Generator Retaining Ring Moisture Protection Guide

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Research Project 2719

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REPORT SUMMARY

Generator rotor nonmagnetic retaining rings that are exposed to moisture are susceptible to intergranular stress corrosion cracking. By keeping rings free of moisture, utilities prolong the service life of these parts. This report describes methods to use during operation, standby, and maintenance.

Background

Nonmagnetic retaining rings, particularly those of an 18% manganese-5% chromium composition that the industry has used for many years, are susceptible to corrosion attack in the presence of moisture. While utilities have found many rings with corrosion damage–even some with significant cracks—very few catastrophic failures have occurred. These findings and replacement costs have made some utilities reluctant to upgrade to rings made from a new, nonsusceptible alloy. Without these new rings, the key to the prevention of corrosion is the elimination of moisture from the rings' operating environment at all times.

Objective

To prevent corrosion attack by providing guidance on methods that utilities can use to keep nonmagnetic retaining rings dry at all times.

Approach

Investigators surveyed EPRI-member utilities for information on a variety of moisture prevention methods. Manufacturers also provided recommendations on keeping rings dry. Since corrosion attack can occur at any time, regardless of the status of the equipment, the investigators collected information to cover conditions during generator operation, standby (either at standstill or on turning gear), and machine open situations. The investigative team then compiled its findings into this document.

Results

Five generator manufacturers and three utilities responded to the survey, providing a compendium of available information on moisture prevention. The utilities' moisture prevention programs, in particular, represent approaches that are in use and have undergone extensive field testing. Respondents also recommended specific hardware that can contribute to a comprehensive and effective moisture prevention strategy.

EPRI Perspective

Requalification of corrosion-susceptible generator rotor nonmagnetic retaining rings for continuing service is a multistep process that involves preventive and predictive components. The first requirement involves verification that the rings do not already contain critical or near-critical corrosion cracks. Utilities can verify ring integrity nondestructively by using suitable ultrasonic and eddy-current inspection procedures. EPRI has conducted extensive research and sponsored several workshops to provide adequate inspection technology. The results of these activities appear in EPRI reports EL-3209, EL/EM-5117-SR, EL-5814, EL-5825, and NP-6167.

In the next step of the requalification process, EPRI recommends conducting a thorough evaluation of the particular ring to determine if it can withstand additional service and under what conditions. The EPRIGEMS™ *RRing-Life* computer program performs detailed finite-element stress analysis, assesses moisture exposure probabilities under various operation scenarios, inputs flaw parameters, and performs probabilistic fracture mechanics studies to determine the ring's tolerance for cracks under prevailing conditions. The program also allows utilities to perform case-specific sensitivity studies to determine the most effective, general remedial actions. These actions include moisture exposure prevention when in service, on turning gear, and during maintenance outages.

The final step of the process involves using remedial actions that the RRing-Life computer sensitivity study determined to be most effective. As the last element in the multistep requalification process, this document provides guidance both on methods that manufacturers have recommended and on those methods that have been effective in specific utility programs.

TR-102949

Interest Categories

Plant electrical systems and equipment
Maintenance practices
Engineering and technical support
Nuclear component reliability

Keywords

Generators
Retaining rings
Stress corrosion cracking
Nondestructive testing
Inspection

ABSTRACT

Provisions for controlling the environment to which nonmagnetic 18Mn-5Cr retaining rings are subjected are necessary for a comprehensive retaining ring maintenance program. Corrosion attack and crack growth can occur whenever a ring is subjected to moisture, whether the generator is in service, on turning gear, at standstill, or disassembled for repairs. Consequently, measures must be taken at all times to ensure a moisture-free environment. Information on moisture prevention measures gathered from utilities and equipment manufacturers is included in this guidelines report in order to assist utility engineers in their retaining ring maintenance programs.

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INTRODUCTION

Nonmagnetic retaining rings have been in use on higher rated generators by most manufacturers since the late 1950's. A majority of these rings have been made from an austenitic 18% Manganese -5% Chromium steel which is cold-expanded to develop the required strength.

In recent years, stress corrosion cracking of generator retaining rings made from these nonmagnetic steels has emerged as an industry-wide problem affecting all manufacturers. Even so, there have been very few retaining ring failures compared to the thousands of non-magnetic rings currently in service.

A recent sensitivity analysis using the EPRI RRing-Life retaining ring life assessment code (1) may offer a partial explanation. RRing-Life is a probabilistic life assessment code developed by Structural Integrity Associates under contract to EPRI. For this analysis, probability of crack growth to critical size versus initial crack depth was determined for two different levels of retaining ring moisture protection. The results are shown in Figure 1-1. As expected, the two curves converge as the initial crack depth approaches the critical size. That is, for deep cracks, the stress intensity is approaching the critical value and failure is imminent regardless of the environment. For shallow cracks, however, the probability of failure is more a function of moisture exposure than of crack depth. It could therefore be suggested that, in many situations, a ring with minimal damage could be returned to service as long as the operator is confident that the generator rotor can be maintained in a moisture-free environment at all times during operation and shutdown. This example analysis was performed for a specific type of ring. Different material properties, stresses or moisture conditions would obviously affect the results.

It has also been hypothesized that an existing stress corrosion crack would not exhibit crack extension immediately upon moisture exposure but would require a delay period prior to continued growth (2). The EPRI NDE Center is in the process of testing actual ring material to determine this delay time. If this delay time is found to be significant, it may show that a ring with existing damage could be subjected to a brief moisture excursion without further consequences.

In summary, retaining rings are stressed at all times, even during shutdown, as a result of the shrink fit. Stress corrosion cracking results from the interaction of stress and environment. Therefore, if the corrosive environment can be minimized or eliminated, the probability of ring damage is greatly reduced and allows for continued service. The purpose of these guidelines is to provide a compiled source of moisture protection measures for nonmagnetic retaining rings gathered from utilities and equipment manufacturers.

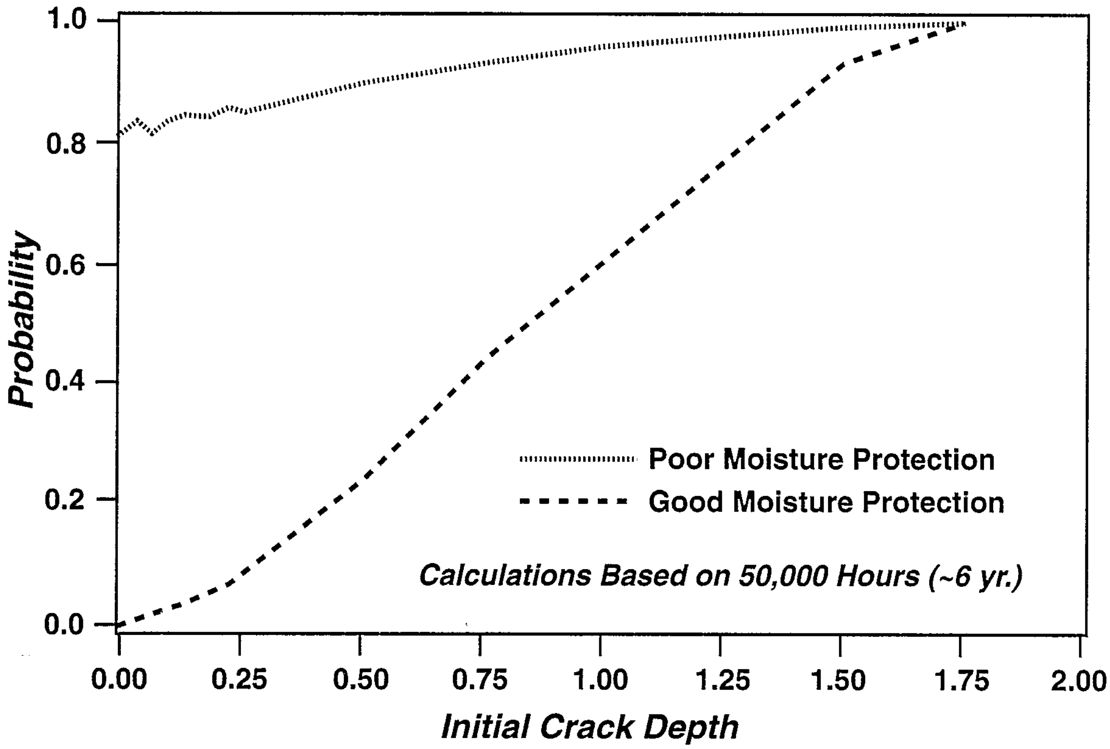

Figure 1-1.
Probability of Failure vs. Initial Crack Depth.

