Aging Identification and Assessment Checklist

Electrical Components

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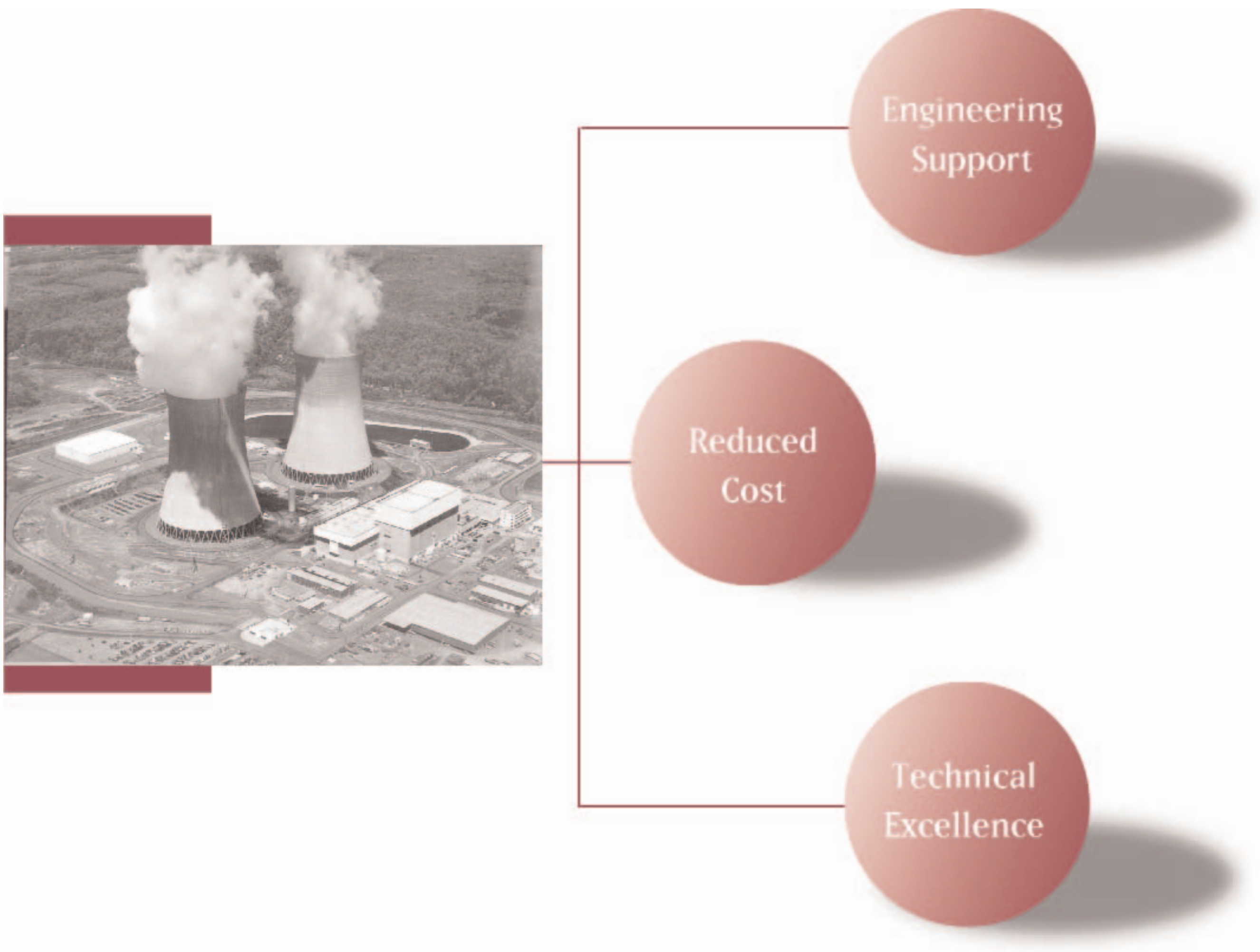

