Long-Term Operations: Normal Temperature and Radiation Dose to Installed Cable for U.S. Nuclear Power Plants in Containment

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ABSTRACT

In support of the current plans of operating much of the existing fleet of nuclear power plants beyond 60 years of service, the Electric Power Research Institute (EPRI) is conducting research to assess the condition of the existing electrical cabling infrastructure. In order to operate through a subsequent licensing period (60–80 years of operation) plants must demonstrate the existing cabling has adequate margins remaining that assure safe operation. This report provides the preliminary results of an effort to collect environmental service condition data during normal plant operations in plant locations where cables are installed. Specifically, temperature and radiation data were collected so that the effects on cable insulation thermal and radiation aging can be evaluated for long-term operation.

The collection of data thus far has been inadequate to reach any conclusions on the likelihood of cables being able to perform reliably during periods of extended operation. However, the radiation and temperature monitoring data that was provided does indicate that original plant design bases radiation and temperature values may have excessive margin as compared to typical plant conditions, with exceptions typically based on stratification, reactor and containment type, and elevation. Therefore, it is recommended that a more specific research and monitoring project be undertaken to gather conclusive evidence regarding this preliminary conclusion.

Keywords

Cable
Environmental Qualification
Long-term Operation
Radiation Monitoring
Temperature Monitoring

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1
INTRODUCTION

This report provides the preliminary results of an effort to collect environmental service condition data during normal plant operations in plant locations where cables are installed. Specifically, temperature and radiation data were collected so that the effects on cable insulation thermal and radiation aging can be evaluated for long-term operation.

In support of the current plans of operating much of the existing fleet of nuclear power plants beyond 60 years of service, the Electric Power Research Institute (EPRI) is conducting research to assess the condition of the existing electrical cabling infrastructure. In order to operate through a subsequent licensing period (60–80 years of operation or beyond) plants must demonstrate the existing cabling has adequate margins remaining that assure safe operation.

It was common in the nuclear industry to use 50 Mrad (0.5 Gray) as the enveloping (or bounding) test and analytical value for normal radiation over the course of a 40 year plant life. Therefore, the NRC used this same 50 Mrad (0.5 Gray) value in various 1996 through 2001 environmental qualification (EQ) tests. This 50 Mrad (0.5 Gray) value was also typically used by the NRC for their EQ research between 1980 and 2001.

Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) typical in containment design basis event conditions are provided in IEEE 323-1974 [10], Table A1, which identifies 150 Mrads (1.5 Gray) for a PWR accident and 26 Mrads (0.26 Gray) for a BWR accident. Therefore, this would result in the desire to perform qualification testing using 200 Mrad (2 Gray) dose in order to envelope both types of plants.

However, when long-term plant operation to 80 years is considered, a simple doubling of the assumed 50 Mrad (0.5 Gray) normal radiation value would greatly increase the needed radiation dose to be bounding for qualification. Therefore, research is desired to justify actual plant normal radiation dose levels as being within the 40 year 50 Mrad (0.5 Gray) value for the entire 80 years. The supposition is that in most cases 80-year cable dose will most likely be bound by 10 Mrad (0.1 Gray) or less. In those cases of higher lifetime dose, the use of specialty cables that are more radiation resilient or periodic replacement will be employed to manage cables exposed to higher radiation environments.

Similarly, cables were evaluated and qualified lives or service lives were determined based on assumed normal design temperatures, with worst-case conditions being used for a majority of the cable population. It is EPRI’s position, based on actual and anecdotal information from the industry that most cables are operating in temperature environments that are significantly less than has been assumed in the plant design.

Background

NRC Research

Research is underway to support nuclear power plants pursuing Subsequent License Renewal (SLR) in order to remain operational for an additional 20 years beyond the current 60-year license renewal period.

The NRC has repeatedly expressed a need for “reasonable assurance” that cables will provide reliable life during the subsequent license renewal period. The soon to be published Expanded Materials Degradation Assessment[1] (Volume 5 is on cables) targets the following research areas:

- Synergistic effects of combined temperature/radiation accelerated aging
- Diffusion limited oxidation (DLO)
- Inverse temperature effects
- Submergence

The NRC research for synergistic effects, DLO and inverse temperature are all related to temperature/dose concerns for original qualification testing:

- Synergistic effects of temperature and dose applied simultaneously versus sequentially for pre-LOCA 40 year aging qualification testing (NRC and National Institute of Standards and Technology [NIST]) (formerly NBS)[2]
- Diffusion limited oxidation due to high temperatures used for thermal aging (NRC and NIST)
- Inverse temperature effects on insulation may indicate aging rates at lower temperatures is > than at higher ones (U.S. Department of Energy [DOE] and Sandia National Laboratories)

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[1] The Nuclear Regulatory Commission (NRC) has developed a Progressive Materials Degradation Approach (PDMA) and published the results in NUREG/CR-6923 [1]. The NRC is continuing this research as the Expanded Materials Degradation Assessment (EMDA) which will document materials knowledge gaps for operation to 80 years.

[2] EPRI report 1021067, *Plant Support Engineering Nuclear Power Plant Equipment Qualification Reference Manual*, [2, Section 13.2], provides a summary of Sandia research on synergistic effects.

In order to better “inform” current NRC-sponsored research efforts, EPRI is attempting to collect historical temperature and radiation profiles for containments and drywells. This information will be provided to the NRC and its research laboratories such that experimental research and results will more closely align with actual plant experience. Some assumptions related to the temperature and radiation monitoring are as follows:

- These effects are temperature and dose dependent. If the actual radiation dose is much less than the 50 megarad (0.5 Gray) assumed as the “worst case dose” in the 1970s, then, these radiation issues may be minimal.
- Actual radiation dose levels most cables in containment are believed to experience are between 1–10 megarad (0.01–0.1 Gray) through 80 years.
- Providing NRC actual temperatures and radiation data as input into their research allowing the effects of actual service conditions to be assessed rather than the effects of excessively adverse, outdated “worst case conditions” from the 1970s.

Conclusions

The collection of data thus far has been inadequate to reach any conclusions on the likelihood of cables being able to perform reliably during periods of extended operation. This Technical Update provides the results obtained from the initial data gathering efforts.

The quantity of survey participants is insufficient to provide conclusive evidence. However, the radiation and temperature monitoring data that was provided does indicate that original plant design bases radiation and temperature values may have excessive margin as compared to typical plant conditions, with exceptions typically based on stratification, reactor and containment type, and elevation.

Therefore, it is recommended that a more specific research and monitoring project be undertaken to gather conclusive evidence regarding this preliminary conclusion.

2 METHODOLOGY

The project will attempt to identify actual measured temperature and radiation dose data at installed cable locations that would support a much lower normal radiation dose value in these nuclear power plant assumptions. If this is the case then thermal aging will be the primary concern in determining life expectancy. It is noted in advance that there are certain nuclear power plants cables that require periodic replacement primarily due to thermal considerations of specific plant locations. The proposed project is intended to identify other cable populations that would not be subjected to significant adverse localized equipment environments (ALEEs) and hence would be able to have their qualified life or service life extended considerably. The project consists of the following steps:

- Publication Data Mining
- Survey Development and Evaluation

Long-Term Cable Background

Therefore, based on the above, a series of sequential considerations need to be examined:

- What causes cable aging?
- Can the causes of cable aging be adequately monitored to assure continued operation in the period of subsequent license renewal?
- Are the design values known and comparable to monitored values?
- What tools, techniques and/or methods exist to provide accurate data that can be correlated to installed cables?

Causes of Cable Aging

EPRI report 1003663 [7], *Integrated Cable System Aging Management Guidance: Low-Voltage Cable*, page 3-1, identifies that the aging of low-voltage cables is caused by exposure to the following four stressors (note that the report herein is concerned with all cable voltages):

- Heat
  - Ambient room temperature
  - Localized high temperature or radiant heat (hot spots)
  - Ohmic heating (power cables only)

- Radiation
  - Gamma during normal operations
  - Gamma plus beta during accident
- Manipulation (generally at terminations from work on associated equipment)
- Wetting (primarily a concern for crimped terminal connections or terminal blocks in wet and salt air spaces. This is a conductor/termination interface concern and not an insulation concern.

This report will focus on the specific causes above that affect cables, specifically:

- Heat (Ambient room temperature)
- Radiation (Gamma during normal operation)

The remaining two items relate primarily to terminations (manipulation) and cables not in containment (wetting) and therefore are not addressed further in this report.