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UTILITY SURVEY RESULTS

Survey Description

A utility survey was conducted to determine current practices for retaining ring protection during unit operation, standby, and shutdown. Additional data concerning the type of damage, if any, that has been experienced on both steam and combustion turbine retaining rings were also gathered. A total of 46 utilities representing 838 large steam turbine generating units responded. A breakdown of the equipment represented by manufacturer is shown in Figure 2-1.

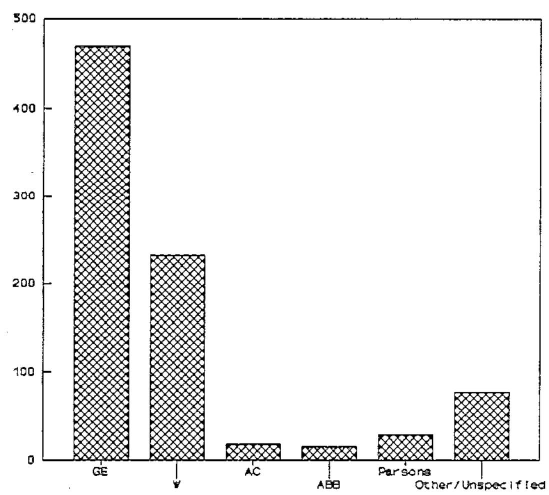

Figure 2-1.
Utility Survey Results. Number of units represented by manufacturers.

Figure 2-2 shows that 39 of the 46 respondents reported some type of ring damage such as corrosion, pitting or stress corrosion cracking. Actual cracking was reported by 16 utilities. Retaining rings have been replaced at 26 of the responding utilities. Additionally, there were also 9 reported cases of damage on combustion turbine generator retaining rings including 2 cases of stress corrosion cracking.

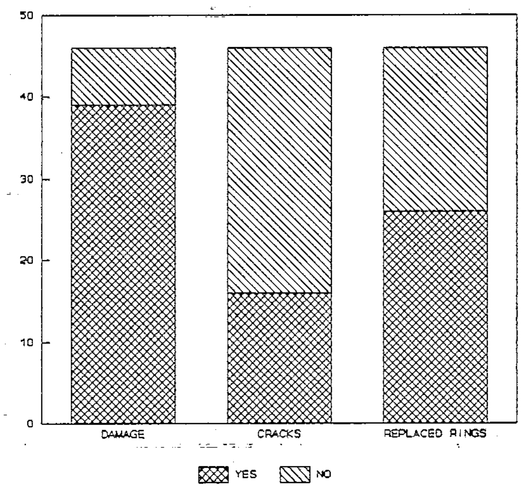

Figure 2-2.
Utility Survey Results. Summary of problems reported for generator retaining rings

Moisture Protection Methods

Following is a summary of moisture protection measures as described in the utility survey responses. Supplemental information is also provided in the appendices.

During Operation

Hydrogen dryers were listed as the most common form of moisture protection during operation with several utilities retrofitting dual-tower hydrogen dryers to their units. The main advantage of dual-tower dryers is their ability to regenerate the drying desiccant in one tower while the other tower is in operation, thus eliminating the need to manually isolate the dryer, purge the dryer of hydrogen and dry out the desiccant. Many of the newer units are also equipped with blowers which provide continued hydrogen circulation while the unit is on turning gear or at standstill.

Other protection measures included monitoring and recording of dew point and relative humidity of the hydrogen gas with alarms for high humidity conditions as well as maintaining hydrogen gas purity and monitoring of the generator liquid detectors.

Unit Offline

While the unit is offline, either on turning gear or at standstill, most utilities maintain the hydrogen gas and seal oil systems and continue to monitor the gas analyzer to ensure hydrogen purity. Also, the hydrogen dryers are kept in service if they have the capability of recirculating the gas.

Other actions listed included isolating the hydrogen coolers to prevent cooling below the dew point and keeping the generator liquid detectors in service.

During Outages

Several methods were listed for protection of the rings if the rotor remains in the stator during the outage. After purging with carbon dioxide or nitrogen, some keep the unit dry by circulating dry instrument air. Others use heat lamps, portable heaters and/or dehumidifiers to maintain a dry environment for the rotors. Another method of heating the rotor is to apply current to the field windings with a welding machine.

With the rotor removed from the stator, the nearly unanimous response was to cover and heat the rotor, with variations in the type of enclosure and heating method. Heating methods ranged from heat lamps to portable heaters and dehumidifiers with humidity monitoring. The most common enclosure was a tent consisting of a wood frame and plastic film cover. At least one utility has constructed a reusable enclosure consisting of. a take-down frame and polyester cover. Regardless of the type of cover, it is imperative that the cover does not contact the ring which could allow condensation to be trapped against the surface.

It is also important to ensure that the ring not come into contact with any moisture retaining materials such as paper or burlap, water-based cleaners, or chlorinated solvents during an outage. Each of these can create initiation sites for stress corrosion cracking.

Replacement Rings

For short term storage, most utilities kept the rings as they were received from the manufacturer in the sealed bags containing desiccant. For long term storage, they were kept in a temperature and humidity controlled enclosure or warehouse.

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SUPPLEMENTAL PROCEDURES AND RECOMMENDED PRACTICES

Several utilities and manufacturers provided detailed information about their retaining ring protection procedures. They are presented in the appendices with the intent of providing the utility engineer with concrete examples representative of current best practices.

Appendix A includes ring protection procedures developed by Philadelphia Electric, Commonwealth Edison, and TU Electric. Appendix B contains recommendations and procedures from several manufacturers and service organizations, including General Electric, Westinghouse, A-C Equipment Services, ABB Power Generation, and GEC Alsthom. Appendix C contains a partial list of equipment suppliers for hydrogen dryers and humidity monitoring equipment gleaned from specific references in the utility survey responses. Appendix D is a compilation of comments from the utility survey.

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CONCLUSIONS

To ensure a reasonable service life, retaining rings basically must be kept free of moisture and corrosive material at all times. Depending on the climate, this would at a minimum require some form of humidity monitoring and control for all operating conditions. The rings should also not be allowed to come in contact with any water-based or chlorinated solvents.

These guidelines, including the detailed supplemental information from utilities and manufacturers, represent the latest information available for developing a comprehensive retaining ring maintenance program.

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2. N. Kilpatrick. "Update on Experience With In-Service Examination of Nonmagnetic Rings on Generator Rotors." Proceedings: Generator Retaining Ring Workshop. Palo Alto, CA: Electric Power Research Institute, May 1988. EL-5825.

A

UTILITY PROCEDURES FOR RETAINING RING PROTECTION

Philadelphia Electric Company's Active Reduction and Intrusion Detection (ARID) Program

Active Reduction and Intrusion Detection (ARID) Program

1.0 INTRODUCTION

1.1 PURPOSE

Active Reduction and Intrusion Detection (ARID) is an operating and maintenance program designed to cost-effectively manage the risks associated with stress corrosion cracking (SCC) of generator rotor retaining rings. SCC can occur when an 18Mn-5Cr alloy retaining ring is exposed to moisture as described in the OEM's service advisory TIL 1001 (Replacement of Non-Magnetic Steel Retaining Rings). In addition to the benefits presented in this report, adherence to ARID also provides increased protection against stator winding degradation attributed to moisture as described in TIL 1098 (Inspection of Generators with Water Cooled Stator Windings). This version of ARID is adapted specifically to the Limerick generators that are indoor units utilizing water-cooled stators.

1.2 METHOD

ARID requires that operators respond to an excursion of generator gas dew point during operation and to an indication of a stator winding water leak prior to shutdown. Additionally, initial ultrasonic examinations of the retaining rings establish their suitability for continued service and provide benchmarks for future comparisons. A number of maintenance and operating practices are prescribed to reduce the likelihood and severity of moisture exposure incidents. The moisture sources are: generator gas coolers, stator windings, seal oil, cooling/purging gas, and atmospheric humidity (during outages).

1.3 BASIS

ARID is based on a study that examined the effects of generator construction, secondary systems, hardware reliability, operating procedures, and maintenance practices related to their potential for introducing moisture into the generator cavity. This information was used in a comparative fault-tree analysis to evaluate the capabilities of various proposed moisture management techniques. These results, in conjunction with associated benefit-to-cost evaluations, determined the tasks selected for ARID.

The benefit-to-cost computations are based on the rate of known end ring SCC service failures and include associated generator repair and power replacement costs. The conclusion showed that ARID is a cost-effective alternative to the OEM's recommendation to replace the rings.

