



IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Facilities

IEEE Power and Energy Society

Developed by the
Nuclear Power Engineering Committee

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STANDARDS

IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Facilities

Developed by the

Nuclear Power Engineering Committee
of the
IEEE Power and Energy Society

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Abstract: Guidelines for assessing, monitoring, and mitigating aging degradation effects on electrical equipment used in nuclear facilities are provided in this guide. Also included are informative annexes on aging mechanisms, environmental monitoring, condition monitoring, aging program essential attributes, and examples demonstrating the application of the basic principles described in this guideline.

Keywords: activation energy, aging, aging assessment, aging effects, aging management, Arrhenius, condition monitoring, degradation, environmental monitoring, IEEE 1205™, license renewal, radiation aging model, residual life, stressor, thermal aging model

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Participants

At the time this guide was completed, the Aging Assessment Working Group had the following membership:

Rebecca L. Steinman, *Chair*
Suresh Channarasappa, *Vice Chair*
George Kyle, *Secretary*

Chris Abernathy
George Ballasi
Steven Graham

Robert Konnik
Thomas Koshy
Jacob Kulangara

Edward Mohtashemi
Khoi Nguyen
Eric Rasmussen

The following members of the individual Standards Association balloting group voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

S. Aggarwal
Gilles Bargone
Alexander Bowman
Thomas Brewington
Keith Bush
Suresh Channarasappa
Sharmeela Chenniappan
Tom Crawford
Leonard Fifield
Shubhanker Garg
Steven Graham
Daryl Harmon

Hamidreza Heidarisafo
Werner Hoelzl
Jonathan Jenkins
John Kay
Robert Konnik
Thomas Koshy
Mikhail Lagoda
Greg Luri
Michael May
Rishi Menon
Khoi Nguyen

Sven-Olof Palm
James Parello
Bansi Patel
Howard Penrose
Jan Pirrong
Eric Rasmussen
Lakshman Raut
David Rouison
Rebecca L. Steinman
John Vergis
John Webb
Yvonne Williams

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Guido R. Hiertz
Ronald W. Hotchkiss
Tyler L. Jaynes
Thomas Koshy
Howard Li
Xiaohui Liu
Kevin W. Lu
Hiroshi Mano

Daleep C. Mohla
Annette D. Reilly
Robby Robson
Daniel Sabin
F. Keith Waters
Sha Wei
Luyang (Eric) Zhang

Introduction

This introduction is not part of IEEE Std 1205-2025, IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Facilities.

In 1988, the Nuclear Power Engineering Committee (NPEC) of IEEE recognized a need for and directed Working Group 3.4 to prepare a guide for providing guidance and promoting uniformity in the evaluation methods used in aging assessment, monitoring, and mitigation. The working group's effort culminated in 1993 with the original issue of IEEE Std 1205™, which reflected the industry focus on identifying and addressing aging mechanisms. The guide was revised in 2000 and 2014 to incorporate industry feedback and bring the approaches discussed in the guide into closer conformance with the industry philosophy at that time. IEEE Std 1205-2014 has been endorsed by the US. Nuclear Regulatory Commission in Regulatory Guide 1.248, [B151] with no exceptions.⁶

IEEE Std 1205-2025 is the result of a thorough review of IEEE Std 1205-2014 and of present practices in aging management of electrical equipment. This revision incorporates current practices and lessons learned from the implementation of previous versions of this standard by the nuclear industry. The impact of subsequent license renewal was evaluated by the Working Group, and no changes were deemed necessary given the higher-level nature of this guidance document.

The working group believes that new programs should not be established solely for the purpose of aging assessment. Aging assessments should not be directed toward an endless search for data and information, but rather should be an effort that is practical, cost-effective, and based on collecting and evaluating a minimum set of data and information collected preferably from existing programs.

