SMiRT-12 / K. Kussmaul (Editor)

D01/4

NUCLEAR POWER PLANT COMMON AGING TERMINOLOGY

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ABSTRACT

Growing U.S. nuclear power industry activities in license renewal, aging management, life management, root cause evaluation, and maintenance created the need for more uniform terminology in these areas. A cooperative industry study used a systematic technical and lexicographical approach in developing common definitions. The definitions cover over a hundred terms related to degradation, life cycle, and aging management of systems, structures, and components. This paper (1) gives an overview of the study; (2) encourages use of the common terms and definitions in plant documents, research efforts, and standards related to aging; and (3) solicits constructive feedback for improving the terminology.

1 INTRODUCTION

During the last ten years, the oldest operating nuclear power plants in the United States have passed the half-way point of their original forty-year licensed term. The central technical issue for license renewal is aging degradation unique to an additional operating term. Also, some unexpected significant aging mechanisms have been experienced (for example, erosion-corrosion led to failure of a main feedwater pipe in 1986). A federal rule on maintenance has been issued. All of this has increased the attention of operators, regulators, researchers, and the public at large to the aging of systems, structures, and components (SSCs).

Considerable research related to the aging of SSCs has been conducted under the sponsorship of the Electric Power Research Institute (EPRI), the U.S. Nuclear Regulatory Commission (NRC), and the U.S. Department of Energy (DOE). Researchers observed that terminology related to aging of SSCs was not uniform in use nor interpretation. Despite constant vigilance by codes and standards organizations, certain formal definitions for terms in the areas of component life, degradation, failure, and maintenance were still somewhat inconsistent. It was recognized that communications about aging would be improved by uniform terminology.

The most important need for more precise aging terminology lies in the area of assessing plant experience. There is general agreement that the determination of root cause of degradation and failure of SSCs is difficult. Root cause determination is made even more difficult by imprecise language during investigation and reporting. A prerequisite to fashioning effective remedies is to discriminate failures caused by aging from failures due to other causes, such as human error.

In recognition of the importance of clear communication in activities related to aging, a cooperative effort among EPRI, the NRC, and the Nuclear Management and Resources Council (NUMARC) has developed a uniform vocabulary of terms related to aging (Grant, 1992). A technical committee from various industry sectors established the scope of the effort and used a systematic technical and lexicographical approach in developing common definitions. The terms are those commonly used to describe the complete plant aging scenario, beginning from what causes aging and ending with repair or replacement of a component whose failure may have been caused in part by aging. The list contains 112 common terms (85 "principal terms" and 27 "acceptable synonyms").

2 COMMON TERMS AND THEIR DEFINITIONS

After establishing the scope of the terminology to be addressed, the study employed the following approach: (1) use existing formal definitions and common usages to the extent possible; (2) employ a sound, systematic technical approach in developing the meanings of terms and their relationships to each other; (3) employ established principles of lexicography; and (4) obtain technical review and comment from as many industry organizations as practicable

Of the 85 principal terms, only 38 had existing formal definitions. Only five existing definitions were deemed suitable enough for adoption as common definitions. New terms were introduced only when they were needed to capture a concept not addressed by existing terms. The major new terms are those relating to errors ("error-induced" conditions, stressors, and aging degradation). Charts were developed to illustrate the technical relationships among the terms (see for example, Fig. 1). In the process of trial use and comment, hundreds of comments were received from about twenty organizations.

Selected terms and their common definitions are presented in glossary form in Table 1.

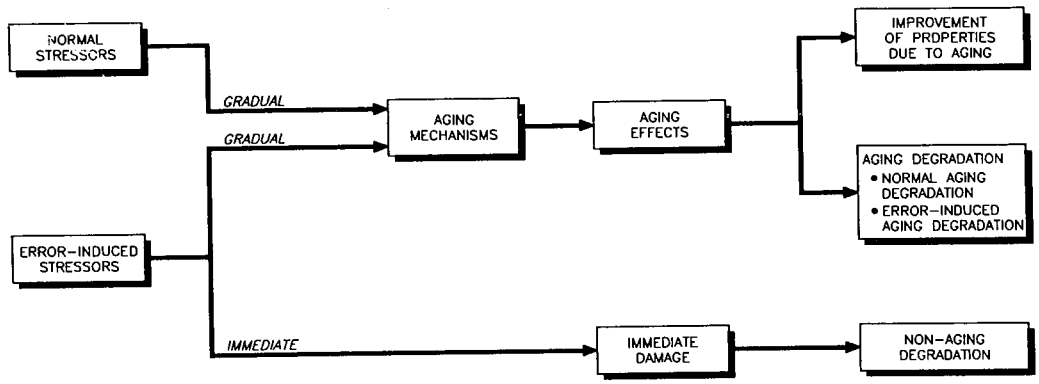

Figure 1: Relationships Among Aging Terms

Table 1. Glossary of Selected Common Aging Terms by Category

CAUSES OF DEGRADATION

condition surrounding physical state or influence that can affect an SSC

service conditions actual physical states or influences during the service life of an SCC, including operating conditions (normal and error-induced), design basis event conditions, and post design basis event conditions

environmental conditions ambient physical states surrounding an SSC

functional conditions influences on an SSC resulting from the performance of design functions (operation of a system or component and loading of a structure)

operating conditions service conditions, including normal and error-induced conditions, prior to the start of a design basis accident or earthquake.