Adequately Monitoring the Causes of Cable Aging to Assure Continued Operation in the Period of Subsequent License Renewal

The main methods to focusing on these specific causes are temperature monitoring and environmental profiling, as discussed in EPRI report 1003663 [7], *Integrated Cable System Aging Management Guidance: Low-Voltage Cable*, page 7-1:

> "Temperature monitoring and environmental profiling are methods used to characterize the environment(s) in which cable systems operate. Environmental monitoring is useful for the assessment of cables found to be aging rapidly and determination of the expected rate of aging in areas that would likely to have elevated temperature and radiation conditions.
>
> Although the operating environments for most cables cannot be significantly altered cost-effectively to reduce thermal or radiation degradation, a more complete understanding of environments can be useful in determining the lives of the cables. Knowledge of actual temperatures at or near the surface of cables that are aging prematurely can be used to determine the most appropriate action to be taken and when to take it. For these cables, use of actual temperatures can also be used with the Arrhenius model to more accurately predict the rate of aging and support the development of replacement schedules.
>
> Temperature and radiation monitoring data can also be used to determine more accurate lives for cables located in areas that are expected to have more severe normal environments. Assumptions made regarding the service environment of cable system components can be overly conservative or not representative of actual thermal or radiation exposure. Estimate of cable life based on conservative thermal or integrated radiation dose analyses can increase significantly if actual temperature or radiation exposure data are used."

Additional information regarding temperature and radiation environments and monitoring related to cables is provided in EPRI report 1003317 [6], *Cable System Aging Management*, page 4-6, which states:

> "Within-containment radiation levels will generally cause less damage than thermal aging, except for locations where radiation streaming occurs through the biological shield wall around process piping. Specific inspection of cables subject to streaming might be desirable.
>
> Adverse Condition Locations
>
> In most cases, high-temperature conditions will be localized near hot process piping or in the upper reaches of confined spaces containing process equipment. Very localized hot conditions also occur in electrical housings of continuously energized, solenoid-operated valves. As such, damage to cables will more likely be in areas where the cable runs adjacent to or is connected to a hot process pipe or component. In most cases, the end device connected to the cable will be the hottest portion of the cable. In some cases, however, cable trays or conduits can be located near hot process equipment such as heat exchangers or headers. When evaluating cable, the run of the tray and conduit system should be considered to determine if additional hot spots (adverse localized environments) occur at locations other than the end device."

Based on the above, temperature and radiation monitoring can and should be compared to plant design values.

Design and Normal Conditions

EPRI report 1021067 [2, Section 6.3.2] states that the definition of normal environmental conditions was the historical practice to identify the maximum design limits or ranges for environmental. The specification of maximum design values was reasonable since the equipment may be required to function at these levels, and conservatively specifying these limits provides some level of equipment design margin. Unfortunately, use of the maximum design values can significantly overestimate the level of age-related degradation occurring during normal service and underestimate the equipment's qualified life. Strong consideration should be given to more accurately defining the time history of environmental parameters. Some utilities specify temperature, radiation, and other normal parameters based on assumed plant durations at various operating modes (that is, startup, shutdown, power operation, refueling outages, and other outages).

Normal conditions can be identified through design calculations or actual in-plant measurements. The design calculations are usually performed based on bounding assumptions collectively producing the largest value of the environmental parameter. For example, plant temperature is often defined by maximum expected outside air and heat sink (for example, river or cooling pond) temperatures, the maximum internal plant heat generation by equipment and system operation, and the minimum availability of cooling and HVAC equipment based on plant technical specifications. Also, normal radiation dose and dose-rate values are typically defined based on the summation of various source points located throughout an area. Also, often, one design temperature is defined for a complete structure, such as a PWR auxiliary building. These plant calculations can overestimate the values in many areas, which may not be a concern provided the resulting equipment life exceeds the plant life.

EPRI report 1021067 [2, Table 6-7] identifies the following example of normal plant environments for temperature and radiation:

Table 2-1
EPRI Report 1021067, Table 6-7 Normal Temperature, Gamma Dose and Neutron Flux Data

Location	Normal Temperature °F (°C)	Gamma Dose (Rad/Grays)	Neutron Flux (N/cm^2)
Containment	50–140°F (10–60°C)	10^3–10^7/10^1–10^5	0–10^{14}
Other general plant areas	40–120°F (4.4–48.9°C)	10^2–10^6/10–10^4	0
Control complex	60–85°F (15.5–29.4°C)	10^2–10^3/10–10^1	0

It is noted that it may, in certain locations, under-predict the actual values. NUREG-1801, Section XI.E1[x] requires plants to perform inspections to locate these adverse localized equipment environments (ALEEs) and to implement specific activities to mitigate the environment, monitor aging, or perform additional testing of the cables to assure continued operability.

EPRI report NP-7399 [3], *Guide for Monitoring Equipment Environments During Nuclear Plant Operation* describes how utilities may be able to extend the qualified lives of some equipment by demonstrating that environments are more benign than assumed. This report provided guidelines for plants to establish monitoring of temperature and radiation during normal operation to aid in the extension of equipment qualified lives and support the license renewal process. This report is further discussed in Appendix B.

Similarly, EPRI report TR-109619 [4], *Guideline for the Management of Adverse Localized Equipment Environments* provides guidance on management of adverse localized equipment environments (ALEE). Plant engineers were concerned with environments that could be consistently and significantly more severe than the surrounding ambient or bulk conditions. Adverse localized equipment environment is defines as 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. Although EPRI report TR-109619 [4] is primarily concerned with environments which are more severe than expected (whereas this report is interested in environments which are less severe than expected), it provides additional guidance on obtaining actual plant environmental conditions.

It is recognized that many utilities already manage cable aging in severe temperature and radiation environments through the use of periodic cable replacement of shorter cable sections. Many completed field modifications facilitate this replacement through the addition of local junction boxes, the use of quick disconnects, and so on. If the components are classified EQ, this is identified in the related EQ files for the various cables and potentially for any end devices.

Publication Data Mining

Several types of documents were researched for information and data related to the actual realistic normal temperature and radiation doses for installed electric cables. Search resources included the following at a minimum:

- NRC NUREG (NRC technical reports)
- EPRI reports
- Environmental Qualification (EQ) test reports
- International Atomic Energy Agency (IAEA) reports

  (To the extent that they are publicly available)
- Publicly available nuclear power plant environmental data
- Curtis-Wright/Scientech Equipment Qualification Database (EQDB)

  (Including all prior surveys and reports)

Survey Development and Evaluation

Based on the preliminary results of the data mining research above, an industry survey was developed to be put out either through EQDB, the Nuclear Utility Group on EQ (NUGEQ) EQ Fax, any EPRI notification system, and/or the Nuclear Energy Institute (NEI) License Renewal/Subsequent License Renewal Task Force. Surveys were to be issued to multiple groups in order to get a thorough coverage of possible participants.

The objective of the survey was to identify nuclear power plants that may have actual temperature and radiation data at installed cables locations.

Primary considerations of the survey were to identify the following:

1. Locations of main interest
2. Plant personnel with most relevant experience
3. Types of data requested
4. Types of documents that may be useful

Locations of Main Interest

The main locations of interest are parts of the following areas where safety-related cables are installed:

- Boiling water reactor (BWR) drywell
- Pressurized water reactor (PWR) reactor building
- Auxiliary/reactor buildings (Note: nomenclature will be different based on plant.)

For containment, cables typically enter via penetrations about 1/3 of the way up the height, with most safety-related cables typically extending higher another 1/3 of the way. Therefore, the main containment focus would be for the middle part of containment, although both top and bottom data can also be useful. Safety related cables are typically routed to EQ end devices, therefore, if temperature or radiation monitoring data is known for end devices it would for the most part be considered applicable for the associated cables.

For Auxiliary Building, it will also be where safety-related cables are routed, and therefore EQ end device data monitoring would be applicable. Rooms which are usually EQ “mild” environment (for example, the Diesel Generator Rooms, Battery Rooms, and so on) would not apply in this research.

Plant Personnel with Most Relevant Experience

The EQ Engineer may have the most relevant temperature-related data (and possibly radiation data).

Another source for temperature data would be any Design Engineering Program Engineers responsible for DBA conditions, as they sometimes have the normal temperature ambient conditions as a starting point for their accident calculations.

For radiation data, typically the Radiation Protection Program would have such data. Alternatively, any Design Engineering Program Engineers responsible for radiation calculations may be another source of the data.