The working group believes that this guide is useful in supporting equipment qualification program aging assessment updates, failure evaluations related to the Code of Federal Regulations Title 10 Part 50.65 (10 CFR 50.65) (known as the “Maintenance Rule”) [B15], other root cause evaluations, and license renewal [B16] aging management reviews. To facilitate these types of uses, the working group changed this guide as follows:

- Modified the scope to explicitly include instrumentation and control equipment in addition to other types of electrical equipment.
- Added a paragraph to acknowledge the existence of risk-informed equipment categorization and cross-reference IEEE Std 1819™ for further details regarding treatment application requirements for that categorization scheme.
- Updated the formatting of the standard for consistency with the latest *IEEE Standards Style Manual*, including some formatting changes resulting in renumbering of clauses and subsequent update of cross-references throughout the document.
- Validated that the aging effects tables in [Annex A](#) continue to reflect the current state of industry knowledge, with some minor terminology and reference updates being performed.
- Updated [Annex C](#) to specifically cross-reference the IEC/IEEE condition monitoring standards.
- Updated the bibliography in [Annex G](#) to reflect recent aging assessment-related research and industry activities.

⁶ The numbers in brackets correspond to the numbers of the bibliography in [Annex G](#).

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IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Facilities

1. Overview

1.1 Scope

This document provides guidelines for assessing, monitoring, and mitigating aging effects on electrical equipment (including instrumentation and control equipment) used in nuclear facilities.

1.2 Application

“Nuclear facilities” is intended to be a generic term that encompasses nuclear power generating stations, enrichment, fuel manufacturing, research, and medical facilities.

It is intended that the user determine the specific applicable equipment and methods described herein that warrant attention using this guide. For example, Class 1E equipment in power generating stations and other nuclear facilities is required to remain capable of performing its intended safety function throughout its service life. This is accomplished through a systematic and disciplined program of quality assurance covering design, qualification, manufacturing, storage, installation, operation, maintenance, periodic testing, and surveillance. If it can be shown that aging considerations have been satisfactorily addressed through other means (e.g., equipment qualification, maintenance), then use of this guide may not be warranted. Similarly, for some equipment, only partial application of this guide may be warranted.

Aging assessment may be pursued in response to a variety of factors, e.g., regulatory guidance, approaching obsolescence, reduced availability, or reliability, or for life extension. Such factors plus economics also affect the method and extent of aging assessment actually performed. Monitoring and/or mitigating the aging of some equipment may be determined to be less cost effective than replacing the equipment. Running to failure may be an option under certain special situations.

This guide provides a framework for the performance of an aging assessment and subsequent implementation of an aging management program once a decision has been made that an aging assessment is warranted.

Facilities adopting a risk-informed program for equipment categorization and treatment (in accordance with regulatory approval) should implement this standard in conjunction with IEEE Std 1819™ [\[B105\]](#).

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{7,8}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC/IEEE Std 60780-323, International Standard Nuclear Facilities—Electrical Equipment Important to Safety—Qualification.^{9,10}

IEEE Std 627™, IEEE Standard for Qualification of Equipment Used in Nuclear Facilities.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹¹

aging assessment: Evaluation of appropriate information for determining the effects of aging on the current and future ability of systems, structures, or components to function within acceptance criteria.

aging degradation: Gradual deterioration in the physical characteristics of a structure, system, or component, due to aging mechanisms that occur with time or use under service conditions that could impair its ability to perform any of its essential functions.

aging effects: Net changes in the physical characteristics of a structure, system, or component due to aging mechanisms that occur with time or use.

aging mechanism: A specific process that changes the physical characteristics of a structure, system, or component with time or use.

⁷ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁸ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

⁹ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

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¹¹ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

Class 1E: The safety classification of the electrical equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise essential in preventing significant release of radioactive material to the environment.

condition monitoring: Measurement of one or more condition indicators of equipment, its components, or materials for which an acceptance criterion can be correlated to the equipment's ability to function as specified during applicable design basis events (DBEs).

design life: The time period (such as operating time, number of operating cycles or other performance interval, as appropriate) during which satisfactory performance can be expected for a specific set of service conditions.

equipment: An assembly of components designed and manufactured to perform specific functions.

NOTE—Certain items that satisfy the definition of the term equipment as used in this document are those referred to as components in ASME Boiler and Pressure Vessel Code¹² and its latest addenda, for example, pumps and valves. Other examples of equipment are motors, transformers, and instrumentation and control devices. Structures and structural support items are not included in the definition of equipment.¹³

essential function: An active or passive attribute necessary to achieve the equipment licensing basis or other design intent.

failure: The termination of the ability of an item to perform a required or essential function.

qualified life: period for which an equipment has been demonstrated, through testing, analysis and/or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in an accident condition or earthquake.

residual life: The remaining period of time during which a structure, system, or component is expected to perform its essential function under specified service conditions.