normal conditions operating conditions of a properly designed, fabricated, installed, operated, and maintained SSC, excluding design basis event conditions

error-induced conditions adverse pre-service or service conditions produced by design, fabrication, installation, operation, or maintenance errors

design conditions specified service conditions used to establish the specifications of an SSC (generally includes margin of conservatism beyond expected service conditions)

stressor agent or stimulus that stems from pre-service and service conditions and can produce immediate or aging degradation of an SSC

normal stressor stressor that stems from normal conditions and can produce aging mechanisms and effects in an SSC

error-induced stressor stressor that stems from error-induced conditions and can produce immediate or aging degradation beyond that produced by normal stressors

design basis event stressor stressor that stems from design basis events and can produce immediate or aging degradation beyond that produced by normal stressors

DEGRADATION/AGING

characteristic property or attribute of an SSC (such as shape; dimension; weight; condition indicator; functional indicator; performance; or mechanical, chemical, or electrical property)

condition the state or level of characteristics of an SSC that can affect its ability to perform a design function

degraded condition marginally acceptable condition of an unfailed SSC that could lead to a decision to perform planned maintenance

aging general process in which characteristics of an SSC gradually change with time or use

aging mechanism specific process that gradually changes characteristics of an SSC with time or use

aging effects net changes in characteristics of an SSC that occur with time or use and are due to aging mechanisms

degradation immediate or gradual deterioration of characteristics of an SSC that could impair its ability to function within acceptance criteria

aging degradation aging effects that could impair the ability of an SSC to function within acceptance criteria

normal aging degradation aging degradation produced by normal conditions

error-induced aging degradation aging degradation produced by error-induced conditions

LIFE

age time from fabrication of an SSC to a stated time

time in service, time from initial operation of an SSC to a stated time

installed life period from installation to retirement of an SSC

service life actual period from initial operation to retirement of an SSC

design life period during which an SSC is expected to function within acceptance criteria

FAILURE`

failure inability or interruption of ability of an SSC to function within acceptance criteria

degraded failure failure in which a functional indicator does not meet an acceptance criterion, but design function is not completely lost

complete failure failure in which there is a complete loss of function

wearout failure produced by an aging mechanism

failure cause circumstances during design, manufacture, test, or use that have led to failure

root cause fundamental reason(s) for an observed condition of an SSC that if corrected prevents recurrence of the condition

failure mechanism physical process that results in failure

failure mode the manner or state in which an SSC fails

MAINTENANCE

aging management engineering, operations, and maintenance actions to control within acceptable limits aging degradation and wearout of SSCs

life management integration of aging management and economic planning to: (1) optimize the operation, maintenance, and service life of SSCs; (2) maintain an acceptable level of performance and safety; and (3) maximize return on investment over the service life of the plant

maintenance aggregate of direct and supporting actions that detect, preclude, or mitigate degradation of a functioning SSC, or restore to an acceptable level the design functions of a failed SSC

preventive maintenance actions that detect, preclude, or mitigate degradation of functional SSC to sustain or extend its useful life by controlling degradation and failures to an acceptable level; there are three types of preventive maintenance: periodic, predictive, and planned

periodic maintenance form of preventive maintenance consisting of servicing, parts replacement, surveillance, or testing at predetermined intervals of calendar time, operating time, or number of cycles

planned maintenance form of preventive maintenance consisting of refurbishment or replacement that is scheduled and performed prior to failure of an SSC

corrective maintenance actions that restore, by repair, overhaul, or replacement, the capability of a failed SSC to function within acceptance criteria

repair actions to return a failed SSC to an acceptable condition

refurbishment planned actions to improve the condition of an unfailed SSC

CONDITION ASSESSMENT

predictive maintenance form of preventive maintenance performed continuously or at intervals governed by observed condition to monitor, diagnose, or trend an SSC's functional or condition indicators; results indicate current and future functional ability or the nature and schedule for planned maintenance

surveillance observation or measurement of condition or functional indicators to verify that an SSC currently can function within acceptance criteria

condition monitoring observation, measurement, or trending of condition or functional indicators with respect to some independent parameter (usually time or cycles) to indicate the current and future ability of an SSC to function within acceptance criteria
condition indicator characteristic that can be observed, measured or trended to infer or directly indicate the current and future ability of an SSC to function within acceptance criteria
functional indicator condition indicator that is a direct indication of the current ability of an SSC to function within acceptance criteria
acceptance criterion specified limit of a functional or condition indicator used to assess the ability of an SSC to perform its design function

DISCUSSION OF KEY CONCEPTS

The following is a summary by category of some of the key technical concepts that are made more precise by common terms and their definitions. Common terms are shown in boldface type. (Some of the terms may not appear in the partial glossary in Table 1).