Types of Data Requested

1. The plant normal ambient temperature and radiation design conditions are needed.
2. Any temperature or radiation data for the locations of interest of above may be useful.
3. Any plant drawings that identify the location of the data monitoring equipment.
4. Any plant drawings that identify the location of safety-related cables or end devices. For example, some plants have EQ “one-line diagrams” that trace end device to cable to power source.

Types of Documents that May Be Useful

This data may already be captured formally or informally. By formally it is meant that various nuclear plants, and their associated EQ programs, have various reports or calculations justifying lower temperature and radiation normal conditions versus design conditions, based on temperature and radiation monitoring. By informally it may just be the raw data in a spreadsheet or tabulated format.

Survey Issuance

Surveys were issued for this report to the industry via the following:

1. Curtis-Wright/Scientech Equipment Qualification Database (EQDB)
2. The NEI License Renewal Working Groups/Subsequent License Renewal Task Force

3
DATA MINING RESULTS

Website Searches

The following approximately twenty websites were searched or queried, with the search terms and results provided in Appendix A. Various combinations of search terms, quotations, and so on, were used to find an optimum amount of temperature and/or radiation monitoring data publicly available. Subsequent steps would then collate the data based on information such as plant type, historical context of data (that is, plant start-up, recent, and so on), building location of monitoring, duration and frequency of monitoring, and relevance and location of monitoring to cables, if known. Table 3-1 identifies a count, the acronym or group represented, a description of the acronym or group, the group's website, and what part of the group website was searched (that is, some websites have search engines of the entire website while other websites have search engines for a particular database or portion of the website).

Table 3-1
List of Websites Searched

No.	Acronym/ Group	Description	Website(s)	Search Engine
1	NRC	Nuclear Regulatory Commission	http://www.nrc.gov/	Main page (includes ADAMs search engine)
2	NRC	Nuclear Regulatory Commission	http://www.nrc.gov/reading-rm/doc-collections/nuregs/	NUREG Search Engine
3	U.S. GPO	U.S. Government Printing Office	http://www.gpo.gov/fdsys/	Main page
4	EPRI	Electric Power Research Institute	http://www.epri.com/Pages/Default.aspx	Main page
5	EQDB	Curtis Wright Scientech Equipment Qualification Databank (licensed by EPRI)	http://eqdb.scientech.com/account/login.aspx	Main page Test Reports Surveys
6	IAEA	International Atomic Energy Agency	http://www.iaea.org/	Main page
7	ETDE Web	Energy Technology Data Exchange	http://www.etde.org/	Main page
8	NEA	Organization for Economic Cooperation and Development (OECD) Nuclear Energy Agency	http://www.oecd-nea.org/	Main page
9	BWR Owners Group	General Electric Boiling Water Reactor Owners Group	http://site.ge-energy.com/prod_serv/products/nuclear/en/bwr_owners_group/index.htm	Main page
10	PWR Owners Group	Pressurized Water Reactor Owners Group	http://www.wog.westinghousenuclear.com/	None available publicly
11	U.S. Nuclear Laboratories	Sandia National Laboratories	http://www.sandia.gov/	Main page
12	U.S. Nuclear Laboratories	Brookhaven National Laboratories	http://www.bnl.gov/world/	Main page

Table 3-1 (continued)
List of Websites Searched

No.	Acronym/ Group	Description	Website(s)	Search Engine
13	U.S. Nuclear Laboratories	DOE Scientific and Technical Information Bridge	http://www.osti.gov/bridge/basicsearch.jsp	Main page
14	INPO	Institute of Nuclear Power Operations	http://www.inpo.info/	None available publicly
15	NEI	Nuclear Energy Institute	http://www.nei.org/	Main page
16	NUGEQ	Nuclear Utility Group on Equipment Qualification	None available publicly	None available publicly
17	Other: • Scientech • Scientech • S&W Technologies • Knovel		http://scientech.cwfc.com/software/spokes/09_RPX.htm (Radiation Protection Management) http://scientech.cwfc.com/software/spokes/08_Rtime.htm (R*TIME) http://swtechnologies.com/vsds.aspx (VSDS) http://why.knovel.com/ (Member search engine)	

Appendix A provides the keyword searches per website. The keywords used remained consistent per website on initial searches, and then more or less broad keywords were used per website depending on how many entries were returned, until a minimum number of reasonably relevant datasets was identified. Some of the keywords/phrases included:

- Cable aging management
- Temperature radiation monitoring
- Nuclear normal radiation value
- Nuclear normal temperature data
- Normal temperature value
- Normal temperature data
- Nuclear environmental service condition temperature
- Nuclear environmental service condition radiation
- Environmental service condition
- Temperature monitoring report
- Ambient temperature data
- Radiation monitoring report

The intention of the data mining was to perform searches for the same key words at each of the websites with the expectation of obtaining a variety of temperature and radiation data. The results indicate that minimal temperature and/or radiation monitoring data is presented in a manner that the data can be easily identified and retrieved from any publicly accessible website. These searches are inconclusive as to whether such data is available on various websites. For example, it is assumed that some temperature and/or radiation monitoring data are available on the NRC website, however, the data that is available cannot be easily identified. As a result of the lack of information from the first few websites, searches of subsequent websites were curtailed to a few keyword searches.

Other Documents

In addition to searching websites for temperature and radiation data, a variety of other documents were reviewed. A number of relevant EPRI reports were reviewed which are summarized in Appendix B.

4
SURVEYS

In 2013, EPRI requested temperature and radiation data from plants in a variety of methods:

- Surveys: Curtis-Wright/Scientech Equipment Qualification Database (EQDB) Group Survey. This group is licensed via EPRI and its distribution includes various environmental qualification (EQ) plant program owners, industry consultants, and vendors.
- Conference Requests: At various long-term operation (LTO) and license renewal conferences, requests for information were publicly announced.
- Plant Engineering Management Requests: The License Renewal/Subsequent License Renewal Task Force that is convened by Nuclear Energy Institute (NEI). A letter was sent to everyone on the distribution list, with the expectation that any request would be filtered to the appropriate plant personnel, most notably EQ and radiation protection personnel.

From the above resources, a limited sample of U.S. nuclear power plants responded with various amounts of information. As of the date of this Technical Update, eighteen (18) units (representing 12 sites and 11 utilities) have responded with temperature data, radiation data, or both. Table 4-1 provides basic information about the thirteen nuclear power plants that responded, including on both a plant and a unit basis: the reactor type, reactor description, nuclear steam supply system (NSSS) supplier, timeframe of operation license issuance, the NRC regions represented, and the design capacity (megawatts electric [MWe]).

Table 4-1
Summary of Survey Responses

Parameter	Plant Count	Unit Count
Reactor Type	12	18
BWRs	5	6
PWRs	7	12
Reactor Description		
BWR/4/Containment: Type 4g (Mark I)	3	3
BWR/4/Containment: Type 5g (Mark II)	1	2
BWR/6/Containment: Type 5h (Mark III)	1	1
PWR/Containment: Type 2ce	1	2
PWR/Containment: Type 2e	1	1
PWR/Containment: Type 3b	5	9
NSSS Supplier		
B&W	2	4
CE	1	3
GE	5	6
Westinghouse	4	5
Operation License Issuance		
1970–1974	–	5
1975–1979	–	1
1980–1984	–	7
1985+	–	5
NRC Regions Represented		
Region I	2	–
Region II	3	–
Region III	3	–
Region IV	4	–

Table 4-1 (continued)
Summary of Survey Responses

Parameter	Plant Count	Unit Count
Design Capacity MWe		
500–800	–	2
801–1,000	–	5
1,001–1,200	–	7
1,201+	–	4

Overall, from all the parameters above, a diverse set of survey responses has been achieved for use in this sample; however, the number of responses in each area is still very low.

The results below are organized per temperature and radiation sub-sections. Only generalities will be discussed, as the sample size is too small to decisively reach definitive conclusions. In other words, no attempt will be made to reach specific results.

