximity to heat source, or both

Type of Equipment Affected: All cables installed in the turbine building

Challenge Presented by Localized Environment: The plant was pursuing license renewal and wished to demonstrate that either the installed environment did not exceed the original maximum design conditions for the cables, or the actual temperature was such that the cable insulation would retain sufficient mechanical and electrical properties essential to the performance of design function.

Solution: Demonstrate by a combination of temperature surveys and analyses that no cables will be exposed to temperatures that will degrade the cables beyond a specified "end point" deemed suitable for operability.

Definition

End-point—The percent retention of a mechanical property (such as elongation).

Systematic Approach Elements Used

1. Determine Concern Driving the Evaluation–The utility was performing an aging management review of cables to support its License Renewal application.

2. Determine Constraints and Define Scope of Evaluation–This study was limited to cables located in the Turbine Building.

3. Determine Supplemental Activities to Be Performed–The project team planned walkdowns of the Turbine Building to identify hot locations. Following the walkdowns, temperature monitoring at the hottest locations was planned.

4. Perform Supplemental Activities and Evaluate Results–The project team determined which areas of the Turbine Building were the hottest during an initial set of walkdowns. From these walkdowns, 32 locations were selected for temperature monitoring. The project team reviewed the data from the temperature monitoring effort. During the walkdowns, the project team observed and photographed general equipment conditions and potential adverse localized environments.

5. Determine Ongoing Activities–Since the maximum recorded temperatures were much less than the temperature the cables could withstand for 60 years, the project team determined that no ongoing activities were currently needed.

Details

The following methodology was used to determine the average annual ambient temperatures at the installed locations of the cables:

1. An imaginary three-dimensional "grid" of the entire Turbine Building was established based on column and row numbers.
2. A thermographic walkdown of the Turbine Building was performed to identify the apparent highest temperature point within each grid subsection.
3. Thirty-two temperature monitoring devices were installed at high temperature locations based on the results of the walkdown.
4. Hourly temperature data was recorded in the 32 locations for a period of two years.
5. Hourly outdoor temperature data was recorded from the site weather station.
6. The operating outage schedule for the plant was obtained and considered in the evaluation.
7. All temperature and operating data were combined and aligned.
8. The highest, lowest, and average seasonal and annual temperatures were determined for all 32 monitored locations for the periods in which the plant was operating.

Table E-1 summarizes the design temperatures in the Turbine Building during normal plant operations. These design temperatures, as defined in the station System Description for the Turbine Building Ventilation System, are the normal maximum bounding temperatures on the hottest summer day and do not take into account daily (day vs. night) and seasonal (Summer vs. Winter) fluctuations.

Table E-1
Turbine Building Design Temperature Data

Structure & Area	Temperature (°F)		Comment
	Max	Min	
Turbine Buildings	Ambient	--	General areas (air from outside)
	Ambient	--	Rooms T131 to T135 (air from Turbine Building or outside)
	75	60	Battery Rooms, Rooms T136 to T139 and T220 to T222

Plant walkdowns that were performed during 1996 to investigate the existence of adverse localized equipment environments looked specifically at the electrical components in the Turbine Building. The walkdowns were performed with the units operating.

Walkdowns of the Turbine Buildings were performed, and a temperature-monitoring program in the Turbine Building was initiated to identify the potential locations of adverse localized equipment environments and assess the effect of elevated temperatures on the equipment installed in those areas. A three-dimensional grid of the Turbine Building was established, and 32 temperature sensors were installed to record temperatures periodically (some every 30 minutes; others, every hour). Ambient outside temperatures were recorded as part of the normal site weather-monitoring program. Temperature monitoring inside the Turbine Building was initiated in mid-July 1996, and data collected between then and late April 1997 have been evaluated.

The program assumed that the worst-case temperatures would occur during the summer months when all three units were operating. Therefore, all monitoring data, ambient temperatures, and unit outage records were compared and aligned to ensure that all temperature data analyzed included the operation of all three units. The operating criterion was met during the four discrete time periods between July 1996 and April 1997 shown in Table E-2. The first time period in Table E-2 is referred to as "Summer" while the second through fourth time periods were grouped together for analysis and are referred to as "Spring."