Causes of Degradation. **Service conditions** are all *actual* conditions that influence an SSC. They encompass **operating conditions** (including **normal** and **error-induced conditions** as well as anticipated transients) and accident conditions. At any given time, **service conditions** include **environmental conditions** (ambient physical states surrounding an SSC) and **functional conditions** (influences resulting from performance of design functions). **Design conditions** are *hypothetical* conditions generally specified to include a margin of conservatism beyond expected actual service conditions.

Life. **Service life** is the *actual* period an SSC provides useful service. This may differ from the *expected* service life, i.e., **design life**. The **age** of an SSC (measured from its time of fabrication) may differ from its **time in service** (measured from initial operation of the SSC).

Degradation/Aging. **Conditions** produce **stressors** and stressors produce SSC **degradation**. Degradation is gradual (aging) or immediate (non-aging). (Immediate means occurring in a duration short with respect to a typical **condition monitoring** interval.) The term **aging** denotes the *general process* that changes **characteristics** of an SSC with time or use. **Aging mechanisms** are the *specific processes* of change such as wear, fatigue, creep, erosion, or corrosion. Aging mechanisms cause **aging effects** which are the net changes in characteristics of an SSC.

Aging degradation is the negative subset of aging effects. It is produced by **operating conditions,** including both **environmental conditions** such as temperature and radiation as well as **functional conditions** such as relative motion between parts. Operating conditions produce **normal stressors** or **error-induced stressors. Design basis events** include anticipated transients during plant operation (which can contribute to **aging**) and design basis accidents and earthquakes (which produce immediate, not aging, **degradation**). A **degraded condition** is marginally acceptable, but is not a **failure.**

Failure. In a **degraded failure, acceptance criteria** on condition or performance are not met, but there is partial function. In **complete failure** there is no function. **Failure** is usually produced by a sequential chain of causes, not a single cause. **Wearout** is a failure whose last cause is an **aging mechanism.** The **root cause** may not be that aging mechanism. **Premature aging** may cause inservice **failure** of an SSC. The term **accelerated aging** should be reserved for **artificial aging,** usually performed in a laboratory. **Failure analyses** identify **failure causes,** the **failure mechanism,** and the **failure mode.** Each of these terms has a different meaning. The **root cause** of **error-induced aging degradation** and failures is *not* **aging,** but rather human error.

Maintenance. **Aging management** consists principally of **maintenance,** but it also includes all other plant activities to control **aging degradation** and **wearout.** It is important to note that both normal and error-induced aging degradation must be controlled. **Maintenance** is a broad term that includes **corrective maintenance** and **preventive maintenance. Maintenance** may be performed by maintenance, engineering, or operations personnel. **Preventive maintenance** includes **predictive maintenance** such as

surveillance, **testing**, and **condition monitoring**. Predictive maintenance is *preventive* in the sense that predictions of future conditions may call for **planned maintenance**, which *prevents* failure. **Repair** is performed only on a failed SSC; **refurbishment** is performed only on an unfailed SSC. An **overhaul** is an extensive repair and/or refurbishment.

Condition Assessment. **Surveillance** examines **functional indicators** when it checks current performance ("go/no-go"). The condition indicators or functional indicators expressed by **acceptance criteria** must be measurable if they are to be compared or trended (**condition monitoring**).

BENEFITS

The principal benefits to be derived from Common Aging Terminology are:

- Improved reporting and interpretation of plant experience on degradation and failure of SSCs
- Improved interpretation and compliance with codes, standards, and regulations related to the aging of nuclear power plants
- A starting point for revisions of existing formal definitions or future development of definitions of terms related to aging that do not as yet have formal definitions
- Improved communication and assimilation of aging research results.

The greatest challenge with regard to plant experience is to perform accurate root cause evaluations. A prerequisite to fashioning an effective remedy is to discriminate failures caused by aging from failures due to human error. Traditionally there has been a tendency to classify many failures as aging-related when the true failure cause was error in fabrication, installation, operation, maintenance, or testing. This can waste resources with attempts to correct the wrong problem and can lead to overblown estimates of aging failure rates that are used in mathematical models of risk that include age-dependent terms. Common aging terminology can help to clarify concepts needed to make accurate root cause and failure rate determinations.

To provide plant personnel and others who address aging with a handy reference to facilitate and encourage widespread use of common aging terminology, EPRI has published a pocket-size glossary (Common Aging Terminology, 1993).

A cooperative effort by the International Atomic Energy Agency (IAEA) and the Organization for Economic Cooperation and Development (OECD) is using these definitions as a starting point for developing common international aging terminology.

As experience with this terminology grows via usage and further development by other industry organizations, EPRI may publish revised versions to keep common aging terminology up to date. Suggestions for improving the terminology are wholeheartedly welcomed.

REFERENCES

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