Temperature – Plant Survey Information

Almost all of the survey responses included some type of temperature monitoring data. Some general observations of the information follow:

- Since almost all plant responders provided temperature monitoring data, the overall plant characteristics identified (that is, BWR or PWR, size of unit, NRC Region, and so on) confirms the diversity of the temperature monitoring nuclear power plant responders.
- Most information has been provided from the plants EQ programs personnel. These engineers typically either have control over the temperature monitoring data or are aware of its existence in other plant programs.
- Almost all responders provided temperature monitoring data to some extent. This data ranged from a single point of data to many years of data, for a particular temperature monitoring device.
- Approximately 1/3 of the temperature monitoring responders provided exact design temperature values for comparison to the temperature monitoring results. This data is obviously available at all nuclear plants; however, in many cases it was not provided. As a general rule, though, a design Containment or Drywell normal ambient temperature is typically around 120°F (48.89°C), and a design Auxiliary Building normal ambient temperature is typically around 104°F (40°C).
- Only two responders provided temperature monitor zone maps. In one case, only the locations of the temperature monitors were recorded and not actual ranges of temperatures. In the other case, minimum and maximum temperatures of zones were shown. Therefore, this is an indicator that temperature zone maps are of minimal use at U.S. nuclear power plants.

- Monitoring periods (for other than those cases where only one data point was identified), lasted anywhere from one to well beyond ten years. Therefore, this is an indicator that of the U.S. nuclear power plants with temperature monitoring, most monitoring is continuous or typically at least one fuel cycle.
- The most commonly recorded location for temperature monitoring was containment/drywell. In a few cases plant wide or auxiliary building temperature monitoring also occurred.
- Monitoring frequency (for other than those cases where only one data point was identified), lasted anywhere from hourly to once every six months. Therefore, this is an indicator that of the U.S. nuclear power plants with temperature monitoring, most monitoring is continuous or typically at least one fuel cycle.
- In all cases of those nuclear power plants that provided temperature monitoring, temperatures were confirmed lower than design values with a few specific exceptions. In addition, there were a few cases that were simply indeterminate since the design data was not provided and the results indicated a large variance in containment temperature values, for example:
  - The PWR containment temperature monitoring results typically identify temperatures of 120°F (48.89°C) and less, with some exceptions. This is due to the large size of the PWR containments.
  - The BWR containment/drywell temperature monitoring results typically identify large fluctuations in temperatures from below 120°F (48.89°C) to much higher than 120°F (48.89°C). This is due to the smaller size of the BWR drywell and the increasing enclosed locations near the top of the drywell.
  - The sample size is insufficient to identify trends in PWR reactor types and BWR reactor types or MWe.

Appendix C provides details of the temperature monitoring data provided.

Radiation – Plant Survey Information

- A smaller subset of nuclear power plants provided radiation monitoring data. However, the overall plant characteristics presented previously continued confirming the diversity of the radiation monitoring nuclear power plant responders. In other words, although the total number of nuclear power plants responding with radiation monitoring was less than the total number of nuclear power plants, the overall diversity remained essentially unchanged.
- Most information has been provided from the plants EQ programs personnel. Unlike temperature monitoring data, for the most part these EQ engineers typically do not have control over the radiation monitoring data. Rather, in most cases, the EQ engineers were able to retrieve the data from Radiation Protection or similar plant programs.
- For the most part, the data provided typically was a final area or zone value rather than a table of data per frequency and monitoring device.

- In most cases, design radiation values were not provided in surveys for comparison to the radiation monitoring results. This data is obviously available at all nuclear plants; however, in many cases it was not provided. In other cases, the data provided was actually continuing updates or revisions to original design radiation calculation results rather than radiation monitoring data.
- Only one responder provided radiation monitor zone maps that did include an actual dose rate. Therefore, this is an indicator that radiation zone maps are of minimal use at U.S. nuclear power plants.
- Monitoring periods were typically not provided and therefore based on some non-identified frequency of data monitoring.
- The most commonly recorded location for radiation monitoring was containment/drywell. In a few cases plant wide or auxiliary building radiation monitoring also occurred.
- Monitoring frequency was typically not identified.
- In one case sufficient data was available to confirm lower than design radiation values on an order of magnitude. Mostly, there was insufficient correlation between design and monitored radiation values at most plants that were provided, to reach a specific conclusion.
- The sample size is insufficient to identify trends in PWR reactor types and BWR reactor types or MWe.
- The quantity of radiation monitoring data provided was significantly less than the amount of temperature monitoring data provided. Therefore, it appears further research would be needed to obtain radiation directly from a primary source.

Appendix D provides details of the radiation monitoring data provided.

5 CONCLUSIONS

This report provides the preliminary results of an effort to collect data on the amount of radiation and thermal aging that electrical cables are exposed to during normal plant operation.

In support of the current industry plans of operating much of the existing fleet of nuclear power plants beyond 60 years of service, the Electric Power Research Institute (EPRI) is conducting research to assess the condition of the existing electrical cabling infrastructure and to provide input to the NRC and national laboratories related to the actual service conditions being experiences by the majority of cables in these plants. In order to operate through a subsequent licensing period (60–80 years of operation) plants must demonstrate “reasonable assurance” that the existing cabling has adequate margins remaining assuring safe operation.

Some of the major conclusions are as follows:

- Data mining did not yield any meaningful results.
- Surveys yielded some results; however, the sample size was insufficient to draw industry-wide conclusions.
- Plants are managing cable aging in extreme temperature and/or radiation environments through the use of the periodic cable replacements.
- Plants, primarily through the Environmental Qualification (EQ), License Renewal, and/or Cable Aging Management Programs are identifying ALEEs and managing their effects on cable aging.

This technical update concludes that there is sufficient evidence to support the premise that temperature and radiation values during normal operation are generally lower than the design values. Specialized temperature and radiation monitoring can confirm these preliminary results.

6
REFERENCES

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4. *Guideline for the Management of Adverse Localized Equipment Environments*. EPRI, Palo Alto, CA: 1999. TR-109619.
5. NUREG-1801, “Generic Aging Lessons Learned (GALL) Report, Rev. 2,” December 2010.
6. *Cable System Aging Management*. EPRI, Palo Alto, CA: 2002. 1003317.
7. *Integrated Cable System Aging Management Guidance: Low-Voltage Cable*. EPRI, Palo Alto, CA and U.S. Department of Energy, Washington, D.C.: 2003. 1003663.
8. *Plant Support Engineering: Aging Management Program Development Guidance for AC and DC Low-Voltage Power Cable Systems for Nuclear Power Plants*. EPRI, Palo Alto, CA: 2010. 1020804.
9. NRC Information Notice No. 93-33 “Potential Deficiency of Certain Class 1E Instrumentation and Control Cables,” April 28, 1993.
10. IEEE Standard 323-1974, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations,” 1974.

A
WEBSITE DATA MINING RESULTS

This appendix provides the data mining search results. Section 3 of this report lists the websites searched for actual temperature and radiation data as related to electrical cables.

Search Results

Table A-1
Nuclear Regulatory Commision (NRC) Website Keyword Search
Website: http://www.nrc.gov/
(Main webpage search engine for entire site including ADAMS search engine)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	204	A review of a number of the titles and descriptions of the approximately 75 items appears that most relate to cable aging or license renewal, and that in some case were NRC Requests for Additional Information related to LR activities. Although some information may be available from a small number of entries, it appears more prudent to obtain directly from the utilities/plants.
Nuclear "Normal radiation value"	2	First item was a 10CFRPart 21; second item was a TVA Q&A with NRC on EQ program (downloaded second item).
Nuclear "Normal radiation data"	1	Only item was a brochure concerning what to do in a nuclear emergency, therefore N/A.
"normal temperature value"	2	Both entries are for Westinghouse new AP1000 reactor design related information, therefore N/A.
"normal temperature data"	3	One entry for Vogtle outside environmental conditions; two entries related to ANO dry cask storage, therefore N/A.
Nuclear "environmental service condition" temperature	1	Only entry for NUREG-1409 for Backfitting Guidelines, therefore N/A.
Nuclear "environmental service condition" radiation	1	Only entry for NUREG-1409 for Backfitting Guidelines, therefore N/A.
"environmental service condition"	9	All nine entries were researched; one entry downloaded from May 1980 was the Indian Point Unit 2 EQ environments; one entry from Duane Arnold in 1983 with EQ environments; one entry for Kewaunee 1981 SCEW submittal; documents for Calvert Cliffs and Limerick identifying ESCs in other reports.

Table A-1 (continued)
Nuclear Regulatory Commision (NRC) Website Keyword Search
Website: http://www.nrc.gov/
(Main webpage search engine for entire site including ADAMS search engine)

Keywords Used	No. of Results	Results
“ambient temperature data”	79	Reviewed first several dozen entries; referred to outside temperatures or even backwash fluid temperatures and many non-nuclear plants.
Nuclear “normal temperature” data	1,600	Many of these entries have individual or specific temperatures.
“temperature monitoring report”	3	Two of the three entries were for the same report cited in NRC documentation to a utility with no data provided. The third entry refers to river water temperature monitoring. Therefore, none of these entries provide relevant data in the source documents.
“radiation monitoring report”	78	Almost all entries deal with a “Jefferson Proving Ground” licensee; therefore N/A. A small number cite periodic plant process radiation monitoring reports; however, no data provided.