1.4 OVERVIEW

The tasks proposed in ARID are presented beginning with section 2.0 of this report. For each principal task, an items-of-interest summary is tabulated as follows:

UNIT NO. (1)	OTG NON (2)	SCHED (3)	INITIAL COST (4)	RECUR. COST (5)	B/C (6)	RESP. GRP. (7)

LEGEND:

(1) Unit Number
(2) Outage / Non-Outage task
(3) Schedule of task (FRO = refueling outage, S/D = shutdown)
(4) Initial cost of task
(5) Recurring costs of task (per refueling outage)
(6) Benefit-to-cost ratio of task
(7) Responsible implementation group

2.0 GAS DEW POINT MONITORING

UNIT	OTG NON	SCHED.	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	N	Biwkly	$6,500	$3,640	632	LGS
U/2	N	Biwkly	$6,500	$3,640	640	LGS

2.1 ACQUIRE A PORTABLE DEW POINT MONITOR AND DESIGNATE A GENERATOR GAS SAMPLING TAP

1. Background: The gas sample must be representative of the dew point at each rotor retaining ring. An appropriate source is the generator core monitor piping for the following reasons:

1. The core monitor derives its sample from the generator fan discharge that is a common flow path for generator gas during operation.

2. The core monitor returns its gas sample to the generator fan inlet, thereby providing a closed loop system that eliminates the hazards of hydrogen handling.

3. The installed sample piping can support the flow requirements of the proposed dew point monitor in addition to the existing core monitor.

2.2 MONITOR DEW POINT

1. The generator gas dew point should be kept as low as practical to minimize the risk of developing SCC. However, if an upward trend in dew point is observed, initiate the moisture source identification and isolation procedures proposed in section 8.1. If dew point exceeds 14° C (@ 70 psi operating pressure) purge the unit with dry gas to reduce the dew point below this value. This will ensure that the generator gas is below 80% relative humidity when the retaining rings are most susceptible to condensation inside the generator. This worst case condition assumes that the generator is at operating pressure and its internal components have cooled to turbine hall minimum design temperature (65° F).

3.0 GAS COOLING SYSTEM

3.1 EDDY CURRENT TEST COOLER TUBES

UNIT	.OTG NON	SCHED.	INITIAL COST	RECUR COST.	B/C	RESP. GRP.
U/1	0	1 RFO	$3,000	$2,000	57	NMD
U/2	0	1 RFO	$3,000	$2,000	58	NMD

1. Background: The current practice of pressure testing coolers is not considered a predictive technique. It is expected that eddy current testing will provide predictive information following a period of baseline trending.

3.2 BLOCK AND DRAIN COOLERS WHEN GENERATOR IS OFF-LINE

UNIT	OTG NON	SCHED.	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	N	S/D	$1,500	$ 350	50	LGS
U/2	N	S/D	$1,500	$ 350	51	LGS

1. Background: During shutdown, gas is not circulated through the generator, and it is therefore impossible for the proposed dew point monitoring system to obtain a gas sample that represents the moisture level at each retaining ring.

   Also, the installed generator casing liquid detection system response time is poor under low leak rate conditions. This is because the sensing line pipewalls are long with a coating of absorbent corrosion products and, additionally, the detector float chamber is a relatively large volume. As such, a small leak or light spray directly onto a retaining ring might not activate the alarm in time to take action to prevent ring damage.

Therefore, the most cost effective method for ensuring against undetected gas cooler water intrusion during shutdown is to block and drain the coolers.

3.3 ESTABLISH A PREVENTIVE MAINTENANCE PROGRAM FOR THE GAS COOLER FLOW CONTROL COMPONENTS

1. Clean and calibrate primary controller.

2. Stroke valve.

3. Inspect and repair resilient components.

3.4 STUDY THE FEASIBILITY OF MAINTAINING THE HYDROGEN COOLER WATER AT LOWER PRESSURE LESS THAN THE GENERATOR GAS

1. Background: Cooling water to generator gas differential pressure is positive during the winter months and negative during the summer months, varying with service water system demand. Establishing and maintaining a negative differential is recommended because it will inhibit water leakage into the machine in the event of a cooler tube failure. The cooling water flow control valves installed as part of the temperature control system should be considered for this application.

   NOTE: A potential concern with maintaining high negative differential is the possibility of entraining H_2 in the service water as a result of a tube failure.

4.0 STATOR LIQUID COOLING SYSTEM

4.1 SAMPLE THE WINDING COOLANT SYSTEM TANK VENT FOR EXCESS GENERATOR GAS PRIOR TO SHUTDOWNS

CAUTION: A freely exhausting rotameter or other measurement means should be substituted for the OEM's roof vent bag-collection method to preclude a possible explosive accumulation of hydrogen.

UNIT	OTG NON	SCHED.	INITIAL COST	RECUR COST.	B/C	RESP. GRP.

U/1	N	S/D	$2,500	$2,000	164	EGS
U/2	N	S/D	$2,500	$2,000	166	LGS

1. TIL 1098 (Inspection of Generator With Water Cooled Stators) recommends the following action levels relative to hydrogen released by the tank vent:

   ≥ 10 Cubic feet/day - Inspect for stator winding leaks during the next outage.

   ≥ 200 Cubic feet/day - remove generator from service immediately.

2. If winding leak(s) become a concern, the generator gas pressure should be pressed up to maximum and the windings drained as soon as possible. Subsequently, Turbine/Generator Group's helium leak detection apparatus should be used for locating and sizing the suspected leak(s).

3. Background: The purpose of this monitoring is to detect a breach in the stator coolant system inside the generator cavity. This task is crucial because winding water leaks in the endturn areas are known to occur frequently and there is a potential for non-detection during shutdown, as described in section 3.2. An example of a failure mode under such conditions is a small winding leak resulting in a slow, repeated water drip directly onto a localized area of a stationary retaining ring, rapidly leading to ring damage.

   This leak detection technique relies on the presence of differential pressure between generator gas and the stator water. This differential is maintained by a control system which is designed to regulate the stator water flow to maintain winding water pressure 3 psi lower than gas pressure during normal operation[1]. If a breach in the water/gas boundary is present under this condition gas will be forced into the water circuit, and after exceeding solubility limits, it will begin releasing through the winding coolant tank vent. The presence of excess generator gas at the vent is therefore a precursor to water leakage that might occur after the differential pressure is reduced or reversed.

Winding leak detection methodologies are continually evolving. For example, the trending and comparison of stator bar temperatures to indicate H_2 leakage into the water circuit is one alternative method which should be studied for applicability. NED will assess industry developments and propose new approaches. In the interim, the above-listed OEM recommendations should be followed.

[1] NOTE: A minimum stop on the water flow regulating valve limits the water pressure to 22 psi even though generator gas pressure might continue to decrease. Therefore, the differential pressure that inhibits stator winding water leaks would be lost at this reduced generator gas pressure.

4.2 MAINTAIN GENERATOR GAS PRESSURE ABOVE STATOR WATER PRESSURE DURING SHUTDOWN

1. Background: Maintaining this pressure differential will inhibit leakage of stator water into the generator cavity in the event of a winding system breach. Gas pressure should be maintained until the winding is drained and dried.

4.3 PRESSURE TEST STATOR WINDINGS

UNIT	<u>OTG</u> NON	SCHED.	INITIAL COST	RECUR COST.	B/C	RESP. GRP.
U/1	0	1 RFO	CP	CP	CP	NMD
U/2	0	1 RFO	CP	CP	CP	NMD

1. This test is currently performed (CP) by Turbine/Generator Group during each refueling outage and should continue, utilizing the pressure/vacuum testing skid supplied by the OEM.

4.4 PERFORM PREVENTIVE MAINTENANCE ON THE STATOR WINDING WATER PRESSURE CONTROL COMPONENTS

CAUTION: The controller and valve operator are direct-piped to the generator hydrogen. Precautions must be taken to prevent a hydrogen explosion/fire while working on this system.

UNIT	OTG NON	SCHED.	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	0	1 RFO	CP	CP	CP	NMD
U/2	0	1 RFO	CP	CP	CP	NMD

1. Clean and calibrate primary controller.
2. Stroke Valve.
3. Inspect and repair resilient components.

4.5 PERFORM THE OEM'S ENGINEERING CHANGE NOTICE (ECN) G313-76 "REDUCE PRESSURE IN WATER COOLED BUSHINGS" ON UNIT NO. 1

1. Background: Implementation of this ECN will reduce the water pressure in the water-cooled high voltage bushings to below the generator gas pressure, thereby providing differential pressure protection in the generator cavity. This work has been completed on Unit No. 2.

5.0 SEAL OIL SYSTEM

5.1 EDDY CURRENT TEST THE LUBE OIL COOLER TUBES

UNIT	OTG NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	0	below	$3,000	$1,000	38	NMD
U/2	0	below	$3,000	$1,000	38	NMD

1. Set testing intervals as required to assure leak free operation between outages.

2. Background: A lube oil cooler tube leak would inject water into the oil. A large leak would exceed the ability of the vacuum treatment system to dry the oil, resulting in a diffusion of moisture into the generator cavity at the seal oil to generator gas interface.