PLANT SUPPORT ENGINEERING

Aging Identification and Assessment Checklist

Electrical Components

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Final Report, January 2005

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PRODUCT DESCRIPTION

Aging-related degradation continues to cause equipment reliability problems in nuclear power plants, in part because effective strategies to address aging issues are not consistently applied. Two major obstacles to forming an effective aging management strategy are a lack of understanding by plant personnel of the leading indicators of aging degradation and a lack of simple methodologies to support plant staff application of this knowledge. This report contains component-level checklists that present likely visible indicators of aging degradation, the degradation mechanisms likely to be occurring, and the potential ramifications of such degradation. The following components are covered in this report:

- Cables, conduits, cable trays, buses, terminations, and splices
- Transformers
- Motors and generators
- Breakers and switches

Results and Findings

This report provides practical information describing the aging degradation mechanisms that may affect various plant components. The checklists detail the potential indicators of aging degradation that might be observed during a typical walkdown. In some cases, the indicators themselves may be a degraded condition that may either cause or accelerate the aging degradation mechanism.

Challenges and Objectives

This product is intended for use by plant engineers during a walkdown of the systems and/or components for which they are responsible. Having this type of information readily available during a walkdown allows a plant engineer to:

- Identify the indicators that a component is aging
- Understand the aging degradation mechanisms that are likely to affect different plant structures, systems, and components (SSCs)
- Understand the potential impact of the degradation
- Identify conditions under which aging degradation is likely to occur

System or component engineers will be able to integrate these component-level checklists into their system walkdown procedure. In this way, many of the site-specific system monitoring requirements for license renewal and the Maintenance Rule can be addressed in a walkdown.

Applications, Values, and Use

As nuclear plants continue to age, plant staff will need practical tools to identify and address aging degradation of a particular component type. These checklists provide plant engineers with practical guidance to identify aging degradation based on their observations.

EPRI Perspective

EPRI has created numerous products to help plant personnel meet the challenges of working with aging SSCs. This report provides this information in a form that will allow plant personnel to have a ready reference with them as they investigate the condition of plant SSCs.

Approach

These checklists were developed to complement EPRI product numbers 1007932, *Identification and Detection of Aging Issues Training Materials;* 1007933, *Aging Assessment Field Guide;* 1009743, *Aging Identification and Assessment Checklist: Mechanical Components*; and 1011224, *Aging Identification and Assessment Checklist: Concrete and Steel Structures.* The report also incorporates years of nuclear industry research and investigation into understanding and identifying aging degradation.

Keywords

Aging
Aging management
Equipment reliability
Material degradation

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1
INTRODUCTION

Background

Unanticipated equipment failures from aging-related degradation continue to negatively impact utilities' efforts to maintain equipment availability, reliability, and the maximum useful life of plant structures, systems, and components (SSCs).

Many nuclear power plants have taken or are taking the appropriate actions to renew their operating licenses for an additional 20 years. In many cases, a renewed license will allow a plant to continue operating for as much as 30 years or more from the date of renewal. The plants must continue to meet safety, production, and cost goals during that extended period. Additionally, rising prices of replacement power and environmental issues have an added impact on the cost of operation. These factors place additional focus on the need for enhanced plant reliability. Efficient management of aging effects on the plant SSCs for the remainder of plant life becomes a significant factor in maintaining plant reliability. Two major obstacles to the formation of an effective equipment aging strategy are lack of understanding by plant personnel of the leading indicators of aging degradation and a lack of simple methodologies to support plant staff application of this knowledge.

Related Products

In 2002, EPRI Plant Support Engineering (PSE) initiated a project to develop practical tools that enhance a plant staff's understanding of aging-related degradation of SSCs and to identify the leading indicators of the various degradation mechanisms. The tools developed from this project help plant staff to recognize degradation indicators and to take action before the degradation unacceptably reduces overall plant reliability. These tools are intended to be complementary and to help plant personnel identify and understand the mechanisms of aging-related degradation. The following products have also been developed from this project:

- *Identification and Detection of Aging Issues Training Materials* (EPRI product number 1007932). These training materials provide a broad overview of aging management and the degradation mechanisms associated with particular material types.
- *Aging Assessment Field Guide* (EPRI product number 1007933). This pocket reference describes likely degradation mechanisms of various material types to assist plant staff in identifying both the indicators of degradation and the steps required to minimize the consequences of the degradation.