Table A-2
Nuclear Regulatory Commision (NRC) NUREG Reports Website Keyword Search
Website: http://www.nrc.gov/reading-rm/doc-collections/nuregs/
(NUREG search engine)

Keywords Used	No. of Results	Results
“Cable aging management” temperature radiation monitoring	14	All 14 documents appear to be plant specific SERs for license renewal.

Table A-3
U.S. Government Printing Office (GPO) Website Keyword Search
Website: http://www.gpo.gov/fdsys//
(Main Page)

Keywords Used	No. of Results	Results
Nuclear cable aging management temperature radiation monitoring	524	A review of the “government authors” column does not indicate any applicable authors for this task.

Table A-4
Electric Power Research Institute (EPRI) Website Keyword Search
Website: http://www.epri.com/Pages/Default.aspx
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	4,372	Number of entries too large for reasonable review.
"cable aging management" nuclear	747	Sorted by Relevance, which appears best approach rather than alphabetical or date. However, the entries appear to deal with cable aging management (based on the query, titles and descriptions) and do not explicitly indicate any type of temperature or radiation monitoring data.
Nuclear "Normal radiation value"	55	Same search without 'nuclear' returned the same result. Many of these 55 entries have titles for "renewable energy" and therefore appear N/A; highlighted these entries.
Nuclear "Normal radiation data"	55	Same search without 'nuclear' returned the same result. Many of these 55 entries have titles for "renewable energy" and therefore appear N/A.
Nuclear "normal temperature value"	3,144	Number of entries too large for reasonable review.
"normal temperature data"	3,201	Number of entries too large for reasonable review.
Nuclear "environmental service condition" temperature	3,479	Number of entries too large for reasonable review.
Nuclear "environmental service condition" radiation	2,125	Number of entries too large for reasonable review.
Nuclear "environmental service condition" and "ambient temperature" data	1,529	Sorted by Relevance, which appears best approach rather than alphabetical or date. Number of entries too large for reasonable review.
nuclear "environmental service condition" and "normal temperature" data	2,798	Note that attempting to have two sets of phrases in " " results in the response "Maware deformed".
nuclear "environmental service condition" and "normal radiation" data	55	Assumed the same 55 entries as per other searches; no action taken.

Table A-4 (continued)
Electric Power Research Institute (EPRI) Website Keyword Search
Website: *http://www.epri.com/Pages/Default.aspx*
(Main Page)

Keywords Used	No. of Results	Results
Nuclear "temperature monitoring report"	2,890	Reviewed approximately the titles and descriptions of the first 50 entries; none appear to have temperature data explicitly identified.
Nuclear "radiation monitoring report"	1,867	Reviewed approximately the titles and descriptions of the first 50 entries; none appear to have temperature data explicitly identified.

Table A-5
Equipment Qualification Data Bank (EQDB) Website Keyword Search
Website: http://eqdb.scientech.com/account/login.aspx

Keywords Used	Search Location	No. of Results	Results
Cable aging management temperature radiation monitoring	Test Reports (Used "full text" as search criteria.)	12	
Cable aging management temperature radiation monitoring	Main Page	27 pages	Too many entries to be of value.
"environmental service condition"	Surveys	19	None of the 19 entry titles appear to have strong links to temperature and radiation data. Multiple entries related, for example, to harsh – mild thresholds or removal of EQ equipment.

Table A-6
International Atomic Energy Agency (IAEA) Website Keyword Search
Website: http://www.iaea.org/
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	4	A review of all four documents identifies no applicable monitoring information.

Table A-7
Energy Technology Data Exchange (ETDE) Website Keyword Search
Website: http://www.etde.org/
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	1	Entry reviewed as it is the same as one of the four IAEA entries

Table A-8
Nuclear Energy Agency (NEA) Website Keyword Search
Website: http://www.oecd-nea.org/
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	3 Publications 21 Documents 17 Web pages	Query appears to have returned results that are not applicable; over-generalized results returned

Table A-9
BWR Owners Group Website Keyword Search
Website: http://site.ge-energy.com/prod_serv/products/nuclear/en/bwr_owners_group/index.htm
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	3,381	Too many entries to be of value

Table A-10
PWR Owners Group Website Keyword Search
Website:http://www.wog.westinghousenuclear.com/
(None publicly available)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	N/A	N/A

Table A-11
Sandia National Laboratories Website Keyword Search
***Website:* http://www.sandia.gov/**
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	0	

Table A-12
Brookhaven National Laboratories (BNL) Website Keyword Search
Website: http://www.bnl.gov/world/
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	0	

Table A-13
Department of Energy (DOE) Scientific and Technical Information Bridge Website Keyword Search
Website: http://www.osti.gov/bridge/basicsearch.jsp
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	2	1. A 1995 review of aging information by Pacific Northwest Lab 2. A 2011 DOE – EPRI LTO Research Plan No specific information

Table A-14
Nuclear Energy Institute (NEI) Website Keyword Search
Website: http://www.nei.org/
(Main Page)

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	At least 30 pages; exact count not provided	Too many entries to be of value

Table A-15
Scientech Website Keyword Search
Website: http://scientech.cwfc.com/software/spokes/09_RPX.htm

(Radiation Protection Management)http://scientech.cwfc.com/software/spokes/08_Rtime.htm
*(R*TIME)*

http://swtechnologies.com/vsds.aspx
(VSDS)

http://why.knovel.com/
(Member search engine)

RPX, Rtime, and VSDS are computer software; therefore, it would only be end user data that would be useful.

Have downloaded computer brochures and websites. No actual data provided but indications that these are plant tools. Would be enveloped by any data collection from the plants.

Keywords Used	No. of Results	Results
"Cable aging management" temperature radiation monitoring	0 (Knovel search)	

B
OTHER DOCUMENTS

EPRI Reports Providing Temperature and/or Radiation Monitoring Review

Below is some further information related to temperature and radiation monitoring obtained from doing reviews of various EQ, LR, and AMG-related EPRI reports:

EPRI report NP-7399, *Guide for Monitoring Equipment Environments During Nuclear Plant Operation*, June 1991

This report is arranged in two parts:

- Part I: Guide
- Part II: Workshop Papers

Part I provides generic information only. Part II is further divided into three sections:

- Experience with Elevated Temperatures
- Plant Environmental Monitoring Programs
- Monitoring Temperature and Radiation Levels

These sections contain various papers, provided by various nuclear plants, which contain temperature and/or radiation monitoring data. Summaries of relevant papers are provided below (Note: report was issued in 1991; therefore, years of recording typically are shown as through 1990; however, continued monitoring may have occurred):

Section No.	1
Paper No.	2
Title	Reactor Building Temperature Reduction Project Data Acquisition, Evaluations and Proposed Actions Arkansas Nuclear One, Unit 1
Plant	Arkansas Nuclear One
Year(s) Recorded	1987 - 1989
Location	Reactor Building
Environments Monitored	Temperature
Reference Section Review	No additional significant references necessary to review

Section No.	1
Paper No.	3
Title	Perry Nuclear Power Plant Area/Equipment Temperature Monitoring Program
Plant	Perry
Year(s) Recorded	During first fuel cycle and beyond
Location	Drywell
Environments Monitored	Temperature
Reference Section Review	No reference section

Section No.	1
Paper No.	4
Title	Evolution of Elevated Containment Temperatures at Calvert Cliffs Nuclear Power Plant
Plant	Calvert Cliffs
Year(s) Recorded	1988 –1989
Location	Containment
Environments Monitored	Temperature
Reference Section Review	No reference section

Section No.	2
Paper No.	1
Title	Virginia Power’s Containment Environmental Monitoring Program
Plant	Surry Unit 1
Year(s) Recorded	1988 – 1989
Location	Containment
Environments Monitored	Temperature
Reference Section Review	No reference section

Section No.	2
Paper No.	2
Title	Monitoring Actual Temperatures in Susquehanna SES Reactor Buildings
Plant	Susquehanna
Year(s) Recorded	1986 – 1990
Location	Reactor Building
Environments Monitored	Temperature
Reference Section Review	No additional significant references necessary to review