Table E-2
Periods of Temperature Monitoring Data from the Turbine Building Used in Analysis

Season	Start Date	Start Time	End Date	End Time	Elapsed Time (Hours)
Summer	7/18/96	11:46 a.m.	9/21/96	11:21 a.m.	1,532
Spring	3/14/97	10:23 a.m.	3/20/97	9:12 a.m.	143
Spring	3/21/97	1:02 p.m.	3/28/97	2:42 p.m.	169
Spring	4/11/97	4:12 p.m.	4/22/97	12:50 p.m.	260

Temperature Ranges

Figures E-1 and E-2 compare the range of Summer and Spring ambient-air temperatures at the site to those measured at 32 locations inside the Turbine Building. The temperatures inside the Turbine Building are higher than the outside ambient air (as would be expected) because most of the Turbine Building areas are ventilated using outside air. Although temperature ranges in a few areas exceed 48.9°C (120°F), an analysis of all of the hourly summer temperature measurements (~50,000) inside the Turbine Building determined that more than 80% of them are less than 48.9°C (120°F).

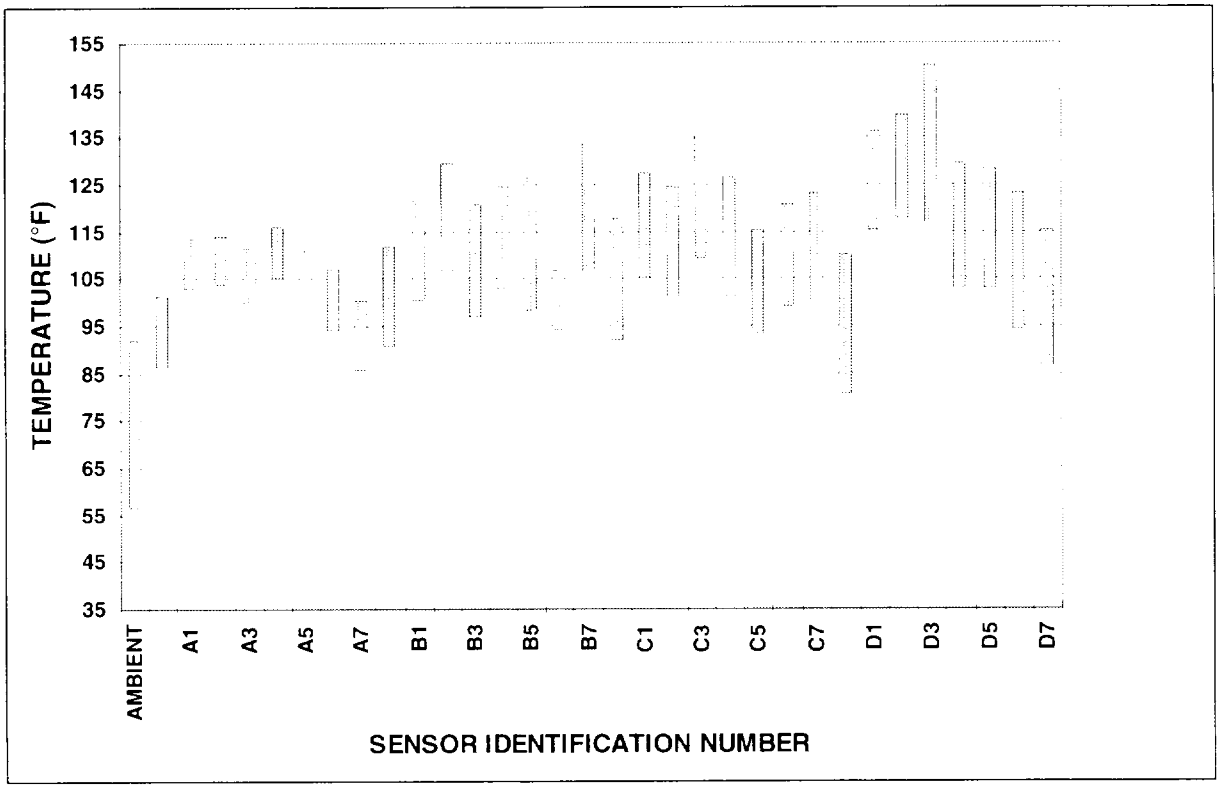

Figure E-1
Range of Monitored Summer Temperatures in the Turbine Building

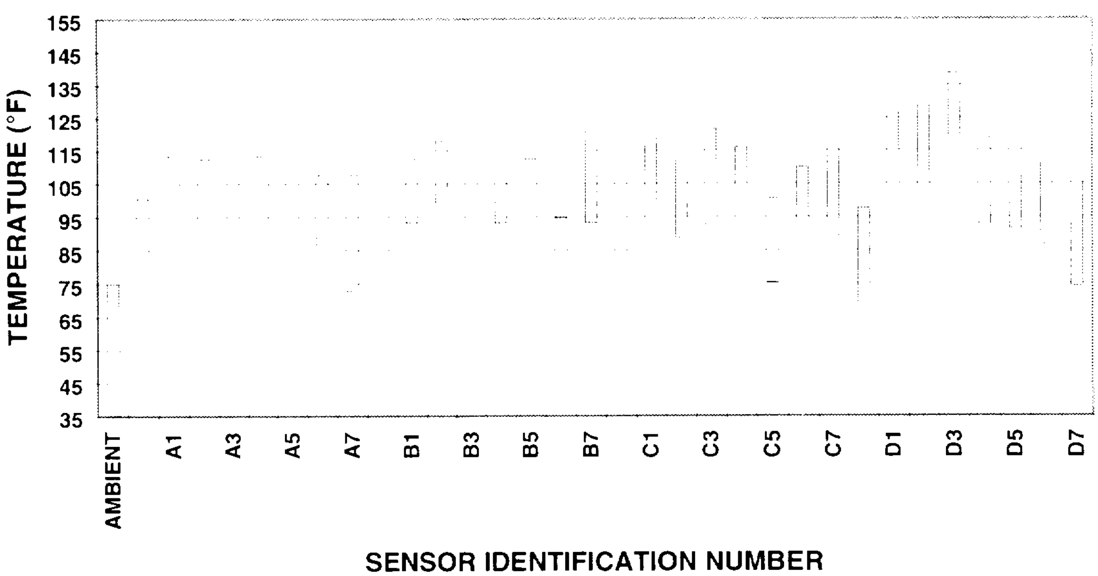

Figure E-2
Range of Monitored Spring Temperatures in the Turbine Building

Temperature Averages

The amount of degradation occurring in organic materials can be approximated through evaluation of the typical or "average" temperature to which the material is exposed over time. All the monitored hourly temperature data at each sensor location was used to calculate an "average" temperature at that sensor for the two seasons (summer and spring). The results are summarized in Table E-3.