NOTE—See Figure 1 for the relationship of various terminology related to SSC life.

safety function: One of the processes or conditions (e.g., emergency negative reactivity insertion, post-accident heat removal, emergency core cooling, post-accident radioactivity removal, and containment isolation) essential to maintain plant parameters within acceptable limits established for a design basis event.

NOTE—A safety function is achieved by the completion of all required protective actions by the reactor trip system or the engineered safety features, or both, concurrent with the completion of all required protective actions by the auxiliary supporting features, or both.

service conditions: Environmental, loading, power, and signal conditions expected as a result of normal operating requirements, expected extremes (abnormal) in operating requirements, and postulated conditions appropriate for the design basis events (DBEs) of the station.

service life: The actual period from initial operation to retirement of a structure, system, or component.

NOTE—See Figure 1 for the relationship of various terminology related to SSC life.

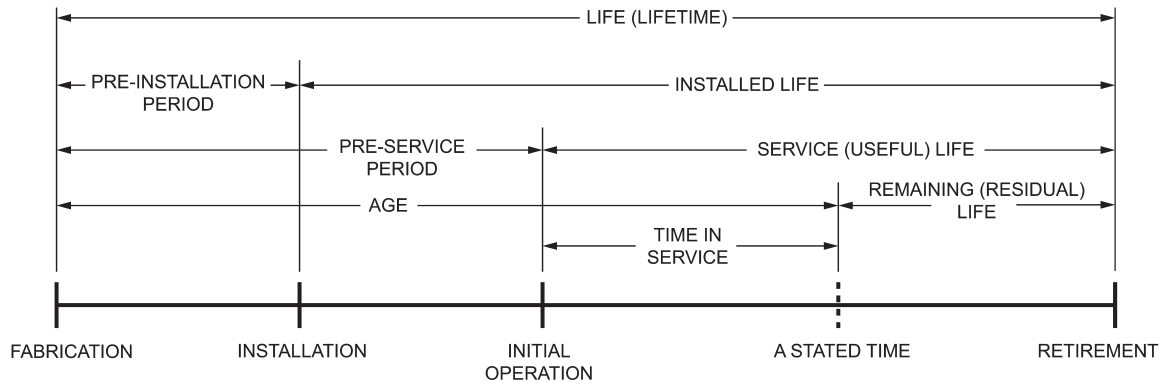
significant aging mechanism: An aging mechanism that, under normal and abnormal service conditions, causes degradation of equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its essential function(s).

¹² ASME publications are available from the American Society of Mechanical Engineers (<http://www.asme.org>).

¹³ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

stressor: An agent or stimulus that stems from fabrication, pre-service (storage) or service conditions and can produce degradation of a structure, system, or component.

synergistic effects: A combination of aging effects such that the overall effect is greater than the sum of the individual effects.



NOTE: THESE TERMS DEFINE ACTUAL MILESTONES IN THE PAST OR FUTURE HISTORY OF A SYSTEM, STRUCTURE, OR COMPONENT. SYNONYMOUS TERMS ARE SHOWN IN PARENTHESES.

Figure 1—Relationship among different terms used to describe SSC life

3.2 Acronyms and abbreviations

AFW	auxiliary feedwater
CAF	conductive anodic filaments
CCW	condenser circulating water
CMOS	complementary metal oxide semiconductor
DBE	design basis event
DLO	diffusion limited oxidation
DSC	differential scanning calorimetry
EEPROM	electrically erasable programmable read-only memory
EM	electromagnetic
EMC	electromagnetic compatibility
EMPA	electron microprobe analysis
EQ	environmental qualification
ESD	electro-static discharge
ESF	engineered safety feature
FDR	frequency domain reflectometry
FSAR	final safety analysis report
FTIR	Fourier-transform infrared
HPCI	high-pressure coolant injection

HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IR	insulation resistance
IRIS	Industry Reporting Information System
LOCA	loss-of-coolant accident
LPSI	low pressure safety injection
LIRA	line impedance resonance analysis
MSIV	main steam isolation valve
NDT	nondestructive test
NIR	near infrared
NMR	nuclear magnetic resonance
NSSS	nuclear steam supply system
OIT	oxidation induction time
OITP	oxidation induction temperature
PCB	printed circuit board
PD	partial discharge
PI	polarization index
RC	reactor coolant
RTD	resistance temperature detector
SEE	single event effects
SEU	single event upset
SSC	structure, system, or component ¹⁴
TFDR	time-frequency domain reflectometry
TGA	thermogravimetric analysis
UPC	universal product code
UV	ultraviolet
VLF	very-low-frequency

¹⁴ It is recognized that the NRC NUREG-1801, Generic Aging Lessons Learned (GALL) Report defined SSC as system, structure, and component like the historical usage in IEEE Std 1205. However, 10 CFR 50.59 and most other IEEE standards utilize structure, system, and component for this acronym, so this guide is being revised to match broader current industry usage.

4. Stressors, aging mechanisms, and aging effects

4.1 Stressors

A stressor that stems from fabrication, storage, installation, or service conditions may produce aging mechanisms and effects or degradation of electrical equipment. The following two types of stressors should be considered for aging:

- a) *Environmental*. These are stressors that exist continuously in the environment surrounding the equipment, whether it is in storage, operating, or shut down. Examples include vibration, heat, pressure, radiation, and humidity. [Annex A](#) provides a representative listing of stressors and their effects, while [Annex B](#) provides considerations for environmental monitoring.
- b) *Operational*. These are stressors arising from equipment operation. Examples are heating effects from electrical or mechanical loading, physical stresses from mechanical or electrical surges, vibration, and abrasive wearing of parts.

The aging degradation of electrical equipment is usually a function of the duration, range, and intensity of stressors experienced by the equipment. Aging degradation due to a single stressor is often represented as a simple first-order relationship involving stressor intensity and time, as described for thermal aging in [6.7.4](#); however, aging degradation due to a combination of more than one stressor may exceed the sum of the individual effects and may result in conditions that are not appropriately modeled by this simple representation. Typically, the concern is associated with the potential for synergistic effects between temperature and radiation in some polymers. Several of the references listed in [Annex C](#) provide additional details on synergistic effects in polymers, and should be considered for additional information on this topic.

4.2 Aging mechanisms and aging effects

One method of determining the susceptibility of equipment to aging mechanisms and consequent aging effects is by understanding the behavior of the individual materials that make up the electrical equipment when subjected to environmental and operational stressors. These mechanisms may apply to solid-state electronic components as well as electrical equipment. Some examples of stressors, aging mechanisms, and aging effects are provided as follows:

- a) High-temperature environments can cause organic insulating materials to become brittle at a faster rate.
- b) Moisture, strong electric fields, or physical contact may result in a loss of dielectric integrity.
- c) High-humidity environments can accelerate bearing wear in rotating equipment lacking special seals or pressure lubrication.
- d) High humidity can increase pitting and corrosion of contacts on relays and controllers.
- e) Vibration can loosen fasteners on linkages, causing misalignment of components or loss of electrical contact integrity. Misalignment accelerates wear in moving parts, and loose electrical contacts may lead to heat-related degradation.
- f) Support systems or components subject to high humidity or contact with water and/or chemicals may corrode if not protected by coatings or covers.
- g) Radiation can break down organic materials and produce embrittlement similar to that caused by high temperature. The amount of degradation may be impacted by the rate at which the radiation is received. For example, high dose rates affect the doping of silicon devices used in instrumentation and control devices. Dose rate effects for polymers are a result of diffusion-limited oxidation (DLO).

- h) Continuous operation of certain electronic components (e.g., diodes, resistors) at high ambient temperatures can cause operation outside of their performance specification.
- i) Excessive voltage cycling can result in premature failure of electrolytic capacitors.
- j) Exposure to moisture can result in delamination of insulated wires.

Table A.1, Table A.2, Table A.3, and Table A.4 provide, in summary form, a listing of typical aging mechanisms and their effects on polymers, lubricants, metals, and printed circuit boards (PCBs), respectively.

Aging is significant for the purpose of an aging program if it satisfies all of the following criteria:

- In the normal service environments, an aging mechanism promotes the same failure mode as that resulting from exposure to abnormal or design basis event (DBE) service conditions.
- The aging mechanism adversely affects the ability of the equipment to perform its essential function in accordance with its specified requirements.
- In the normal service environment, the aging mechanism causes degradation during the design life of the equipment that is appreciable compared to degradation caused by the DBE.
- The deterioration caused by the aging mechanism is not amenable to trending by in-service inspection or surveillance activities that provide confidence in the equipment's ability to function in accordance with its specified requirements during the intervals between surveillances.