Section No.	2
Paper No.	3
Title	Monitoring Equipment Environment During Nuclear Plant Operation at Salem and Hope Creek Generating Stations
Plant	Salem and Hope Creek
Year(s) Recorded	1988 – 1990
Location	Pressurizer Enclosure (Salem); Drywell (Hope Creek)
Environments Monitored	Temperature
Reference Section Review	No additional significant references necessary to review

Section No.	2
Paper No.	4
Title	Qualified Life Enhanced by Environmental Monitoring at Nine Mile Point Units 1 and 2
Plant	Nine Mile Point Units 1 and 2
Year(s) Recorded	1982 – 1990
Location	Various
Environments Monitored	Temperature (Both units) and Radiation (Unit 2)
Reference Section Review	No reference section

Section No.	2
Paper No.	7
Title	Equipment Environmental Monitoring: Perspective from the BWR License Renewal Lead Plant
Plant	Monticello
Year(s) Recorded	Approximately 1990
Location	Temperature
Environments Monitored	Control Room, Cable Spreading Room, Switchgear Room; Reactor and Turbine Buildings
Reference Section Review	Refers to several EPRI and plant specific reports that may have applicable data, such as: NSPE-12-8669, December 1988, “Monticello Nuclear Plant Environmental Monitoring Program Test Results” EPRI NP-6541-M, September 1989, “BWR Pilot Plant Life Extension Study at the Monticello Plant: Phase 2”

Section No.	2
Paper No.	8
Title	Monitoring Equipment Temperature Environments for License Renewal
Plant	Vermont Yankee
Year(s) Recorded	Six months of non-identified year; assume around 1990
Location	Outside Containment
Environments Monitored	Temperature
Reference Section Review	No additional significant references necessary to review

Section No.	3
Paper No.	1
Title	Monitoring Containment Environments for an Aging Research Program
Plant	Nine (9) Non-identified plants
Year(s) Recorded	Various
Location	Site of specimens; temperature recording was only of locations near cable specimens; EPRI has issued a series of reports on this topic
Environments Monitored	Temperature
Reference Section Review	No additional significant references necessary to review; one reference was the first EPRI report on this topical area

EPRI report TR-109619, *Guideline for the Management of Adverse Localized Equipment Environments*, June 1999

See Tables D-11 – D-14 as follows:

- Table D-11: Identifies for 21 plants if temperature monitoring was performed in areas suspected of exceeding design conditions
- Table D-12: Identifies for 21 plants any high temperature areas revealed by temperature monitoring
- Table D-13: Identifies for 21 plants the specific areas exceeding bulk area or general design temperatures
- Table D-14: Identifies for 21 plants any other high temperature areas

Appendix E also provides two case studies where plants used monitoring to confirm or revise design temperatures as appropriate:

- Case Study 1: Evaluation of Cable Temperatures in Random-Filled (Unspaced) Cable Trays
- Case Study 2: Evaluation of Turbine Building Cable Temperatures

EPRI report TR-106687, *Cable Aging Management Program for D.C. Cook Nuclear Plant Units 1 and 2*, December 1996

Section IV.C provides containment temperature monitoring data from a period of 7 years (January 1987–January 1994)

EPRI report 1021067, *Plant Support Engineering: Nuclear Power Plant Equipment Qualification Reference Manual, Revision 1*, September 2010 (Page 12-10 excerpts)

"Localized high temperatures can significantly accelerate cable thermal aging...Temperature monitoring equipment was installed on conduits in close proximity above the RCS hot legs to record temperatures during the operating cycle to establish the qualified life for the new cables. The maximum temperature recorded was 149°F (65°C)."

EPRI Reports Providing Related Cable Temperature and/or Radiation Monitoring Processes Review

EPRI report NP-7399, *Guide for Monitoring Equipment Environments During Nuclear Plant Operation*, June 1991

Section No.	2
Paper No.	6
Title	Environmental Conditions Analysis Program
Description	Report identifies a software program (available at that time of 1990) that had the capability of determining the steady state temperatures of environmental zones (rooms), along with the basic steady state heat transfer equation. The program does not appear available currently; however, this paper is identified such as that it identifies a means of calculating anticipated temperatures. Since any re-development of such software code would be cost prohibitive, and since the software would only predict temperatures, it is recommended that this course of action not be pursued, as opposed to actual temperature and radiation monitoring.

Section No.	3
Paper No.	4
Title	Cable Tray Ampacity and Cable Operating Environments
Description	Areas of concentrated heat generation in a cable mass can easily occur when old, unenergized cables are abandoned in place and new cables are placed over the top of the old cables. Curves are presented in the paper which deals with the problem of calculating the cable temperatures for these situations.

EPRI report 1003317, *Cable System Aging Management*, April 2002

EPRI report TR-109619, *Guideline for the Management of Adverse Localized Equipment Environments*, June 1999

Both of the two prior reports contain various methods to investigate and identify temperature hotspots, including in cable locations. To a smaller extent, the following EPRI report also provides walkdown and investigative tools:

EPRI report 1007933, *Aging Assessment Field Guide*, December 2003.

C
SURVEY RESULTS – TEMPERATURE

The responses of the survey for temperature data is summarized in the following tables.

Plant Designator: Plant 1, Unit A

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: One year	Monitoring Frequency: Once a week
Monitoring Location(s):	Containment
Data Provided:	EPA temps: 108.34°F (42.41°C) & 94.78°F (34.88°C) (depending on sub-component) vs. 120°F (48.89°C) design PORV SOVs: 98.13°F (36.74°C) vs. 120°F (48.89°C) design Namcos (various locations): 108°F (42.22°C) – 115°F (46.11°C) vs. 120°F (48.89°C) design (design temp. remained QL basis) Rosemount: 82.6°F (28.11°C) – 104.70°F (40.39°C) vs. 120°F (48.89°C) design Tobar transmitters: 88.5°F (31.39°C) vs. 120°F (48.89°C) design Incore thermocouples: 110°F (43.33°C) vs. 120°F (48.89°C) design
Evaluation:	Two documents of old data logger locations and descriptions are provided. The plant indicated they were removed long ago. Temperature data not provided – rather, just a single temperature from data loggers per EQ File, and whether that temperature or another temperature was used in an EQ file, along with a comment. FSAR excerpt provides design values (typically 104°F (40°C) outside containment/ 120°F (48.89°C) inside containment). A few cases provided are not shown, as they included temperature rise with end result above 200°F (93.33°C); indeterminate how much was temperature rise vs. ambient temperature.
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 2, Unit B

Reactor Type: BWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 500 – 800		
Monitoring Duration: 18 years	Monitoring Frequency: Hourly	
Monitoring Location(s):	Containment	
Data Provided:	None provided	
Evaluation:	Plant stated that they do have location maps available and temperature monitoring data; however, neither has been provided.	
Do Results confirm lower temperature monitoring than design?	N/A	

Plant Designator: Plant 3, Unit C

Reactor Type: PWR	Operating Plant License Time Frame: 1975 – 1979
Design Capacity Range (MWe): 801 – 1,000	
Monitoring Duration: 1 – 2 years	Monitoring Frequency: Hourly/Daily
Monitoring Location(s):	Containment Aux. Building
Data Provided:	Various Plant provided normal operational values. For containment, the temperature is 46°F (7.78°C) – 179°F (26.11°C). For many other rooms, the temperature is below 104°F (40°C) (a typical Auxiliary Building number).
Evaluation:	Provided Reports: • Report A for Aux. Building Arrhenius Weighted Av. Temperatures • Report B for Containment Arrhenius Weighted Av. Temperatures • Report C for all EQ Environmental Conditions The two temperature reports show temperatures at various locations at AE of 0.5, 1.0, 1.5, and so on. Therefore, an exact conclusion on these reports may be indeterminate.
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 4, Unit D

Reactor Type: BWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: Various	Monitoring Frequency: 1 to 10 years	
Monitoring Location(s):	Containment	
Data Provided:	Various. Containment: Ranges from 95°F (35°C) – 240°F (115.56°C) were shown. Higher temperatures appear to be higher elevations.	
Evaluation:	No conclusion can be drawn from plant data as provided. However, plant appears to have access to temperature data which could be expanded upon.	
Do Results confirm lower temperature monitoring than design?		Indeterminate

Plant Designator: Plant 5, Unit E

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 801 – 1,000		
Monitoring Duration: 10 years	Monitoring Frequency: Hourly	
Monitoring Location(s):	Reactor Building Various	
Data Provided:	Various; for example, Reactor Building Dome values were identified between mid 90°F (32.22°C) – < 110°F (43.33°C). Actual values used previously for qualification were > 122°F (50°C).	
Evaluation:	Ten year average temperatures were taken at various points and compared to temperatures used for various equipment qualification values. In all cases, the temperature monitoring data confirmed lower actual temperatures than design values that were used in qualification.	
Do Results confirm lower temperature monitoring than design?		Yes