Table E-3
Average Temperatures in the Turbine Building

Hot Spot Sensor	Summer Average Temperature °F	Spring Average Temperature °F	Hot Spot Sensor	Summer Average Temperature °F	Spring Average Temperature °F
Outside Ambient	75	56			
A	101	90	C	106	93
A1	114	109	C1	118	105
A2	114	103	C2	114	101
A3	112	102	C3	124	110
A4	116	105	C4	117	105
A5	111	100	C5	106	89
A6	107	99	C6	111	100
A7	101	95	C7	112	103
B	103	92	D	96	84
B1	113	103	D1	126	114
B2	119	110	D2	130	114
B3	111	100	D3	143	130
B4	116	104	D4	117	106
B5	115	102	D5	115	108
B6	101	89	D6	110	99
B7	123	109	D7	102	90

During the summer when the average ambient outside air temperature was 23.9°C (75°F), the average temperature inside the Turbine Building monitored at 32 different areas ranged from 35.6°C (96°F) to 61.7°C (143°F). A majority (59%) of these 32 areas had a summer average temperature of less than 46.1°C (115°F), and 84% had a summer average temperature of less than 48.9°C (120°F).

During the spring when the average ambient air temperature was 13.3°C (56°F), the average temperature inside the Turbine Building monitored at 32 different areas ranged from 28.9°C (84°F) to 54.4°C (130°F). A majority (62%) of these 32 areas had a spring average temperature of less than 40.6°C (105°F), and 84% had a spring average temperature of less than 43.3°C (110°F).

