PREDICTING AND EXTENDING EQUIPMENT LIFE: HOW AND WHY?

by Dave Horvath (Advent Engineering),
Lamis Fleischer (ComEd), and
Tom Hart (IMPCo)

INTRODUCTION

In recent years, a new tool in the form of an industry standard has entered the power industry scene to provide guidance on predicting and extending equipment life. This process is variously referred to as aging assessment, aging mitigation, and aging management. The new tool is IEEE Standard 1205 entitled "Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations". This standard is the culmination of an industry consensus effort to establish a state-of-the-art approach for addressing aging of electrical equipment. Although this guide focuses on Class 1E equipment in nuclear stations, the approaches offered can also be applied to non-Class 1E equipment as well as to equipment outside of the nuclear industry.

HISTORY

Class 1E (safety-related) equipment in nuclear power generating stations must meet safety functional requirements throughout its service life. This requirement is met through a carefully developed and implemented combination of design, qualification, manufacturing, storage, installation, operation, maintenance, testing, and surveillance. Class 1E equipment is kept in a state of readiness through periodic refurbishment and/or replacement. Also, for some Class 1E equipment located in post-accident harsh environment areas (such as those subject to pipe break elevated temperature and pressure effects), rigorous testing and/or analysis may have been employed to assure operability even after the effects of maximum expected aging (i.e., at the end of a pre-established qualified life). For equipment located in mild environment areas, a qualified life demonstration is generally not required because an effective maintenance and surveillance program is sufficient to identify and mitigate the potentially detrimental effects of aging degradation.

The intent of preparing and issuing this guide was not to imply that existing maintenance and surveillance programs are inadequate for aging mitigation. Nor does this guide promote the establishment of new programs for aging assessment or aging management. Instead, this guide is intended to assist in better refining and applying existing resources toward achieving improved aging management and increased reliability/availability of essential equipment. Aging assessments should not be an endless search for data and information, but rather should be a practical, cost-effective effort to collect and evaluate a minimum set of data and information preferably available from existing programs using proven techniques to assess the condition of the equipment.

Another purpose of this guide is to provide a methodology for establishing a technical basis for extending the life of equipment beyond a previously determined design or qualified life. One example of such a need would be for supporting Nuclear Plant Operating License Renewal. The approach in this guide can be used to develop the technical basis for identifying proper aging mitigative actions to assure that safe and dependable plant operation will occur during the equipment's extended life.

IEEE's Nuclear Power Engineering Committee recognized a need to supplement its existing body of standards to provide guidance for aging assessments, control, and mitigation and to promote uniformity in the methods used to establish the technical basis for the results of such efforts. While it would have been possible to incorporate the guidance from this standard into existing related standards, the decision was made to develop a stand-alone document in order to (a) be expedient and promote consistency by providing guidance that can be incorporated or referenced by future standards and (b) help disseminate the body of knowledge and promote uniformity in applications methods while minimizing confusion that could result from differences in licensing basis of the various operating nuclear power stations.

Therefore, IEEE Standard 1205 was designed to both supplement other nuclear standards and provide additional details to assure the use of a uniform and consistent approach to performing aging assessment evaluations for Class 1E equipment. It is believed that use of this guide will result in (a) economic benefits from optimization of equipment service life, (b) improvements of equipment evaluation and root cause analysis, (c) recommendations for improvements in-plant environmental monitoring, and (d) optimization and focusing of inspection, condition monitoring, and maintenance for activities that can improve reliability/availability.

FOUR ELEMENTS OF AN EFFECTIVE AGING MANAGEMENT PROGRAM

IEEE 1205 identifies four elements of an effective aging management program. These are:

- Determination of aging mechanisms (or types of degradation of concern),
- Aging assessment,
- Monitoring & mitigating methods, and
- Data collection, record-keeping, and usage.

The remainder of this article will focus on these four elements.

DETERMINATION OF AGING MECHANISMS

A stressor is an agent or stimulus that causes degradation of a system, structure, or component. There are two major types of stressors: environmental and operational. Environmental stressors are caused by factors external to the structure, system, or component. Examples are: externally produced vibration, heat, radiation, and humidity. Operational stressors arise from functional performance. Examples are: internal heating, electrical or mechanical loading, internally produced vibration, and physical stresses from mechanical or electrical surges or cycles.