- *Identification and Assessment Checklist: Mechanical Components* (EPRI product number 1009743). This checklist details potential indicators of aging degradation that might be observed during a typical walkdown. In some cases, the indicators themselves may be a degraded condition that may either cause or accelerate the aging degradation mechanism. The components covered in this report are pumps and compressors, valves, tanks and pressure vessels, and piping and piping components.
- *Identification and Assessment Checklist: Civil and Structural Components* (EPRI product number 1011224). This checklist is identical in purpose and format to the Mechanical Components Checklist described above but is applicable to concrete structures and supports and steel structures.

The first two products address aging degradation from a materials perspective. They describe the aging degradation mechanisms likely to affect materials in plant SSCs and how to minimize the consequences of the aging degradation. The training materials are intended for engineering staff; however, they can be modified for craft personnel as well. The field guide is intended to be taken into the plant during a walkdown to reinforce or provide specific information about a topic addressed in the training materials. The checklists are also intended for use during specific plant walkdowns and to supplement information included in existing walkdown procedures. However, because each product contains unique information, they may be used independently of one another.

Checklist Overview

Each appendix of this report contains the checklist for a particular component type. This report covers cables, conduits, cable trays, buses, terminations, and splices; transformers; motors and generators; and breakers and switches. These checklists list some potential visible indicators of aging degradation, the degradation mechanisms or stressor likely to be occurring, and the potential consequences of taking no action to mitigate the degradation mechanism.

The checklists are presented as a three-column table, with one table applicable to a particular component type. The first column lists the indicators of aging degradation likely to be observed during a walkdown. The second column lists the likely degradation mechanism occurring or the stressor that may accelerate the aging process. The last column lists the potential consequences of taking no action to mitigate the degradation (see Table 1-1).

Table 1-1
Checklist Format

Component Type		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Observed symptom or condition	Likely mode of degradation or condition causing the aging to be accelerated	Possible results of not acting to mitigate the stressors causing the degradation

Intended Use

Checklists for individual component types can be incorporated into specific system walkdown procedures as needed; they are included here as appendices organized as follows:

Appendix A – checklist for cables, conduits, cable trays, buses, terminations, and splices

Appendix B – checklist for transformers

Appendix C – checklist for motors and generators

Appendix D – checklist for breakers and switches

A

CHECKLIST FOR CABLES, CONDUITS, CABLE TRAYS, BUSES, TERMINATIONS, AND SPLICES

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Tray and Conduit System		
Broken or tightly bent flexible conduit; broken or damaged rigid conduit; loose or damaged conduit connectors	• Vibration or excessive maintenance-related flexing • Physical contact in high pedestrian traffic areas • Construction or modification activity • Possible inappropriate maintenance practices • Minimum bend radius exceeded	• Mechanical damage to cable insulation leading to short or open circuit conditions and/or loss of shielding • Ingress of moisture or chemicals and degradation of cable insulation or terminations • Stressed or disturbed terminations leading to high resistance connections and overheating • Loss of seismic capacity • Broken insulation leading to shorts that can cause loss of function of powered equipment
Missing or damaged termination or pull box/fixture ceovers; loose or damaged cable tray sections; loose or damaged environmental seals	• Vibration • Physical contact in high pedestrian traffic areas • Construction activity or inappropriate use of cable trays as staging or ladders • Possible inappropriate maintenance practices	• Mechanical damage to cable insulation • Ingress of moisture or chemicals and degradation of cable insulation or corrosion of terminal connectors • Stressed or disturbed terminations leading to high resistance connections and overheating • Loss of EQ barrier; inoperability