Plant Designator: Plant 5, Unit F

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 801 – 1,000		
Monitoring Duration: 10 years	Monitoring Frequency: Hourly	
Monitoring Location(s):	Reactor Building Various	
Data Provided:	Various; for example, Reactor Building Dome values were identified between mid 90°F (32.22°C) – < 110°F (43.33°C). Actual values used previously for qualification were > 122°F (50°C).	
Evaluation:	Ten year average temperatures were taken at various points and compared to temperatures used for various equipment qualification values. In all cases, the temperature monitoring data confirmed lower actual temperatures than design values that were used in qualification.	
Do Results confirm lower temperature monitoring than design?		Yes

Plant Designator: Plant 5, Unit G

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 801 – 1,000		
Monitoring Duration: 10 years	Monitoring Frequency: Hourly	
Monitoring Location(s):	Reactor Building Various	
Data Provided:	Various; for example, Reactor Building Dome values were identified between mid 90°F (32.22°C) – < 110°F (43.33°C). Actual values used previously for qualification were > 122°F (50°C).	
Evaluation:	Ten year average temperatures were taken at various points and compared to temperatures used for various equipment qualification values. In all cases, the temperature monitoring data confirmed lower actual temperatures than design values that were used in qualification.	
Do Results confirm lower temperature monitoring than design?		Yes

Plant Designator: Plant 6, Unit H

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Various	Monitoring Frequency: Hourly	
Monitoring Location(s):	Containment	
Data Provided:	Various Containment: Ranges from 65°F (18.33°C) – 110°F (43.33°C) were shown	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature. It is assumed that since the drawings are generic; that the data is considered representative of all three units; therefore data is shown for all three units.	
Do Results confirm lower temperature monitoring than design?		Yes

Plant Designator: Plant 6, Unit I

Reactor Type: PWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Various	Monitoring Frequency: Hourly	
Monitoring Location(s):	Containment	
Data Provided:	Various Containment: Ranges from 65°F (18.33°C) – 110°F (43.33°C) were shown	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature. It is assumed that since the drawings are generic; that the data is considered representative of all three units; therefore data is shown for all three units.	
Do Results confirm lower temperature monitoring than design?		Yes

Plant Designator: Plant 6, Unit J

Reactor Type: PWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Various	Monitoring Frequency: Hourly	
Monitoring Location(s):	Containment	
Data Provided:	Various Containment: Ranges from 65°F (18.33°C) – 110°F (43.33°C) were shown	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature It is assumed that since the drawings are generic; that the data is considered representative of all three units; therefore data is shown for all three units	
Do Results confirm lower temperature monitoring than design?	Yes	

Plant Designator: Plant 7, Unit K

Reactor Type: BWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: 24 years	Monitoring Frequency: Approximately every 6 months	
Monitoring Location(s):	Containment All Non-Containment	
Data Provided:	Various In almost all cases, temperatures < than 120°F (48.89°C) or even 100°F (37.78°C)	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature and 104°F (40°C) is design Aux. Building temperature	
Do Results confirm lower temperature monitoring than design?	Yes	

Plant Designator: Plant 8, Unit L

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: 10 years	Monitoring Frequency: Daily
Monitoring Location(s):	Containment
Data Provided:	Various Containment: 75°F (23.88°C) – 156°F (68.88°C) temperatures although most < 120°F (48.89°C) Design report identifies main temperature of 110°F (43.33°C) in upper compartment regions, with various lower compartment regions much higher
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature for some but not all cases; it is dependent on location
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 8, Unit M

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: 10 years	Monitoring Frequency: Daily
Monitoring Location(s):	Containment
Data Provided:	Various Containment: 75°F (23.88°C) – 156°F (68.88°C) temperatures although most < 120°F (48.89°C) Design report identifies main temperature of 110°F (43.33°C) in upper compartment regions, with various lower compartment regions much higher
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature for some but not all cases; it is dependent on location
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 9, Unit N

Reactor Type: BWR	Operating Plant License Time Frame: 1980 – 1984
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: 8.5 years	Monitoring Frequency: Not identified
Monitoring Location(s):	Drywell
Data Provided:	Containment: 135.7°F (57.61°C) Drywell: < 145°F (62.78°C)
Evaluation:	Results confirm lower monitored temperature than design containment (150°F (65.56°C)) with a maximum sustained operating temperature no higher than 145°F (62.78°C)
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 9, Unit O

Reactor Type: BWR	Operating Plant License Time Frame: 1980 – 1984
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: 8.5 years	Monitoring Frequency: Not identified
Monitoring Location(s):	Drywell
Data Provided:	Containment: 139.1°F (59.5°C) Drywell: < 145°F (62.78°C)
Evaluation:	Results confirm lower monitored temperature than design containment (150°F (65.56°C)) with a maximum sustained operating temperature no higher than 145°F (62.78°C)
Do Results confirm lower temperature monitoring than design?	Yes

Plant Designator: Plant 10, Unit P

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 801 – 1,000		
Monitoring Duration: 17 years	Monitoring Frequency: Daily	
Monitoring Location(s):	Containment	
Data Provided:	Various Containment: 90°F (32.22°C) – 120°F (48.89°C)+ temperatures	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature	
Do Results confirm lower temperature monitoring than design?	Yes	

Plant Designator: Plant 11, Unit Q

Reactor Type: BWR	Operating Plant License Time Frame: 1970 –1974	
Design Capacity Range (MWe): 500 – 800		
Monitoring Duration: Not identified	Monitoring Frequency: 1 point provided	
Monitoring Location(s):	Containment Drywell	
Data Provided:	Containment: 79°F (26.11°C) – 90°F (32.22°C) Drywell: 114°F (45.56°C) – 167°F (75°C)	
Evaluation:	For temperature, just 24 containment/drywell locations with one data point identified	
Do Results confirm lower temperature monitoring than design?	Indeterminate	

Plant Designator: Plant 12, Unit R

Reactor Type: PWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: 11 months	Monitoring Frequency: 3 times a day	
Monitoring Location(s):	Containment	
Data Provided:	Various Containment: 65°F (18.33°C) – 120°F (48.89°C) temperatures	
Evaluation:	Results confirm lower temperature if 120°F (48.89°C) is the design Containment temperature. Report A: 6 page report provides instrument locations. Report B is a calculation that provides inside containment data for temperature monitoring for 1992. Data loggers in 12 locations were used and calibrated every six months.	
Do Results confirm lower temperature monitoring than design?	Yes	

D
SURVEY RESULTS – RADIATION

The responses of the survey for radiation data is summarized in the following tables.

Plant Designator: Plant 1, Unit A

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: 3 months	Monitoring Frequency: Daily	
Monitoring Location(s):	Containment	
Data Provided:	Containment High Range Monitors is approximately 1 rad/hour (0.01 Gray/hour) Raw data shows gas and particulate values only	
Evaluation:	The USAR is provided with one page of normal radiation dose and dose rates values per various EQ zones. Oper. Dose rates listed in USAR for containment range from way less than 1 rad/hour (0.01 Gray/hour) (on Operating floor) to way more than one hour. Therefore, no way to correlate data provided.	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 2, Unit B

Reactor Type: BWR	Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 500 – 800		
Monitoring Duration: N/A	Monitoring Frequency: N/A	
Monitoring Location(s):	N/A	
Data Provided:	None	
Evaluation:	Plant has stated that they have a new “calculated” radiation data due to their fuel change from GE14 to GNF2. However, they confirm that they have no actual normal radiation readings.	
Do results confirm lower radiation monitoring than design?		N/A

Plant Designator: Plant 3, Unit C

Reactor Type: PWR	Operating Plant License Time Frame: 1975 – 1979
Design Capacity Range (MWe): 801 – 1,000	
Monitoring Duration: Not identified	Monitoring Frequency: Not identified
Monitoring Location(s):	All
Data Provided:	Various. For Containment, there is only 1 room identified. The 60 year normal dose is 6.81E+06 rad (6.81E+04 Gray).
Evaluation:	Report A page 9 states: "The calculated 40-year normal operation dose is based on plant radiation surveys that are scaled upwards to conservatively account for crud buildup and reactor coolant activity at the technical specification limit of 1 μCi/gram dose equivalent Iodine-131 and then integrated over a forty (40) year plant life." Table 1 of Report A provides the normal radiation dose values for 40 and 60 years (using a 1.5 multiplier) per room number.
Do results confirm lower radiation monitoring than design?	Indeterminate