Certain mechanisms may not be operative or produce significant aging effects in equipment in a given service environment for a given period of time. In some cases, aging mechanisms may be readily judged to be of little or no importance because they are not significant relative to the essential function of the electrical equipment. For example, metals in electronic components (except at electrical contact points or other areas susceptible to corrosion) may not require aging assessment.

5. Principles of aging assessment

5.1 Need for an aging assessment

Aging assessments at a nuclear facility are often performed in the larger context of a desire for improved reliability, safety, and operation of the overall facility. Understanding the aging mechanisms that affect electrical equipment permits the identification, monitoring, and mitigation of aging effects (aging degradation) that may significantly affect the performance of a component. By effectively managing the replacement of components prior to failure, the number of forced outages and unplanned transients can be reduced. An aging management program may provide the facility with improved safety performance through fewer challenges to safety systems.

Reasons for performing an aging assessment may include the following:

- Industry-identified equipment problem
- Facility-specific equipment problem
- License renewal equipment review
- Maintenance due to equipment failure
- Equipment qualification

An effective aging management program should coordinate and integrate information from existing programs, such as those developed for maintenance, in-service inspection and surveillance, equipment qualification,

and operational experience. Once the significant aging mechanisms have been identified, it is necessary to determine whether an existing program is adequate to address the specific aging management concern, or a separate aging assessment is warranted.

The determination of whether an aging assessment is warranted should be weighed against factors such as the following:

- Reportability of potential age-related equipment failures
- Likelihood of recurrence of the aging mechanism/failure mode
- Obsolescence (e.g., superseded technology, lack of vendor support)
- A lack of a viable source of spare parts
- Changes in environmental conditions
- A need for requalification in accordance with IEC/IEEE Std 60780-323
- Replacement or attention for other reasons (e.g., regulatory requirements)
- Manufacturer's recommendation

The description of the aging assessment process in this guide assumes that a decision has already been made that an aging assessment is needed. [Annex D](#) provides examples that illustrate the application of the aging assessment process.

5.2 Objective and benefits

The purpose of performing an aging assessment is to establish the technical basis that demonstrates the continued functional performance capability of the equipment. Such an aging assessment may require some understanding of the type of stressors, the nature of the aging mechanisms affecting the equipment, and the often more discernible resultant aging effects (refer to [Annex A](#)).

Any aging management program should be integrated into the existing surveillance and maintenance programs at nuclear facilities. Data collection in these activities should be tailored to assess aging. Testing that takes advantage of available maintenance windows can integrate the aging assessment into existing work practices with minimal additional resources. For example, activities such as transformer oil analysis, equipment hot-spot mapping using infrared thermography, vibration monitoring of motors, and root cause analysis of equipment failures are existing facility activities that can be directed toward aging assessment.

Critical to an ongoing aging management program that takes advantage of industry and facility-specific lessons learned is the development of engineering evaluations. Such an evaluation would review the significance of the data or test results, the operability of the component, the reportability of the event, the extent of the concern, and the potential causes for not meeting acceptance criteria (if any). For recurring inspections or testing, the goal would be to assess age-related degradation and whether, considering the environment, material, and observed condition or test results, the component could remain in service until the next regularly scheduled inspection or test.

5.3 Aging assessment elements

Aging assessments are performed at nuclear facilities on a routine basis, although they may not be identified as such. A brief discussion of typical elements of an aging assessment process follows.

[Clause 4](#) establishes the relationship between aging mechanisms and aging effects. The identification of known operational stressors, aging mechanisms, and the resultant aging effects can be useful elements in

an aging assessment process. There is no intended order of performance with regard to investigating aging mechanisms and aging effects. Specific knowledge of the equipment and its service conditions (stressors) should be applied to determine if any significant aging effects are discernible or if aging mechanisms may be considered to provide insight into aging effects not yet apparent.