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Tray and Conduit System		
Missing padding, fairleader, bells, or bushings from cable drop-outs in cable tray or from cable entry points into conduit	• Vibration • Construction activity • Possible inappropriate maintenance practices	• Mechanical damage to cable insulation leading to shorts and arcing
Broken or degraded cable vertical support system	• Improper restoration following maintenance or modification • Vibration • Time-related loosening of Kellums grip(s) or other devices (for example, tie-wraps) used in design of support system	• Mechanical damage to cable insulation system due to concentration of the vertical load at the transition from horizontal to vertical and pinching of the cable at the top support point • Seismic capacity may be degraded
White stains on bottom of galvanized cable tray	• Water leakage onto the surface causing corrosion of zinc galvanizing • Boric acid leak or spill	• Water or chemical degradation of cable insulation material • Corrosion of cable tray and supports • Corrosion of terminations, shielding, or conductor • Loss of seismic capacity of cable tray system

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Cracks or discoloration, especially a change from black to greenish brown in cable jackets	• Exposure to high temperature or radiation • For PVC cables, exposure to UV from lighting (especially fluorescent lights) • Damage from missing thermal insulation on adjacent steam lines and valves • Widespread thermal damage caused by cable or neutral overload (power cables only)	• In containment and in high-energy line break (HELB) areas, possible insulation failure under accident environment conditions • Manipulation during maintenance may cause the insulation to crack, making cable susceptible to shorting in moist environments • In extreme cases after cracking of insulation, loss of insulating capability and development of shorts to ground or between phases
Cracks in wire insulation where there is no jacket (particularly white insulation)	• Exposure to UV from lighting (especially fluorescent lights) • Exposure to sunlight	• Loss of insulating capability and development of shorts to ground or between phases

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Soft, discolored, or embrittled cable jacket and/or insulation materials	• Exposure to chemical spillage or fumes • Radiation exposure • Exposure to high temperature	• Manipulation during maintenance will cause insulation cracks, making insulation susceptible to shorting in moist environments • In extreme cases after cracking of insulation, loss of insulating capability and development of shorts to ground or between phases • Personnel safety: electrical shock hazard
Elevated ambient temperature and humidity in area occupied by cable and other electrical equipment	• Steam leak in the area • Missing thermal insulation on adjacent steam piping (very rapid effects on adjacent cable) • Loss of ventilation air flow pathway(s) or failure of active ventilation equipment • Proximity to heat source such as steam pipe or steam turbines • Possible inappropriate maintenance practices	• Thermal damage of insulation material causing it to become brittle and crack, allowing moisture intrusion and electrical faults • Corrosion of terminal connections and other exposed metal surfaces leading to high resistance connection and further overheating resulting in eventual termination failure • Degradation or loss of bus work insulation and shorting

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Mechanical damage to cables	• Improperly controlled pulling practices • Insufficient slack after installation • Inadequate vertical support of long vertical runs • Tight wiring across hinged doors on switchgear cubicles and control cabinets • Physical contact in high pedestrian traffic areas • Inappropriate use of cable trays as scaffolds and work surfaces • Construction activity • Possible inappropriate maintenance practices (likely locations of damage include splices, penetrations, saddles, cable ties, sharp bends, conduit edges, tool drop areas, ladders, and vibrating equipment) • Vibration	• Exposure of shield or conductor to corrosion attack • Physical damage to cable insulation • Ingress of moisture or chemicals leading to degradation of cable insulation • Stressed or disturbed terminations leading to high resistance connections and overheating • Loss of circuit continuity or development of electrical faults
Cable forced into tight radius bend	• Improper installation practices • Possible inappropriate maintenance practices	• Low-voltage cable: possible invalidation of environmental qualification leading to accident environment failure • Medium-voltage cable: loss of concentricity of shielded cable conductor and shield causing a loss of shielding value; disruption of shield layer leading to electrical failure