Plant Designator: Plant 4, Unit D

Reactor Type: BWR	Operating Plant License Time Frame: 1985+
Design Capacity Range (MWe): 1,001 – 1,200	
Monitoring Duration: Various	Monitoring Frequency: Flexible
Monitoring Location(s):	Containment
Data Provided:	Various
Evaluation:	Westinghouse issued Report A for radiation and thermal monitors. Report and was issued in 2009. They use Westinghouse LTMs and CITMs. The quirk of the report is that it identifies the radiation monitored during the installed period. Each monitor was installed for at least one fuel cycle, some up to or around 15 years. However, not provided was any plant report correlating this 2 – 15 year doses to plant 40/60 year doses/design dose. However, the survey response indicated that the data shows that the original estimate of 50 megarads for normal dose in containment was off by more that a magnitude (nearly 2 magnitudes!).
Do results confirm lower radiation monitoring than design?	Yes

Plant Designator: Plant 5, Unit E

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974
Design Capacity Range (MWe): 801 – 1,000	
Monitoring Duration: Not identified	Monitoring Frequency: N/A
Monitoring Location(s):	Not identified
Data Provided:	None
Evaluation:	N/A
Do results confirm lower radiation monitoring than design?	N/A

Plant Designator: Plant 5, Unit F

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974
Design Capacity Range (MWe): 801 – 1,000	
Monitoring Duration: Not identified	Monitoring Frequency: N/A
Monitoring Location(s):	Not identified
Data Provided:	None
Evaluation:	N/A
Do results confirm lower radiation monitoring than design?	N/A

Plant Designator: Plant 5, Unit G

Reactor Type: PWR	Operating Plant License Time Frame: 1970 – 1974
Design Capacity Range (MWe): 801 – 1,000	
Monitoring Duration: Not identified	Monitoring Frequency: N/A
Monitoring Location(s):	Not identified
Data Provided:	None
Evaluation:	N/A
Do results confirm lower radiation monitoring than design?	N/A

Plant Designator: Plant 6, Unit H

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	Containment	
Data Provided:	Map shows 4 data points: • RCS Piping: 45,000 mrad/hour (0.45 Gray/hour) • Rx Vessel Vicinity: 10,000 mrad/hour (0.10 Gray/hour) • SG Compartments: 5,000 mrad/hour (0.05 Gray/hour) • Outside Bioshield: 2,725 mrad/hour (0.02725 Gray/hour)	
Evaluation:	A one page containment radiation zone map with 4 data points provided	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 6, Unit I

Reactor Type:	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	Containment	
Data Provided:	Map shows 4 data points: • RCS Piping: 45,000 mrad/hour (0.45 Gray/hour) • Rx Vessel Vicinity: 10,000 mrad/hour (0.10 Gray/hour) • SG Compartments: 5,000 mrad/hour (0.05 Gray/hour) • Outside Bioshield: 2,725 mrad/hour (0.02725 Gray/hour)	
Evaluation:	A one page containment radiation zone map with 4 data points provided	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 6, Unit J

Reactor Type:	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	Containment	
Data Provided:	Map shows 4 data points: • RCS Piping: 45,000 mrad/hour (0.45 Gray/hour) • Rx Vessel Vicinity: 10,000 mrad/hour (0.10 Gray/hour) • SG Compartments: 5,000 mrad/hour (0.05 Gray/hour) • Outside Bioshield: 2,725 mrad/hour (0.02725 Gray/hour)	
Evaluation:	A one page containment radiation zone map with 4 data points provided	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 7, Unit K

Reactor Type: BWR	Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,201+		
Monitoring Duration: One time	Monitoring Frequency: One time	
Monitoring Location(s):	Containment	
Data Provided:	Dose rates and dose equivalent at 7 locations using 5 difference vendor monitor types; however, only at 11%, 24%, and 45% power.	
Evaluation:	All data is from a 3 page except of a 1987 Drywell radiation study provided. Insufficient to reach any conclusions, especially due to power levels and non-identification of monitor locations from report excerpt.	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 8, Unit L

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	All	
Data Provided:	Various For Containment, there is only 1 room identified. The 60 year normal dose is 6.81E+06 rad (6.81E+04 Gray).	
Evaluation:	Report A indicates that some radiation monitoring has occurred for specific components/locations. The report also includes drawings/zone summary tables. These zone summary tables identify the maximum normal radiation dose at various locations; the main body provides background detail on various items. However, no specific radiation monitoring data is provided and/or compared to design values.	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 8, Unit M

Reactor Type:	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	All	
Data Provided:	Various For Containment, there is only 1 room identified. The 60 year normal dose is 6.81E+06 rad (6.81E+04 Gray).	
Evaluation:	Report A indicates that some radiation monitoring has occurred for specific components/locations. The report also includes drawings/zone summary tables. These zone summary tables identify the maximum normal radiation dose at various locations; the main body provides background detail on various items. However, no specific radiation monitoring data is provided and/or compared to design values.	
Do results confirm lower radiation monitoring than design?		Indeterminate

Plant Designator: Plant 9, Unit N

Reactor Type: BWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	Not identified	
Data Provided:	None	
Evaluation:	Radiation zone data provided; however, there is no distinguishment between design and monitored values; therefore, any monitored value is unknown	
Do results confirm lower radiation monitoring than design?		N/A

Plant Designator: Plant 9, Unit O

Reactor Type:	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 1,001 – 1,200		
Monitoring Duration: Not identified	Monitoring Frequency: Not identified	
Monitoring Location(s):	Not identified	
Data Provided:	None	
Evaluation:	Radiation zone data provided; however, there is no distinguishment between design and monitored values; therefore, any monitored value is unknown	
Do results confirm lower radiation monitoring than design?		N/A

Plant Designator: Plant 10, Unit P

Reactor Type: PWR	Operating Plant License Time Frame: 1980 – 1984	
Design Capacity Range (MWe): 801 – 1,000		
Monitoring Duration: Not identified	Monitoring Frequency: N/A	
Monitoring Location(s):	Not identified	
Data Provided:	None	
Evaluation:	No drawings	
Do results confirm lower radiation monitoring than design?		N/A

Plant Designator: Plant 11, Unit Q

Reactor Type: BWR		Operating Plant License Time Frame: 1970 – 1974	
Design Capacity Range (MWe): 500 – 800			
Monitoring Duration: Not identified		Monitoring Frequency: Not identified	
Monitoring Location(s):		All	
Data Provided:	None		
Evaluation:	Calculation A from 2011 provided that includes detailed radiation information including for EPU and LR. However, upon reading the report, it appears to be built upon a series of radiation dose calculations back to the original design specifications, and simply re-calculated based on various factors. Therefore, this report is not based on any radiation monitoring.		
Do results confirm lower radiation monitoring than design?			N/A

Plant Designator: Plant 12, Unit R

Reactor Type: PWR		Operating Plant License Time Frame: 1985+	
Design Capacity Range (MWe): 1,001 – 1,200			
Monitoring Duration: Not identified		Monitoring Frequency: N/A	
Monitoring Location(s):		Not identified	
Data Provided:	None		
Evaluation:	N/A		
Do results confirm lower radiation monitoring than design?			N/A

E

ACRONYMS AND ABBREVIATIONS

ALEE	Adverse Localized Equipment Environment
BNL	Brookhaven National Laboratories
BWR	Boiling Water Reactor
DLO	Diffusion Limited Oxidation
DOE	U.S. Department of Energy
EDMA	Expanded Materials Degradation Assessment
EPRI	Electric Power Research Institute
EQ	Environmental Qualification
EQDB	Curtis-Wright/Scientech Equipment Qualification Database
ETDE	Energy Technology Data Exchange
GALL	Generic Aging Lessons Learned
GPO	U.S. Government Printing Office
IAEA	International Atomic Energy Agency
LRA	License Renewal Applications
LTO	Long-term Operation
MWe	Megawatts electric
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute
NIST	National Institute of Standards and Technology) (formerly NBS)
NSSS	Nuclear Steam Supply System

NUGEQ	Nuclear Utility Group on EQ
NRC	Nuclear Regulatory Commission
OECD	Organization for Economic Cooperation and Development
PDMA	Progressive Materials Degradation Approach
PWR	Pressurized Water Reactor
SER	Safety Evaluation Report
U.S.	United States

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