5.2 PERFORM PREVENTIVE MAINTENANCE ON THE SEAL OIL SYSTEM

UNIT	<u>OTG</u> NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	N	below	$ 350	$ 350	370	LGS
U/2	N	below	$ 350	$ 350	374	LGS

1. Perform the following testing and inspections:

EQUIPMENT	MEGGER MOTOR/MCC	VIBRATION & FERROGRAPHY	INSPECT MCC
Main Pump	X	X	X
Vacuum Pump	X	X	X
Recirc. Pump	X	X	X
Backup Pump	X	RFO	X
Actuating Switch	TEST	-	-

5.3 INITIATE PRIORITY CORRECTIVE ACTION IF A SERVICE FAILURE OCCURS ON THE ABOVE LISTED SEAL OIL COMPONENTS OR ON THE TURBINE GLAND SEAL(S)

1. Background: A failure of any of the above listed seal oil system components would render the vacuum treatment portion of the system inoperable. Moisture that is absorbed into the lube oil from normal sources (e.g. gland seals, atmospheric exposure) would then carry over into seal oil and diffuse into the generator gas. Therefore, it is important for the vacuum treatment system to be operating in concert with the seal oil system at all times.

Excessive gland seal steam leakage could inject sufficient moisture into the lube oil to overcome the seal oil treatment system, and similarly diffuse moisture into the generator gas.

Additionally, failure of the back-up pump to operate on demand would result in the loss of seal oil pressure with an attendant loss of generator gas through the seals. Eventually, the gas pressure could fall below the minimum pressure setpoint of the winding water system, resulting in the loss of differential pressure protection between the winding water and generator gas as described in section 4.1, note 1. This scenario would also necessitate a significant load reduction due to generator cooling limitations.

5.4 TEST AND MONITOR THE SEAL OIL LIQUID DETECTION SYSTEM

UNIT	OTG NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	O/N	below	$1,350	$ 350	57	LGS
U/2	O/N	below	$1,350	$ 350	57	LGS

1. Functionally test the detector during each refuel cycle, by injecting water into the inlets of the sensing lines.

2. Instruct the plant operators to monitor the level of fluid in the detector chamber and to log changes during their shift rounds in the operating and shutdown modes.

    1. If the detector trips or if fluid from the detector chamber is removed, log the activity and inform the system engineer. All effluent is to be retained for analysis. Initiate the leak isolation procedures proposed in section 8.1.

3. Background: The presence of excessive water in this detector indicates a lube oil cooler leak or a malfunction of the vacuum treatment system. It might also indicate moisture removal from the generator gas (i.e. reverse diffusion).

5.5 LUBE OIL/SEAL OIL MOISTURE CONTENT SAMPLING

UNIT	OTG NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	N	below	$1,000	$1,680	—	LGS
U/2	N	below	$1,000	$1,680	—	LGS

1. Concurrently sample the seal oil (upstream of the hydrogen seal) and lube oil for moisture content for one operating cycle to establish the moisture removal efficiency baseline of the seal oil treatment system. This baseline can be compared against future samples to determine whether seal oil is contributing to a potential future dew point excursion.

6.0 GENERATOR CAVITY

6.1 TEST THE GENERATOR CAVITY LIQUID DETECTION SYSTEM

UNIT	OTG. NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	O/N	below	$1,350	$ 350	60	LGS
U/2	O/N	below	$1,350	$ 350	61	LGS

1. Functionally test the detector during each generator disassembly by injecting water into the inlets of the sensing lines (located at the bottom of the generator cavity).

2. Instruct the plant operators to monitor the level of fluid in the detector chamber and to log any changes as part of their shift rounds in the operating and shutdown modes.

    1. If the detector trips or if fluid from the detector chamber is removed, log the activity and inform the system engineer. All effluent is to be retained for analysis. Initiate the leak isolation procedures proposed in section 8.1.

6.2 CORRECT THE SLOPE OF COLLECTOR-END GENERATOR CASING LIQUID DETECTION PIPING (UNIT #2).

1. Background: The sensing line is sloped opposite to the design requirements. This condition necessitates that a large volume of piping be filled with collector-end casing effluent before the detector is tripped, thereby reducing the effectiveness of the liquid detection system.

6.3 CHECK DEW POINT OF ALL GASES BEING INTRODUCED INTO THE GENERATOR CAVITY

UNIT	OTG NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	N	below	$ 700	$100	—	LGS
U/2	N	below	$ 700	$100	—	LGS

1. Ensure that dew point of purging air is less than 14° C.

2. Continue using Industrial High Purity Grade H2 as described in Air Products and Chemical Inc. Specification 10.1.7. The dew point of this gas is guaranteed to be -68° C. Formalize this as a purchase specification and periodically sample deliveries to ensure vendor compliance.

   Note: A given sample of gas will condense at a lower temperature when it is pressurized. (e.g. a gas with a dew point of -11° C at atmospheric pressure will have a dew point of roughly +14° C (alarm point) at 70 psi generator operating pressure.

3. Continue using Industrial High Purity Grade C02 as described in Air Products and Chemicals Inc. Specification 10.1.4. The dew point of this gas is guaranteed to be -40° C. Formalize this as a purchase specification and periodically monitor deliveries to ensure vendor compliance.

6.4 CHECK THE % H_2 PURITY METER and GENERATOR FAN DIFFERENTIAL PRESSURE MANOMETER.

UNIT	OTG NON	SCHED	INITIAL COST	RECUR. COST	B/C	RESP. GRP.
U/1	O/N	Below	$3,400	$3,200	—	LGS
U/2	O/N	Below	$3,400	$3,200	—	LGS

1. During outages:

    1. Check for blockage in sensing lines. Calibrate instrumentation and loop check alarm, as required.

2. During operation:

    1. Instruct the plant operators to periodically monitor the desiccant used in the % H_2 purity meter sampling line (located inside of Panel 10C120). The system engineer should be informed of desiccant discoloration or other signs of moisture. If signs of moisture are noted, immediately take a generator gas dew point reading.

    2. Develop action levels which the plant operators can use to evaluate the % H_2 Purity readings against the Generator Fan Differential Pressure readings during their rounds. This would provide for an early indication of high generator gas moisture should it develop during the period between the prescribed dew point readings.

    3. Background: Generator Fan Differential Pressure is a panel manometer reading representing pressure rise across the shaft mounted generator fan ordinarily taken at operating speed. % H_2 Purity is a panel meter reading based on the thermal conductivity of the generator gas (see GED 4674). As such, the following conclusions can be drawn:

        Air mixing with generator hydrogen will increase the fan differential pressure due to increased density of the composite gas mixture. Simultaneously, it will reduce the % H2 purity reading due to reduced thermal conductivity.

Water mixing with generator hydrogen will also increase the fan differential pressure reading due to increased density of the composite gas mixture. However, the % H_2 purity reading will decrease (depending on the condition of the sample line desiccant) less than it would for air because the thermal conductivity of water is closer to that of hydrogen.

These effects are summarized as follows:

CONTAMINANT	FAN DIFFERENTIAL PRESS. READING	% H_2 PURITY READING
AIR	Increase	Decrease
WATER	Increase	Small change

This information should be empirically developed into criteria for use by the operators as a possible "early warning" check for moisture intrusion and also to verify that the dew point monitor is in range.

7.0 <u>OUTAGE ACTIVITIES</u>

7.1 INSPECT RETAINING RINGS

1. Perform an ultrasonic examination capable of detecting flaws on the internal surfaces of each. ring during the next generator disassembly outage. Also perform a fluorescent dye penetrant examination of the external surfaces. The results will determine whether the rings are suitable for continued service and will provide a benchmark for future comparisons in the event of a moisture exposure incident. Consult NED for flaw detection sensitivity and acceptance criteria.

2. Continue to perform fluorescent dye penetrant examinations of the external ring surfaces during each generator disassembly outage.

7.2 PROTECT RETAINING RINGS FROM ATMOSPHERIC MOISTURE

1. Circulate dehumidified air through the generator if it is to be opened to atmosphere longer than twenty-four hours. Ensure that the ring dew point is at least 18° F above ambient. Turbine/Generator

Maintenance Group uses a portable monitoring/recording/alarming instrument designed specifically for this application.