Once the equipment is selected for evaluation, several pieces of information are collected to form the technical basis for an aging assessment. The actions that should be performed are as follows:

- a) Define and determine the equipment boundaries relative to the aging assessment process
- b) Identify the equipment's essential functions, as appropriate
- c) Identify the environment at the equipment's installed location
- d) Identify the credible aging stressors operating on the equipment
- e) Identify the parts and materials included in the equipment's assembly
- f) Identify and assess the aging effects on the equipment

An assessment of the aging effects on the equipment is done to determine if a reasonable correlation can be made with respect to the stressors that exist in the equipment's installed location, a material's sensitivity to the stressors, and a loss of equipment functional capability. If a correlation is apparent, an aging mechanism may be identified. As a minimum, the assessment should be comprehensive enough to support and implement an effective aging management decision.

Figure 2 defines the individual elements of the aging assessment process. Assessments that result in the need for an aging management program should be validated or refined as needed. Implementing aging management would most likely be an iterative process. That is, the results of monitoring and mitigating effects would allow future refinement of the aging assessment.

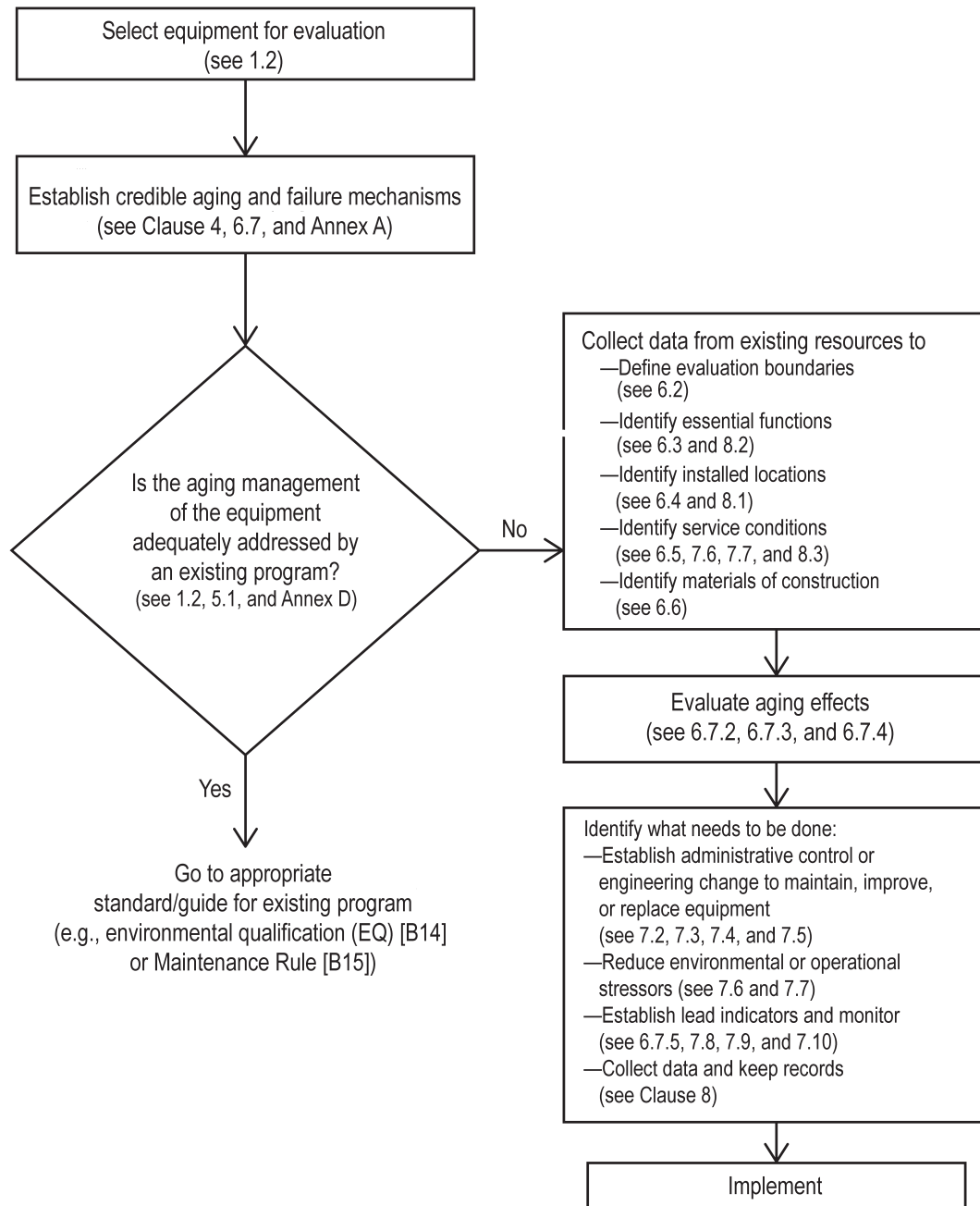


Figure 2—Overview of assessing aging effects

6. Aging assessment

6.1 General

This clause provides guidance for data collection in support of the aging assessment and also for performing the aging assessment, as graphically depicted in [Figure 2](#). The level of detail selected for aging assessments should be determined prior to starting the evaluation.

6.2 Define evaluation boundaries

The boundaries of the evaluation should be defined for the aging assessment to clearly define the parts or portions of the equipment to be examined. The need for a clear definition is especially true where equipment to be evaluated interfaces (e.g., terminations, splices) with field cables or other equipment. The boundary should determine the inclusion or exclusion of equipment, parts, or connections external to the device being evaluated. A description of the equipment and its boundaries being evaluated, not discussed elsewhere in the evaluation, should be provided. Additional guidance on the determination of equipment boundary interfaces is provided in IEEE Std 627™.

6.3 Identify essential functions of equipment

Equipment essential functions are evaluated in terms of the functions that define the purpose of the system. For more complex pieces of equipment (e.g., emergency diesel generators), it would also be important to identify subassembly essential functions. For performing an aging assessment, the following functions should be identified:

- a) Equipment essential functions susceptible to known aging effects
- b) Subassembly essential functions susceptible to known aging effects
- c) Equipment and subassembly functions whose degradation or failure could cause loss of an essential system function (e.g., electrical penetration O-ring performing a pressure-retention function)

Typical sources of information pertaining to equipment essential functions are provided in [Clause 8](#).