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Slimy surface on cable insulation	• Microbiological attack of insulation materials, for example, biological activity in continuously damp areas and in direct buried conditions • Release of plasticizer from PVC jacket and insulation material, particularly in warmer exposures (green or black tacky surface) • Lubricant contamination from an external source	• Softening and degradation of other nearby polymers that come in contact with the released plasticizer • Softening by oil leaked from external source • Embrittlement of the cable PVC jacket and insulation as the plasticizers migrate from the material • Degradation of the insulation can lead to electrical shorts and personnel safety hazards • Degraded insulation value resulting in shorts between adjacent conductors
Embrittlement and/or cracking of cable jacket or wire insulation	• Cable located in close proximity to fluorescent lighting or in outdoor area with significant direct exposure to sunlight	• Embrittlement and cracking of jacket exposes insulation to UV, leading to similar degradation and ultimately exposure of conductor to moisture, resulting in shorts and arcing • UV degradation of wire insulation where there is no jacket (particularly white insulation)

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Cables located in close proximity to heat source (such as steam pipe, hot water pipe, or continuously energized solenoid)	• Thermal degradation of jacket and insulation	• Embrittlement and cracking of jacket and insulation, leading to exposure of conductor to moisture, resulting in electrical shorting
Traces of soot, burnt surface, arc strike, or other apparent electrically related damage	• Low-voltage cable (<600V): — Electrical short — High resistance connection • Medium-voltage cable (4160+V): — Partial discharge — Electrical tracking — Electrical short — High resistance connection	• Tracking where current follows the surface of an insulator to ground or another lead leaving a burned path behind • Partial discharge (small arcs that do not completely bridge the insulation) is indicative of damaged insulation and localized high electrical stress in medium-voltage systems and can lead to insulation failure • A short circuit that will generally leave a damage site that is observable depending on the level and duration of fault current • High resistance connections can lead to melting or burning of the insulation, leading to electrical shorts, arcing, and potentially, fire

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Buildup of contamination on insulator or bushing	• Contaminant-laden atmosphere (for example, soot, salt, or dust/dirt)	• Electrical tracking across the insulator exterior surface • Flashover of the insulator, particularly under moist conditions
Water in electrical manhole	• Ground water intrusion • Rain water runoff • Condensation	• Degradation of cable duct seals • Corrosion of cable supports • Degradation of cable insulation with potential shorts
Corroded fasteners in electrical manhole; water marks on manhole walls	• Previous presence of water in the manhole	• Degradation of cable support capacity • Degradation of cable duct seals • Degradation of cable insulation with potential shorts
Presence of water in NEMA 4 enclosure	• Condensation inside conduits feeding from non-NEMA 4 enclosures in a high humidity area	• Corrosion of components inside NEMA 4 enclosure • Loss of function of components inside NEMA 4 enclosure

Table A-1
Cables, Conduits, Cable Trays, Buses, Terminations, and Splices (Continued)

Cables, Conduits, Cable Trays, Buses, Terminations, and Splices		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Cable Jacket and Insulation System		
Corrosion on electrical terminals	• Exudation of plasticizers and processing aids from cable jacket and insulation • Condensation in high humidity areas • Water drainage/spillage from overhead equipment	• High resistance connection • Loss of continuity in signal cables • Loss of connection
Loss of space heater operation in bus ducts	• Heater failure • Loss of power to heater	• Increased humidity • Corrosion of fasteners • Bus grounds

B
CHECKLIST FOR TRANSFORMERS

Table B-1
Transformers

Transformers		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
High-pitched sound coming from the cooling fans	• Bearing wear or failure	• Loss of one or more fans imminent with potential impact on transformer cooling system capacity • Forced reduction in transformer through-put
Change in pitch or sound type	• Degradation of iron core lamination	• Heat generation • Oil decomposition and combustible gas generation
Oil level no longer visible in bushing sight glass	• Leakage through degraded gasket seals • Cracked or broken porcelain	• Loss of insulating capability within the bushing • Partial discharge within the bushing • Catastrophic failure of bushing

Table B-1
Transformers (Continued)