2. Continue the practices currently used to store the generator rotor while it is removed from the stator.

    1. Store inside a tent and circulate dehumidified air

    2. Do not allow tarps or other vapor barriers to contact the rings.

    3. Do not use water-based or chlorinated solvents on the ring.

    4. Monitor dew point. Turbine/Generator Maintenance Group utilizes the above-mentioned instrument to assure protection of the. rings when the rotor is out of the machine. The temperature of each ring and the moisture content of the air immediately surrounding is continuously monitored and recorded. If the dew point of the surrounding air approaches within 18° F of the ring temperature, the unit alarms. Corrective action is taken by increasing dehumidifier output or by increasing rotor temperature. Rotor heating is controlled by manually adjusting field current supplied by a welding machine dedicated for this purpose.

8.0 MISCELLANEOUS

8.1 PRACTICES AND PROCEDURES

1. Formalize the recommended tasks to ensure continued adherence to the program.

2. Develop procedures for rapid on-line identification and isolation of potential water leaks into the generator cavity. Consult NED for specific recommendations.

3. EPRI sponsored computer code ("RRing Life") is available for analysis of the integrity of non-magnetic retaining rings and assessment of their remaining life. The code uses fracture mechanics principles, automated finite element analysis, and statistically based material property data bases in conjunction with unit-specific design characteristics and operating data.

   To best utilize the software, operating data should be recorded on a regular basis. The recommended data collection procedure is prescribed in Action/Information Tracking List #AO371961, Evaluation #19.

8.2 ASSUMPTIONS USED IN ANALYSIS

a. Eddy Current test is 90% effective in predicting failures.

b. Detection of excess H_2 in stator water is 95% effective.

c. Dew point monitoring/response is 98% effective.

Commonwealth Edison's Recommended Guide for Humidity Control in the Generators with Non-Magnetic Retaining Rings

I. Introduction

Turbine-generator manufacturers have recently issued recommendations concerning protection of non-magnetic generator rotor retaining rings made of 18Mn-5Cr alloy steel. Units with 18Mn-5Cr non-magnetic rings require protection against moisture exposure through humidity control to prevent corrosion and/or stress corrosion cracking which ultimately could lead to possible failure of the retaining rings. It is important to remember that stress corrosion cracks, even if initiated, can be arrested by controlling humidity and moisture exposure. This document is intended to be a guide and specific procedures for humidity control will have to be developed by the individual stations.

Some of the fossil units have magnetic retaining rings and are considered outside the scope of this guide. A few generators have been fitted with more resistant 18Mn-18Cr rings and are not affected by this document. Normal operating procedures as recommended by the manufacturer should be applied to the units with magnetic and 18Mn-5Cr non-magnetic rings.

II. Purpose

The purpose of this procedure is to outline recommended methods for keeping retaining rings dry under all conditions.

III. References

"Recommendations for Keeping Nonmagnetic Retaining Rings on Generator Rotors Dry". Westinghouse Electric Corp. Operation and Maintenance Memo 038, November 11, 1983.

"Recommendations for Control and Detection of Stress Corrosion of Non-Magnetic Retaining Rings and Zone Rings on Generator Rotors", Westinghouse Electric Corp. Operation and Maintenance Memo 068. March 18, 1987.

"Inspection and Protection of Nonmagnetic Generator Retaining Rings", General Electric Company Technical Information Letter 1014, August 26, 1987.

"Replacement of Nonmagnetic Steel Retaining Rings to Provide Resistance to Corrosion and Stress-Corrosion Cracking", General Electric Company Technical Information Letter 1001, October 27, 1986.

Modern Refrigeration and Air Conditioning. Althouse, Turnquist, and Bracciano: The Goodheart - Willcox Company, Publisher, 1982.

IV. Caution

A. Recommendations contained in this document involve the use of heat producing and electrically operated equipment. All applicable Company safety precautions should be observed when using this equipment.

B. Large turbine-generators are cooled with Hydrogen gas. Company safety precautions and manufacturer's recommendations should be followed when purging or filling generators to prevent a possible explosion or fire.

V. Bases for Humidity Control

Attached curve in Figure I shows the relationship between operating temperature versus system dew point for maintaining various levels of percent relative humidity. For example, when the ring temperature is 70°F and the dew point of the surrounding environment is 45°F, the relative humidity if 40% (point A in Figure 1). To maintain relative humidity of 40% or below, the dew point has to be less than 27°F if the ring temperature is only 50°F.

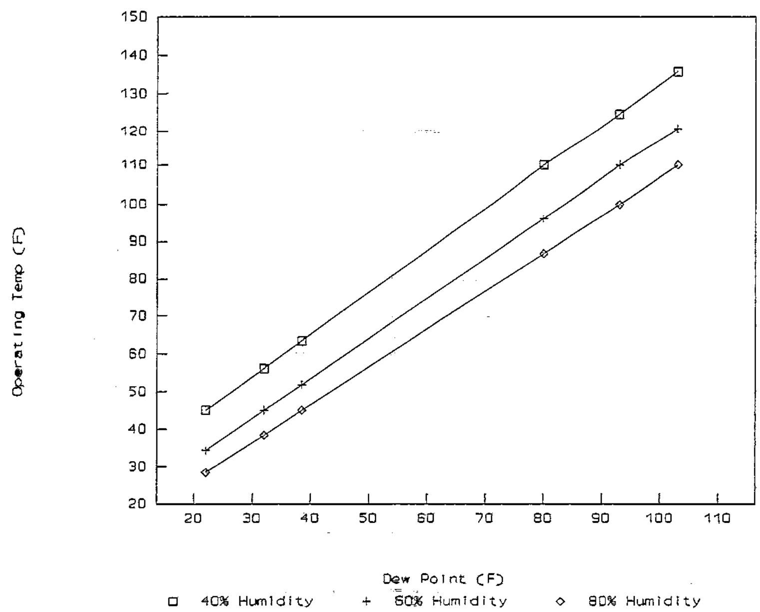


Figure 1.
Dew Point vs. Retaining Ring operating temperature
(Recreated from chart provided by Commonwealth Edison)

Laboratory data shows that 18Mn-5Cr steels are subject to stress corrosion cracking and crack propagation at an alarmingly high rate (up to 0.001 inch/hour under high stress condition), when exposed to air with more than 80% relative humidity. It is, therefore, important to keep the rings "dry" during operations, shut down, outage, storage and even during shipping. Very high state of stress exists even when the machine is not running because of high level shrink stresses in the retaining rings.

It is important to recognize that unlike high vibration levels which may trip the unit, an excursion of relative humidity above the specified limits cannot be corrected quickly. Corrective action, therefore, has to be initiated as soon as an increasing trend is recognized in the moisture content of the surrounding environment. The following three states are proposed for levels of concern with regard to protecting the rings:

A. Alert state.

Relative humidity between 40 to 60 percent. Investigate possible cause and be prepared to implement corrective action.

B. Alarm state.

Relative humidity between 60 to 80 percent. Implement corrective action immediately.

C. Concern state.

Repeated excursions above 80 percent relative humidity. Plan for inspection of the rings (possibly replacement) in the next opportune outage when cumulative exposure exceeds 48 hours.

VI. <u>Procedure</u>

A. Generator On-Line

1. Check the dew point of hydrogen at least once a week.
NOTE: Consideration should be given to continuous monitoring meter such as the one supplied by Panametrics.

2. Maintain the dew point of hydrogen in the system at 45°F or lower.

a. Check hydrogen dryer for proper operation it the dew point drifts about 10°F above the normal value for the particular generator or 45°F, whichever is lower.

b. Purge hydrogen if the dryer is inoperative temporarily and fix the dryer as soon as possible.

c. Check for potential source of moisture such as hydrogen cooler leaks.

3. Check hydrogen purity on a daily basis and maintain hydrogen purity at 95% or above.

a. Check hydrogen dryer if purity is below 95%.

b. Purge hydrogen if dryer is unable to maintain purity.

B. Generator Off-Line (Stand-by with hydrogen pressure maintained in the generator).

1. Check dew point of hydrogen at least once a week. (See Note in VI.A.1 above.)

2. Maintain dew point of hydrogen in the system lower than the temperature defined in Figure 1.

    a. Purge hydrogen to maintain dew point.
    NOTE: Hydrogen dryers are generally inoperative when the generator is not at rated speed. If regular purging is required, it may be justifiable to install a new style dryer which will maintain hydrogen circulation and drying cycles with the machine on turning gear.

C. Generator Open to Atmosphere (Rotor in the machine)

1. Follow manufacturer's recommendation for degassing the machine.

2. Maintain Relative Humidity inside the generator below 40% on the average with no excursions above 80%.

    a. Heaters or dehumidifiers should be used.

1. Heaters may be placed inside the generator. Raising the temperature 10°F above ambient temperature will help to control humidity under most conditions. Approximately 100W per foot length of rotor will maintain a 10°F rise if air circulation is minimized.