Through September 1997, monitored data for one full year with all three units operating was insufficient to describe all possible temperature ranges. However, some preliminary conclusions concerning the typical seasonal average temperatures can be made, and they are summarized in Table E-4.

Table E-4
Typical Average Temperatures Inside Turbine Building

Season	Temperature
Summer	< 120 °F (48.9 °C)
Fall	< 110 °F (43.3 °C)
Winter	< 100 °F (37.8 °C)
Spring	< 110 °F (43.3 °C)
All Year	< 110 °F (43.3 °C)

When the range of ambient air temperatures is lower in the spring, the ranges of temperatures in the monitored areas inside the Turbine Building are also lower, as shown in Figure E-2.

Once the average temperatures were established for each location, then an analysis was performed to compare the average temperatures in the Turbine Building to the highest temperature that various cable insulation materials can withstand for a period of 60 years.

The typical "endpoint" for cable thermal aging data is 40% to 60% retention-of-elongation. Research funded by the NRC and published in NUREG/CR-6384 [33] determined that the retention-of-elongation of most cable insulation materials can be reduced to 0%, and the insulation will still be capable of withstanding a loss-of-coolant accident (LOCA) and remain functional.[2] Since the insulated cables and connections located in the Turbine Building either will not be subjected to an accident environment or are not required to function after being subjected to an accident environment, the endpoints chosen for this review are extremely conservative. Therefore, the useable 60-year life temperature for a typical cable insulation is significantly higher than the values shown in Table E-5.

2 Page 5-57 of NUREG/CR-6384 [24]

Table E-5
Cable Insulation Temperature Data[3]

Insulation	Maximum Temperature for 60-Year Life	Activation Energy (ϕ), eV	Intercept, "b"	Endpoint
SR	273°F (133.9°C)	1.81	-16.69	50% Retention-of-Elongation
Kapton	248°F (120.0°C)	3.916	-43.208	Failure
Phenolic	220°F (104.7°C)	1.37	-12.14	50% Retention of Impact Strength
Polyalkene	189°F (87.2°C)	1.11	-9.79	Mean-Time-To-Failure
XLP, XLPE, Vulkene, FR-XLPE	188°F (86.7°C)	1.35	-13.19	60% Retention-of-Elongation
Kerite-HTK	185°F (85.2°C)	1.07	-9.33	20% Retention-of-Elongation
EP, EPR, EPDM, FR-EPR	155°F (68.3°C)	1.10	-10.51	40% Retention-of-Elongation
Hypalon	154°F (67.8°C)	1.14	-11.13	50% Elongation
PE	131°F (55.0°C)	1.14	-12.37	T75 Induction Period
Nylon	130°F (54.4°C)	0.84	-7.44	28% Retention of Tensile Strength
Butyl	125°F (51.7°C)	1.10	-11.34	40% Retention-of-Elongation
PVC	112°F (44.4°C)	0.99	-10.00	Mean-Time-To-Failure

The temperature monitoring program and associated evaluation confirmed that the actual temperatures in the Turbine Building are much lower than the 60-year temperatures for almost all the cable insulation materials.

In addition to determining the actual temperature profiles in the Turbine Building, the following benefits were obtained from this effort:

1. A general inspection of the overall condition of various systems and equipment occurred.

2. Specific examples of several cable installations that could result in accelerated cable aging were identified.

3 References for all the activation energy and endpoint data are given in Table 5-17 of EPRI Report TR-107527 [34].

3. Moisture and chemical spills were confirmed as not being significant occurrences for the plant.

During the walkdown of the Turbine Building and selection of areas for installing temperature monitors, plant personnel took the opportunity to examine the overall condition of the installed equipment and systems in the Turbine Building. Photographs taken established a historical record of the overall conditions in the Turbine Building after more than 20 years of operation. The inspection also identified certain cable installations that could result in accelerated cable aging because of the close proximity of the cables to high-temperature process lines. In addition, the inspection noted the absence of any indication that long-term pooling of water had occurred, or that chemical residue existed in the Turbine Building.

Target:
Nuclear Power

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