Transformers		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Rust stains on bottoms of radiator; corrosion product accumulations within the cooling coils of the radiator	• Degraded protective coating allowing corrosion of exposed metal surfaces • Accumulation of dirt in cooling coils of radiator promoting coating failure and corrosion	• Perforation of radiator cooling coils leading to oil leakage • Reduced cooling capacity in areas where cooling coil surfaces are fouled with corrosion product or dirt
Oil accumulation on bottom of radiator; oil leakage from transformer penetrations; oil staining on transformer tank; oil accumulation on the ground	• Perforation of radiator cooling coils by corrosion or mechanical damage • Leakage from degraded radiator connection gasket seals • Leakage from degraded transformer penetration gasket seals	• Reduction in transformer oil volume • Loss of transformer insulation system rating • Transformer failure if undetected or unabated • Environmental issues with oil spillage onto the ground
Accumulation of a dirt film on the bushing and lightning arrestor porcelain	• Exposure to excessive dust, soot, salt, and other airborne contaminants • Inadequate rainfall to periodically provide cleaning of the porcelain	• Electrical tracking across the porcelain • Flashover • Loss of through-put
Increase in transformer oil temperature	• Increased loading • Inadequate cooling (fan failure, oil pump degradation, blocked radiator cooling coils) • Circulating currents • Higher internal electrical losses caused by loosening of iron stack(s)	• Thermal degradation of oil • Dissolved gas (including combustible gases) generation • Potential to exceed rated transformer temperature • Catastrophic transformer loss if combustible gases exceed permissible levels and internal arcing occurs

Table B-1
Transformers (Continued)

Transformers		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Low transformer oil temperature	• Light load • Excessive cooling	• Static electrification if oil pumps run continuously with lightly loaded transformer and low oil temperature; could lead to transformer failure
Detectable increase in normal level of transformer noise (humming)	• High through-fault current levels resulting in mechanical structure degradation • Marginal design for maintaining core stack in highly compressed status	• Approved noise emission levels exceeded • Left uncorrected, losses will increase, generating greater internal heating and accompanying gas generation
Loss of or reduction in nitrogen gas blanket pressure (if no conservator)	• Local nitrogen supply depleted • Upper regions of transformer tank leaking resulting in inability to maintain nitrogen pressure	• Introduction of moisture-laden air into space meant to hold dry nitrogen • Corrosion of internal metallic parts above oil level and introduction of corrosion products into insulating oil and paper • If undetected/unabated, transformer could fail due to loss of insulation system rating
Incorrect fan rotation; reversed air flow	• Fan motor improperly reconnected during maintenance	• Reduced or lost cooling capacity • Overheating and oil degradation

Table B-1
Transformers (Continued)

Transformers		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Loss of space heater operation in electrical enclosures	• Heater failure • Loss of power to heater	• Increased humidity • Corrosion of fasteners or terminations • High resistance connections
Evidence of water in junction and control boxes	• Condensation inside conduits feeding from non-weather-tight enclosures • Degraded weather seals or gaskets	• Corrosion of fasteners or terminations inside enclosure • Loss of function of components inside enclosure • Loss of transformer control
Corrosion on electrical terminal in auxiliary boxes	• Condensation inside box • Introduction of water through connecting conduit	• High resistance connections
Low nitrogen blanket pressure	• Degradation of gaskets and seals • Loss of automatic pressurization	• Ingress of air and moisture leading to corrosion • Absorption of moisture into oil leading to reduced dielectric strength
Degraded or depleted desiccant condition during transformer storage	• Degradation of environmental wrapping • Introduction of humidity or moisture • Degradation of seals or gaskets	• Corrosion of transformer components • Degraded capability of transformer to function when installed • Loss of transformer capability

Table B-1
Transformers (Continued)

Transformers		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Degraded cabling/connectors on fans and motors	• UV degradation of jacket and wire insulation • Mechanical damage • Corrosion	• Reduced ability to maintain oil temperature • High resistance connections leading to fan motor degradation or failure • Overheating and decomposition of transformer oil
Crackling	• Corona discharge	• Generation of combustible gases in transformer • Degradation of transformer paper insulation
Hydran indicator of oil total combustible gases	• Oil decomposition • Insulation decomposition	• Shortened transformer life or impending failure
Dirty coolers/fins	• Exposure to dusty/dirty environment • Inadequate maintenance	• Reduced ability to maintain oil temperature • Overheating and decomposition of transformer oil
Lightning counter indication	• Multiple lightning strikes to the lightning arrestors	• Loss of lightning arrestor function • Increased dissolved gas analysis (including combustible gases) generation • Progressive degradation of arrestor and transformer