2. One or more dehumidifiers may be ducted into the machine for humidity control.

    b. Relative humidity should be monitored continuously using a recording hydrometer to insure that equipment is properly operating.

D. Rotor Out of Stator

1. Enclose rotor to protect it from contamination without delay.

    a. Construct enclosure using sheet polyethylene and lumber.

    b. Avoid contact between the rings and any porous substances like canvas, wood or cardboard. Avoid contact between the rotor body and polyethylene sheet.

2. Install heaters or dehumidifiers to maintain relative humidity below 40%.

    a. Heaters should be sized at about 100 Watts per foot length of rotor or as required to maintain a relative humidity of 40% or less. Slow circulation of air and venting may have to be provided to allow moist air to escape.

b. Dehumidifiers may be preferable to heaters during the summer months. Two home-type dehumidifiers should be adequate for rotors up to 40 ft. long.

3. Relative humidity should be monitored continuously using a recording hydrometer to verify proper operation of drying equipment.

VII. Instrument Check

1. Recording hydrometers, dew point measuring instruments and hydrogen purity meters should be checked for proper operation by SMAD every six months.

In summary, it is recognized that non-magnetic retaining rings are susceptible to crack initiation and growth in the presence of excessive moisture. It is necessary to maintain an acceptable environment for the rings during operation, shut down, outages, storage and shipping. An acceptable environment is one in which no liquid water comes in contact with the rings and relative humidity (based on the temperature of the ring and the dew point temperature of the surrounding environment) is 80% or less.

Originally Prepared by: A.T. Peyer, F.S.D. Revised by: S.M. Gaitonde, S.M.A.D. B. W. Piechalak, S.M.A.D.

Nonmagnetic Retaining Rings - User's Perspective (by E. W. Floyd, TU Electric)

(Reprinted from Proceedings: Generator Retaining Ring Workshop. Palo Alto, CA: Electric Power Research Institute, May 1988. EL-5825.)

ABSTRACT

The consequence of failure of the 18Mn 5Cr retaining rings and the cost of replacing all 18Mn 5Cr rings with 18Mn 18Cr stimulated an extensive evaluation from a user's perspective. This treatise is intended to portray the evolution of the current TU Electric philosophy for the optimum short and long term solution to exposure to stress corrosion.

INTRODUCTION

Following the 1983 EPRI "Retaining Rings for Electric Generators" workshop, users began to become aware of increased concern over contamination of nonmagnetic rings with moisture and other corrosive liquids. In 1985, one of the generator manufacturers presented an overview of the retaining ring issue including the history of ring materials, failure history, metallurgical effects of moisture and recommended solutions. As a result, TU Electric began to survey the manufacturers of the system generating units to determine the type of materials used on each unit; concerns felt by each manufacturer; inspection techniques and recommended long term solutions. With this information in hand, TU Electric began to analyze the alternatives and develop the current philosophy.

MANUFACTURER'S PRELIMINARY RECOMMENDATIONS

The initial recommendations made by the manufacturers involved environmental constraints, testing recommendation, surface protection and action to be taken if indications were found. A wide variation was found in these recommendations.

Environmental Constraints

All manufacturers agreed on the need to keep the rings dry and free from liquids that could support stress corrosion. Heat seemed to be the accepted way to minimize the possibility of condensation but there was not a consistent direction given on environment control. In fact, observed practices by manufacturer's personnel seemed to violate recommended methods. This was noted both in field work and manufacturer's support facilities.

Testing Recommendations

Testing was the obvious area of greatest difference of opinion. Each manufacturer had a different recommended approach. One manufacturer recommended ultrasonic testing only; another recommended red dye penetrant with the ring in place and fluorescent penetrant on rings removed; another recommended no in place test but pull the ring and perform an eddy current test; while the other manufacturer recommended fluorescent penetrant with ultrasonic tests including an internal fiber optic inspection if the penetrant test revealed excessive indications.

Because of the inconsistency in the recommendations, TU Electric began to attempt the development of a philosophy to standardize the inspection procedures to use on all nonmagnetic rings. During the development, TU Electric continued to utilize the original equipment manufacturer's recommendation.

Surface Protection

Originally all of the manufacturers recommended a paint coating on the ring outside diameter but due to concerns with application, one manufacturer recommended eliminating the paint and use only turbine oil to coat the rings to help minimize moisture on the ring surface. However this manufacturer did not object to the use of the paint if the user desired.

Action Taken

The recommended action if indications were observed also was not consistent between manufacturers and one manufacturer was inconsistent concerning their recommendation.

The recommendations were: If ultrasonic tests revealed questionable reflection, remove the ring and determine the condition (this was recognized as a judgment call); If penetrant tests revealed indications one approach was to map the indications and remove them by grinding the total surface to the depth of the deepest one; another was to determine if indications were in clusters or lining up (If they were, then remove them). No method was defined to differentiate between forging inclusions and stress corrosion. Once again a consistent procedure was needed for TU Electric but the original equipment manufacturer's recommendation was followed until this procedure could be established.

CURRENT MANUFACTURER'S RECOMMENDATION

The manufacturers continue to stress the need for environment control but there had not been a convergence on tests required nor methods of interpreting test results. One manufacturer recommended replacement of all 18 Mn 5 Cr rings within a 6-year time period regardless of the testing results. This recommendation has been amended to continue to use the 18 Mn 5 Cr rings if the environmental constraints are strictly adhered to. Also one manufacturer has proposed tests to differentiate between stress corrosion and forging inclusions. All manufacturers are telling us the rings as designed are adequate if the environment is controlled but methods to verify the rings current condition still are not consistent.

TU ELECTRIC'S EXPOSURE

Figure I shows a tabulation of TU Electric units. This includes the subject ring material as well as the magnetic rings and the new 18 Mn 18 Cr rings we have retrofitted. Also Figure I identifies tests performed and results.

Plant	OEM	Inservice Date	Type Ring	Liquid Penetrant		Ultrasonic		Date Tested
				Test?	**Indications?**	**Test?**	**Indications?**	
Monticello 2	W	12-08-75	18/18	18/5 Rings Removed				1986
Martin Lake 2	W	05-23-78	18/18	18/5 Rings Removed				1986
Lake Hubbard 1	W	06-18-70	18/18	18/5 Rings Removed				1987
Martin Lake 1	W	05-16-77	18/18	18/5 Rings Removed				1986
Monticello 1	W	12-23-74	18/18	18/5 Rings Removed				1987
Mt. Creek 7	GE	03-07-58	M	**		**		
North Lake 1	GE	12-22-59	M			**		
Lake Creek 1	GE	04-25-53	M	Yes	No	**		1986
Collin	GE	06-26-55	M	Yes	No	**		1985
Parkdale 1	GE	06-19-53	M	**		**		
Morgan Cr. 2	GE	07-03-50	M	**		**		
Dallas 3	GE	05-04-54	M	**		**		
Mt. Creek 2	GE	12-14-45	M	**		**		
Strykee Cr. 1	GE	06-26-58	M	Yes	No	**		1986
Morgan Cr. 3	GE	05-13-52	M	**		**		
Parkdale 3	GE	03-25-57	M	**		**		
Handley 2	GE	12-30-50	M	**		**		
Trinidad 5	GE	12-28-49	M	**		**		
Mt. Creek 3	GE	04-07-49	M	**		**		
Eagle Mt. 2	GE	12-23-56	M	**		**		
River Crest	W	06-30-54	M	Yes	No	Yes	No	1985
Handley I	W	04-29-48	M	No		No		1986
North Main	W	03-29-52	M	No		No		
Dallas 9	W	02-14-51	M	No		No		
Morgan Cr. 4	W	05-18-54	M	Yes	No	Yes	No	1984
Parkdale 2	W	03-31-55	M	No		No		
Handley 5	AC	01-07-77	NM	**		Yes	No	1985
Graham 1	AC	11-26-60	NM	Yes	Yes	Yes	No	1982
Handley 4	AC	10-04-76	NM	**		Yes	No	1982
Eagle Mt. 1	GE	1981**	NM	Yes	Yes	**		1986
Lake Hubbard 2	GE	11-20-73	NM	Yes	Yes	**		1983
Morgan Cr. 6	GE	06-17-66	NM	Yes	Yes	**		1984
Sandow 4	GE	05-15-81	NM	Yes	Yes	**		1985
Mt. Creek 8	GE	1979**	NM	No		**		