6.4 Identify facility locations where the equipment is installed

It is important to identify the location where the equipment is installed in the facility. Location information is needed for determining service conditions. Typical sources of equipment locations are facility drawings, equipment databases, and facility walkdowns.

6.5 Identify the electrical equipment service conditions

The electrical equipment's service conditions are determined in order to assess the influences that can affect its service life. Service conditions include both environmental conditions (e.g., temperature, humidity, radiation) and, if applicable, equipment operational conditions (e.g., cyclic stresses, self-heating, vibration). These service conditions are the stressors that cause the aging of the electrical equipment. [Annex A](#) identifies other stressors that may be applicable to equipment.

Environmental temperatures for most facility areas are normally available in various heating, ventilation, and air conditioning (HVAC) design specifications, safety analysis reports, or design basis documents. For areas in which equipment temperature data are not available or the existing data require reevaluation, new temperature data should be gathered. In addition to the ambient thermal environment, temperature rise due to component self-heating or proximity to local heat sources (e.g., process fluid carrying pipes or energized equipment) can also contribute to equipment thermal aging and, where applicable, should be addressed in the evaluation. Equipment self-heating temperature rise information can be obtained from manufacturers' data, from equipment item-specific analyses, or from tests. Self-heating temperature rise is added to the ambient temperature to determine the total temperature to be considered for thermal aging of the equipment and materials.

Radiation data, for facility areas where it is applicable, are normally available from the safety analysis report or from the environmental qualification (EQ) program, as radiation mapping is normally done to determine

normal electrical equipment radiation doses. In instances where no radiation data are available, information may be obtained from the survey data.

If needed, humidity for facility areas can be obtained from HVAC design specifications, the safety analysis report, or periodic facility monitoring, or it can be conservatively established.

Cyclic stresses are an operative concern depending on the degree of the stress and the number of cycles. A cyclic stress service condition only needs to be identified for the aging assessment if there are known aging effects. Examples are mechanical, electrical, and environmental cycling. See [Annex A](#) for additional information.

Sources of design and actual service condition data can be found in [Clause 8](#). Information on the monitoring of the environments is contained in [Annex B](#). In addition, EPRI TR-109619 [B44] provides guidance for obtaining service condition data.¹⁵

6.6 Identify the materials of construction

The equipment's parts and construction materials should be identified for evaluation under their service conditions. In cases where it is not possible to determine all materials or the exact materials of construction, the goal is to have reasonable assurance that age-sensitive materials have been identified.