C
CHECKLIST FOR MOTORS AND GENERATORS

Table C-1
Motors and Generators

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Change in noise (more applicable to smaller motors that generate less noise: <600 V, <200 Hp)	• Increased electrical load on generator • Increased mechanical load on motor • Increased friction within motor or generator, for example, bearing load or wear due to loss of lubrication • Time at temperature and resultant loosening of iron core stack(s)	• Thermal degradation of power lead insulation • Thermal degradation of winding insulation • Thermal degradation of bearing lubricant • Increased vibration levels • Failure of motor or generator • Delamination of stator
High-pitched noise	• Loss of lubrication in bearing • Bearing wear • Partially blocked cooling fan pathway(s)	• Bearing failure • Thermal degradation of winding insulation
“Hot” smell (smell of overheated or burning insulation)	• Overheated conductors, including coils • High resistance connection causing localized heating	• Degraded insulation leading to electrical shorts and arcing • Potential personnel safety hazard • Equipment shutdown

Table C-1
Motors and Generators (Continued)

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Change in color of paint on the casing	• Localized hot spot due to loss of bearing lubrication • Overheated surface caused by electrical turn shorting or increased winding resistance • Increased electrical or mechanical load • Chemical spill	• Bearing failure • Thermal degradation of winding insulation • Additional turn-to-turn insulation failures • Loss of motor due to internal faulting • Corrosion of casing • Introduction of chemicals into the motor or generator may attack and degrade wiring insulation

Table C-1
Motors and Generators (Continued)

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Increased ambient temperature in immediate vicinity of motor or generator	• Temporary tarps or structures used for nearby maintenance work blocking cooling air flow to motor or generator • Degraded or lost ventilation system for the area • Increased friction within motor or generator, for example, bearing load or wear due to loss of lubrication • Possible inappropriate maintenance or housekeeping practices	• Thermal degradation of power lead insulation • Thermal degradation of winding insulation • Thermal degradation of bearing lubricant • Thermal degradation of rotor and stator iron varnish insulation system • Equipment shutdown
Casing hot to touch	• Temporary tarps or structures used for nearby maintenance work blocking cooling air flow to motor or generator • Internal cooling paths blocked • Increased friction within motor or generator, for example, bearing load or wear due to loss of lubrication • Possible inappropriate maintenance or housekeeping practices	• Thermal degradation of power lead insulation • Thermal degradation of winding insulation • Thermal degradation of bearing lubricant and bearing failure • Thermal degradation of rotor and stator iron varnish insulation system • Equipment shutdown

Table C-1
Motors and Generators (Continued)

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Increase in temperature of power leads to motor or generator (iso-phase bus duct to large generator)	• Increased electrical load on generator • Increased mechanical load on motor • Obstructed or malfunctioning area ventilation system or ventilation dedicated to the motor or generator	• Thermal degradation of power lead insulation • Thermal degradation of winding insulation • Thermal degradation of bearing lubricant • Catastrophic loss of bus duct
Grease leakage from motor bearing housing	• Overgreasing • Degraded seal • Overheating of bearing	• Loss of lubricant causing bearing wear or failure • Grease may also be leaking into the windings where lubricant may block cooling passageways causing overheating • Lubricant interaction with wiring insulation materials and loss of insulation rating
Accumulated dirt film on casing	• Exposure to contaminant-laden environment • Possible inappropriate housekeeping practices • Possible inappropriate maintenance practices	• Dirt accumulation within cooling air channels causing increased heating and thermal degradation of winding insulation and bearing lubricant
Stator cooling water system temperature increase; deionizer differential pressure rise; conductivity rise; flow reduction	• Plugged resin in ionizer due to corrosion (copper) • Change in electrical load • Restricted flow through cooling water strainer	• Reduced cooling capability • Overheating of generator internal assemblies and increased rate of aging of system • Increased vibration due to temperature-induced rotor bowing