Plant	OEM	Inservice Date	Type Ring	Liquid Penetrant		Ultrasonic		Date Tested
				Test?	**Indications?**	**Test?**	**Indications?**	
Valley 1	GE	11-16-62	NM	Yes	Yes	**		1984
Valley 2	GE	12-29-67	NM	Yes	No	**		1981
North Lake 3	GE	07-02-64	NM	Yes	Yes	**		1986
Graham 2	GE	02-22-69	NM	Yes	Yes	**		1984
Monticello 3	GE	08-01-78	NM	Yes	No	**		1984
Tradinghouse 2	GE	06-01-72	NM	Yes	Yes	**		1984
De Cordova	GE	05-01-75	NM	Yes	No	**		1986
Valley 3	GE	05-31-71	NM	Yes	Yes	**		1987
Trinidad 6	GE	05-26-65	NM	Yes	No	**		1984
Eagle Mt. 3	GE	06-09-71	NM	Yes	Yes	**		1986
Lake Creek 2	GE	07-09-59	NM	Yes	Yes	Yes**	No	1985
Handley 3	W	03-18-63	NM	Yes	Yes	Yes**	No	1986
North Lake	W	12-22-61	NM	No		No		
Tradinghouse 1	W	04-04-70	NM	Yes	No	Yes	Yes	1985
Stryker Cr. 2	W	12-26-65	NM	Yes	No	Yes	No	1984
Morgan Cr. 5	W	06-02-59	NM	Yes	No	Yes	No	1984
Permian 5	W	04-19-58	NM	Yes	No	Yes**	No	1985
Big Brown 2	W	12-06-72	NM	Yes		Yes**	No	1985
Big Brown I	W	12-23-71	NM	Yes	Yes	Yes**	No	1986
Permian 6	W	12-11-73	NM	No	Yes	Yes**	No	1984
Martin Lake 3	W	04-01-79	NM	Yes	No	Yes**	No	1985
Mr. Creek 6	W	02-22-56	NM	No		Can't be UT Tested		
Spare 750	W	05-16-77	NM	Yes	No	Yes	No	1983

M = Magnetic NM = Nonmagnetic *** = New Rotor ** = Not Previously Recommended
Date: 09-11-87

TU ELECTRIC PHILOSOPHY

After reviewing the information available, TU Electric adopted a philosophy of continued operation of the 18 Mn 5 Cr rings unless the ring condition warranted replacement. When the 18 Mn 5 Cr rings are replaced the 18 Mn 18 Cr rings will be specified.

In order to maintain unit reliability, adopting this philosophy places a great importance on environmental control and an inspection program.

Environmental Control

The causes of crack propagation are fatigue cracking. corrosion fatigue and stress corrosion cracking (1). The probability of successfully detecting a fatigue crack during normal overhaul schedules is high. Conversely, corrosion induced cracking can begin and rapidly grow to failure in a wet environment. Fortunately, removal of the moisture arrests the crack growth. Therefore stress corrosion is the key and environment control is the solution.

The environment control philosophy address four (4) situations: normal operation, purging the generator, opened generator with the rotor in place and the rotor outside the stator.

Normal Operation. During normal operation the temperature of the field\retaining rings must be maintained above the dew point of the hydrogen gas. While the generator is in service the field body and rings are kept warm by the field excitation but during a shutdown the temperature will decline making the dew point more critical. The TU Electric philosophy includes installing dew point indication in all units to monitor the gas to facilitate correction as soon as the dew point becomes excessive. On units with unresolved problems holding the dew point at a satisfactory level, dual tower dryers are recommended for control. Any time a water leak is detected in the unit, the cause must be determined and isolated as soon as possible.

If the dew point begins to approach the gas temperature, measures must be taken to reduce the dew point including purging the generator with dry hydrogen.

Purging the Generator. Since the generator is purged with three gases, carbon dioxide, instrument air and hydrogen, each one could contribute moisture to the generator. The TU Electric philosophy is to monitor the instrument air to maintain proper dew point as well as test carbon dioxide and hydrogen supplies to insure wet gas is not injected into the generator.

Opened Generator. When the generator is degassed and opened, moist air can enter the unit. As a result, a flow of dry air should be used to insure dryness. Two acceptable methods are to purge with verified dry instrument air and utilize a dehumidifier. If the unit is water cooled, additional protection can be accomplished by warming the generator by circulating warm water. On conventional cooled and gas intercooled units electrical heating of the field will help prevent condensation.

Rotor Outside The Stator. It is the author's opinion that the majority of damage experienced on retaining rings has resulted from exposure during the time the field is removed from the stator. To eliminate this exposure is a sizable task. TU Electric approached this solution by designing a portable building to house all rotors, utilize a dehumidifier to maintain dryness in the enclosure and electrically heat the field.

Figure II is a sketch of the building planned. The building is expandable in 10 ft. sections to accommodate all fields in the system including a lathe, power rollers, boring or any other equipment required to maintain and/or repair a field. The top 10 ft. sections are designed to be removed for access without disturbing the side covering to minimize exposure. The construction was designed for ease of fabrication. The structure is comprised of columns (weight 125#), roof truss (weight 114#) and purlins (weight 45#) Figure III. All like members are interchangeable to minimize assembling procedures. The covering is a three layer laminate of a nylon fiber reinforced polyvinylchloride material used for roofing.

To insure the dryness of the air in the enclosure a 1125 cfm dehumidifier is planned to provide moisture removal. Two types of units were investigated, the refrigeration type and the desiccant type. The desiccant type appeared to be the most advantageous.

Heating the field is designed to insure the field temperature is always above the ambient. Three methods of heating were investigated; utilizing the field winding, application of a heating blanket on the rings and use of external heat. The most desirable design was using the windings as a heater. This requires a resistance feed back from the field winding to use for temperature regulation. In addition, thermocouples are used as backup to provide a fail-safe system.

During a test, an electric welder was used. The temperature was brought up to 50°C with the field in the stator and held. As the field was removed the welder was disconnected. The field temperature dropped at a rate of 1°C per hour in a 24°C ambient. This allowed moving the field with the temperature staying above the dew point of the ambient.

<u>Monitoring</u>

Monitoring is a very important component of this program. Since exposure to moisture is the concern, records should be complete to facilitate analysis to determine inspection requirements. The monitoring should include recording any out of limits operation as well as providing a hard copy recording of the exposure during field removal.

<u>Testing</u>

The TU Electrical approach on testing includes fluorescent penetrant, ultrasonic detection and visual inspection.

<u>Fluorescent Penetrant.</u> After the rings are cleaned by an abrasive wheel the outside diameter is inspected utilizing the fluorescent penetrant method. In the event the rings

are removed an internal inspection is also conducted. Since pits in the high stress areas of the ring can close with the ring removed a disk is prepared to shrink the ring on to facilitate a more complete inspection.

On the initial inspections pits were removed by grinding. In some cases this uncovered forging inclusions. As soon as an acceptable method of identifying the inclusions from stress corrosion pits is defined, we will want to use it to determine the amount of stress corrosion pitting. In the interim, we will continue to consider these on a case by case basis with the original equipment manufacturer.

Ultrasonic Testing. One of the difficulties encountered in establishing a consistent philosophy was determining the effectiveness of the ultrasonic testing.

It is currently the only method of detecting internal flaws while the rings are in place. The main shortcoming is the ability to identify small irregularities in the rings and be able to differentiate these from back ground noise.

Since the emphasis is on monitoring and control of the ring environment, the growth of a crack due to moisture will be minimized so the emphasis will be to detect cracks that may have developed due to past exposure and deal with them prior to reaching critical fatigue crack size.

As a result the TU Electrical philosophy is to include ultrasonic detection in the inspection package. Since there are different methods used, further analysis is needed to determine the most desirable.

Visual Inspection. Another area that has proven to be a valuable technique is the visual inspection of the inside surfaces of the ring area and/or other rotor body components subject to the same environment as the ring's inside diameter. One of the original equipment manufacturers has developed their ability to anticipate the condition in the fit area as a result of the condition found on this inspection. Some of the vendor designs limit visual inspection of the rings.

The plan is to utilize this procedure to help in the evaluation of the condition of the ring.

CONCLUSION

The 18 Mn 5 Cr rings as designed have satisfactorily operated in a dry environment. TU Electric considers the control of the environment the most desirable alternative. This requires utilization of tests to monitor the integrity of the rings. In addition monitoring of the environment is important for evaluating the exposure seen by the rings.