In order to determine the susceptibility of equipment to aging, it is necessary to understand the behavior of the individual materials that make up the Class 1E equipment. This determination can be performed through use of Tables A1 through A3 of IEEE 1205. These tables provide a comprehensive list of stressors, aging mechanisms, and associated aging effects for polymers, lubricants, and metals. It is not necessary that every possible type of aging mechanism be identified, only those where degradation potential can detrimentally affect equipment functionability.

AGING ASSESSMENT

Several possible situations may lead to the decision to perform an aging assessment. Examples are "lessons learned" or site-specific experience with a specific equipment model or a need has otherwise arisen to extend the design or qualified life of a particular equipment application (such as for license renewal or to reduce what is appearing to be premature equipment replacements). To be effective, an aging assessment must be structured. IEEE 1205 recommends an eight-step approach:

1. describe or define the equipment in terms of its boundaries, make-up, and performance requirements,
2. break the equipment down into simpler parts, components, or subsystems (sometimes referred to as aging units) in order to simplify further evaluation,
3. screen for obsolescence (obsolescence is a valid reason for not continuing an aging assessment; replacement might make better economic sense),
4. identify the aging mechanisms or type of degradation most likely to lead to functional failure in each of the aging units (Tables A1 - A3 would be useful for this step),
5. determine the age-related failure modes for each of the previously determined aging mechanisms,
6. determine the critical characteristic (material property) which would best define when the failure mode occurs (e.g., dielectric strength for a short in electrical insulation),
7. determine what observable (measurable) parameters could best be used to monitor the failure mode (this may or may not be the same as the critical characteristic), and
8. establish residual life.

The standard provides additional guidance on the above methodology.

MONITORING AND MITIGATING METHODS

Monitoring includes both environmental monitoring and monitoring of observable parameters. Environmental monitoring is used to determine or confirm which stressors are significant to the identified aging mechanisms as well as to aid in predict future aging degradation. Monitoring of observable parameters may help to establish or confirm the basis for life predictive criteria and should be correlated with type and frequency of any preventive action. Examples of some measurable indicators of degradation are voltage, load, response time, and setpoint drift.

Annex B of the standard provides additional guidance for developing an effective monitoring program. Tables A1 through A3 provide a list of methods commonly used to monitor several types of aging degradation.

DATA COLLECTION, RECORD KEEPING AND USAGE

There are three types of aging related or support data to be considered: baseline, historical, and inspections & diagnostic testing. These three types correspond to the following three questions which must be asked to assure an effective aging management program:

1. What was the equipment's original design basis?
2. How well has it performed in service?
3. What is its present condition with respect to its intended function?

To prevent being overwhelmed, consideration must be given early on to assure that only relevant data is collected. Only that data which satisfies the needs of the aging assessment methodology needs to be collected, analyzed, and retained.

SUMMARY

The nuclear industry has a need which is stronger than any time in the past for reducing operating and maintenance costs and at the same time assure that equipment replacement intervals are both reliably and conservatively determined as well as not being overly premature. This need can be at least partially, if not completely met, through proper implementation of the guidelines offered by IEEE Standard 1205. These guidelines can be used to develop or evolve existing controls into an effective aging management program which takes advantage of existing maintenance, surveillance, EQ, and trending programs. This methodology although developed for the nuclear industry also has some relevance to non-nuclear applications.

ABOUT THE AUTHORS

Dave Horvath, Lamis Fleischer, and Tom Hart are members of IEEE's standards development Working Group 3.4 (Aging Assessment/ Life Extension). This Working Group operates under the auspices of IEEE's Power Engineering Society and its Nuclear Power Engineering Committee. Dave Horvath is President and Senior Engineering Consultant at Advent Engineering, Ann Arbor, Michigan. Lamis Fleischer is a Senior Electrical Engineer on the Site Engineering Staff at LaSalle Nuclear Station for ComEd (formerly Commonwealth Edison). Tom Hart is a Senior Electrical Engineer on the Technical Staff at the D.C. Cook Nuclear Plant for Indiana-Michigan Power Company. All three were active participants in the development of IEEE Standard 1205.