Table C-1
Motors and Generators (Continued)

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Hydrogen purity/gas analyzer showing decrease in purity level	• Vacuum seal oil pump leakage	• Reduced cooling capacity • Increased operating temperature
Abnormal “sparking” at generator collector ring brush/collector ring interface	• Time at load, that is, end of life of brush • Inappropriate selection of brush material • Loss of brush-to-collector-ring contact pressure (spring constant degradation)	• Damage to collector ring surface with localized heating • Increased brush material wear rate
Disturbed or loose foundation bolts and grout; cracked welds at the housing feet; vibration felt when casing is touched	• Vibration during operation • Cyclic forces induced by the component being driven by the motor (for example, pump) • Frequent starts with high shaft torque	• Bearing wear or failure • Increased vibration due to degradation of foundation/support • Increased wear of coupling between motor and driven component
Air inlet screens, filters, and vents are dirty or blocked by tags, tarps, and so on	• Possible poor housekeeping • Possible inadequate maintenance practices	• Reduced or lost cooling air flow • Overheating and thermal degradation of polymeric insulation leading to shorting or arcing

Table C-1
Motors and Generators (Continued)

Motors and Generators		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Low oil level in sight glass or inability to observe oil level	• Loss of oil • Inadequate oil inventory established at completion of maintenance • Degraded seals or gaskets • Dirty sight glass	• Inadequate bearing lubrication • Bearing overheating and wear • Loss of motor function
Rise in motor bearing closed loop cooling water temperature	• Reduced closed loop cooling water flow to bearing • Reduced heat transfer in closed loop cooling water/service water heat exchanger • Increased heat generation in bearing	• Oil decomposition • Reduced lubrication capability and increased bearing wear
Rise in ambient temperature near motor	• Loss of area ventilation flow • Additional heat source in area	• Overheating of motor • Thermal degradation of polymer materials in the motor • Thermal degradation of bearing lubricant
Temperature control valve position indicating higher flow rate of cooling water to bearing	• Increased thermal load causing need for higher cooling water flow rate to maintain desired bearing temperature	• Increased flow rate causes higher flow velocity through cooling coil tubing and increased potential for erosion damage and other flow-related issues

D

CHECKLIST FOR BREAKERS AND SWITCHES

Table D-1
Breakers and Switches

Breakers and Switches		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Face of breaker warm or hot to touch	• Excessive electrical loading • Proximity to heat source • Loss of area ventilation system	• Contact welding resulting in loss of function • Degradation of polymeric components
“Hot” smell (smell of overheated or burning insulation)	• Excessive electrical loading • Proximity to heat source • Loss of area ventilation system	• Degradation of polymeric components
Buzzing or crackling sound	• Excessive electrical loading • Misalignment of contacts	• Arcing at contact faces leading to loss of function
Discolored/cracked conductor insulation	• Exposure to chemical spillage or fumes • Radiation exposure	• Manipulation during maintenance will cause insulation cracks making insulation susceptible to shorting in moist environments • In extreme cases after cracking of insulation, loss of insulating capability and development of shorts to ground or between phases • Personnel safety: electrical shock hazard
Corrosion on electrical terminals	• Exudation of plasticizers and processing aids from cable jacket and insulation • Condensation in high humidity areas • Water drainage/spillage from overhead equipment	• High resistance connection • Loss of continuity in signal cables • Loss of connection

Table D-1
Breakers and Switches (Continued)

Breakers and Switches		
Observable Indicator	**Possible Stressor or Degradation Mechanism Producing the Indicator**	**Potential Consequence of Taking No Action**
Loss of space heater operation in electrical enclosures	• Heater failure • Loss of power to heater	• Increased humidity • Corrosion of fasteners or terminations • High resistance connections

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