Electrical component materials can be identified from various sources, such as design material lists, component manufacturer drawings, or spectrographic analysis. See [Clause 8](#) for additional sources of information. Where specific component information is lacking, industry aging management guidelines and other reports may be sources of the most common materials used for specific component types installed in the nuclear industry.

Electrical components are constructed with organic and inorganic materials. Depending on the type of component being evaluated, identification of the metals and other inorganic materials may not be necessary. For example, there are no significant aging effects for inorganic materials associated with cables (i.e., copper cable conductor, copper shielding, fillers, and armor); however, some organic materials are sensitive to environmental conditions and may require additional consideration (e.g., certain fluropolymers are sensitive to radiation). Most metals and other inorganic parts in cables are covered by insulation or a jacket and are not exposed to environments that would cause the inorganic materials to degrade under normal circumstances. Although metal, in general, ages when used in other applications, corrosion when it occurs inside cable represents a failure of the insulation and should be considered a special case, not the normal, predictable aging of the cable's inorganics. Although not typical, moisture can seep between various layers of cable construction and, with oxygen introduced, can cause corrosion and metal loss. Degraded cable shielding due to corrosion has the potential to impact the electromagnetic compatibility (EMC). Contacts, linkages, and bearings are inorganic parts of electrical equipment that may also be susceptible to aging. Thermal cycling effects should also be considered.

6.7 Identify and assess aging effects

6.7.1 General

Aging effects are identified and assessed to determine whether any additional aging management efforts are needed to prevent the effects from becoming significant over time. Significant aging effects are those that can detrimentally affect the equipment's essential functions identified in [6.3](#).

The following subclauses describe aging effect identification, other supportive information needed, and use of aging models and condition monitoring to perform aging assessments.

¹⁵ The numbers in brackets correspond to the numbers of the bibliography in [Annex G](#).

6.7.2 Identification of aging effects

Aging effects are identified from either facility-specific or industry failure or degradation experience with the specific equipment or its materials of construction (from 6.6) in a similar application. Alternatively, facility-specific service conditions (stressor values) and materials information may be used to determine applicable and potentially significant aging effects from the tables of Annex A.

6.7.3 Other supportive information needed

The following information should be researched or established as feasible or available:

- a) Evaluation period: Most materials degrade over time, even in benign environments; it is useful to set a specific goal for the equipment's life to be evaluated (see Figure 1). The evaluation period is normally selected on the basis of the facility's operating license but can be selected for any other specific time period (e.g., outage to outage for specific equipment, time periods between tests as dictated by safety analysis, or for license renewal).
- b) Past and future service conditions (from 6.5) as a function of time or as enveloping values for the evaluation period.
- c) Degree of flexibility in controlling or limiting future service conditions.
- d) Aging mechanisms likely to cause the identified aging effects in the identified materials of construction (determined from Annex A or similar sources of information).
- e) Dependence of the aging mechanism and resulting aging effects on the identified service conditions.
- f) Aging information, such as activation energy, accelerated aging test data (temperature and time), temperature rating or maximum continuous-use temperature, radiation dose threshold, and related information, for the equipment or its materials of construction.

To perform the aging assessment, the material's capability is compared to the intensity and duration of a service condition stressor. Results from tests of material properties, after being subjected to accelerated aging, are the best and most readily available sources of material aging information.

The objectives of the aging assessment are to determine the following:

- How long a material will remain functional while exposed to its stressors, or
- A maximum stressor value that a material would be able to withstand for a specified period and still remain functional.

The aging assessment can be performed to achieve either one or both of these objectives, depending on information availability, expected or estimated remaining life margin, and whether specific equipment life goals have been established or are needed.

Knowing the equipment materials and stressors, it is possible to assess the effects of aging on the material to date and to determine how aging will affect the equipment function in the future. For a given material, aging effects (some type of material degradation) can be directly related to a specific environmental or operational stressor. The intensity of the stressor normally determines the rate at which the material degrades.

One or a combination of methods is used to assess aging effects for the equipment's future service conditions. Two models, which extrapolate test results and condition monitoring, are discussed in the following subclauses.