RECOMMENDATIONS

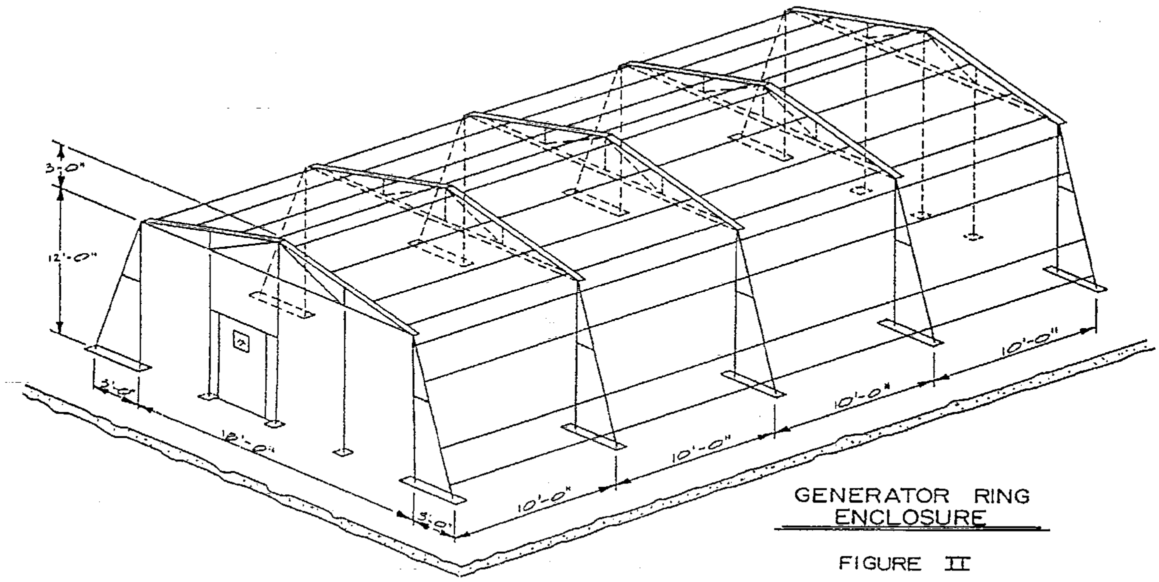
The areas most needing attention are:

1. Developing a process to determine the difference between forging inclusion and stress corrosion.

2. Refine the ultrasonic approach to give a better confidence of determining the condition of the ring.

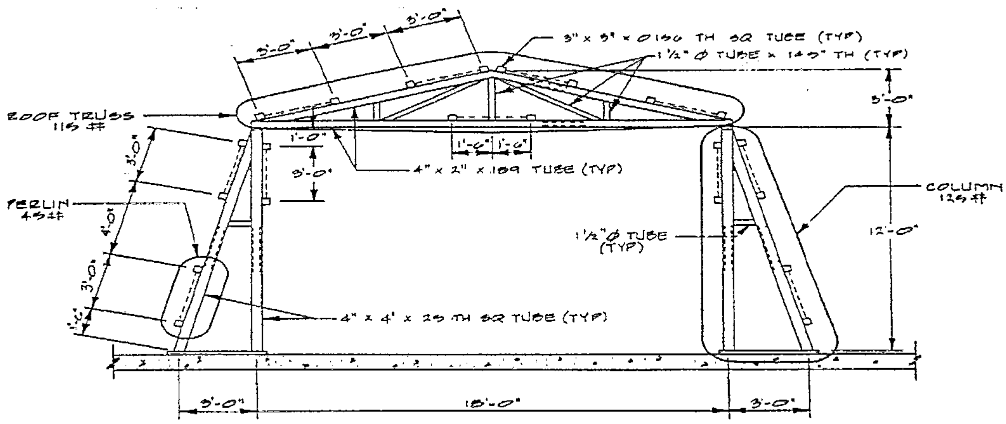
REFERENCES

1. Guidelines for Evaluating of Generator Retaining Rings. Palo Alto, Ca.: Electric Power Research Institute. April . 1987, EPRI EL/EM-5117-SR.



GENERATOR RING ENCLOSURE

FIGURE II



TYPICAL ELEVATION

FIGURE III

B

MANUFACTURER’S RECOMMENDED PRACTICES

General Electric Company Recommended Practices

Protection of 18Mn-5Cr Retaining Rings

Rings must be kept free of moisture and corrosive materials at all times.

- Only solvents approved by GE should be used to clean fields and rings. A list of these solvents can be found in the unit's service manual. Any aqueous solution that contacts a retaining ring should be removed immediately. Solutions containing substances such as chloride and nitrate ions must not be allowed to come in contact with the rings at any time.
- During operation:

  Avoid ingestion of moisture or corrosive materials into open-ventilated units.

  If a water-cooled unit develops a stator bar leak or water cooler leak, bring the unit down as quickly as possible, remove the water, completely dry the inside of the generator and correct the leakage. Rings should be thoroughly inspected as soon as possible afterward.
- During shutdown:

  If the field is kept in the unit, apply current to the field winding or run the heaters in order to keep the temperature of the rings above ambient and prevent condensation.

  If the field is out of the unit, cover it and use heat lamps to keep the field warm. The cover must not touch the field. Provide an air gap between the cover and field to allow adequate ventilation around the field.
- During long-term storage:

  Inspect the rings first for any signs of pits, cracks, etc. These should be removed. Store the ring in sealed, dry bags inside a box. Bags should not contact the rings. Desiccant should be placed inside the bags, but not in contact with the rings. The box should be stored in a heated, low humidity area. Inspect the rings and change desiccant once a year.

- Protective coatings:

  Some retaining ring outer surfaces were painted in the past to provide some limited corrosion protection. If the paint has been. removed to do an inspection of the ring, it should not be replaced on hydrogen-cooled units, since it may be a hindrance to crack detection. Since air-cooled units are continuously exposed to moist air, their rings should be repainted after inspection.

Westinghouse Electric Company Recommended Practices

1. Current recommendations for protecting nonmagnetic 18Mn-5Cr retaining rings from moisture exposure and other contaminants:

   a) During operation:

      OMM 38, issued on 11/83 reads as follows:

      When the unit is operating, it is essential to maintain proper operating conditions, such as maintaining hydrogen purity at 95% or greater and hydrogen gas at a dew point of 45° F or less, to provide a dry environment within the generator. Also, it is essential to assure that other potential sources of water are not leaking, for example, hydrogen coolers.

      OMM 38 is supplemented by OMM 68, issued 03/87, and reads:

      Maintain an acceptable environment for the rings during operation, shutdown, outages, storage, and shipping. An acceptable environment for nonmagnetic rings is one in which no water comes in contact with rings and relative humidity (based on the temperature of the ring and the dew point of the surrounding environment) is 80% or less, with no other corrodents (such as chlorides, nitrides, etc.) being present. It is important that an acceptable environment be maintained at all times; including during periods of operation, shutdown, outages, storage, and shipping.

   b) <u>While unit is offline:</u>

      same as for a)

   c) <u>During outages / rotor in stator:</u>

      The applicable section of OMM 38 reads as follows:

      During outages care must be taken to avoid moisture condensing on the rotor while it is still in the stator. After the unit has been completely degassed in accordance with Westinghouse recommended procedures, protection could be provided by installing a dehumidifier unit at the access covers in the bearing bracket, or heaters may be used to keep the temperature in the generator above the dew point temperature. Any other openings to the atmosphere should be suitably covered. Suitable protection could also be provided by replacing conventional single tower gas dryers with dual tower gas dryers equipped with circulation blowers for normal and standstill operations.

OMM 68 is applicable as well.

d) <u>During outages / rotor removed from stator:</u>

The applicable section of OMM 38 reads as follows:

Once the rotor is removed from the stator and without delay protect it by maintaining an environment where the relative humidity of air contacting the retaining ring does not exceed 80%. Protection 'can be provided by utilizing the rotor environmental bag in which the rotor was shipped and filling the bag with dry nitrogen. If the rotor bag is not available, the rotor should be placed in a previously constructed enclosure. Heaters should be arranged within the enclosure to evenly heat the rotor. The total heating required is about 1 kilowatt per 30,000 pounds of rotor weight. Slow circulation of air and venting should be provided to allow moist air to escape. Avoid contact between the retaining rings and any porous substances like canvas, wood, or cardboard. Daily insulation resistance megger tests should be performed on the rotor winding and recorded.

OMM 68 is applicable as well.

e) <u>While in storage and prior to installation on the rotor:</u>

For rings being stored by our customers the applicable sections of OMM 38 and OMM 68 apply: Keep the ring dry as defined in these documents. For rings in our plant an internal Westinghouse process specification applies.. This process specification requires the rings to be protected from moisture (less than 80% relative humidity is required) and all other corrodents. Special environmental bags are used in conjunction with desiccant and humidity monitoring devices for long term storage. Corrective actions are required if the environmental requirements are not met.

2. Protection of gas turbine generator retaining rings is addressed in the applicable instruction books for the generators. These rings are magnetic rings and, as such, do not require any protection beyond that which is accorded the entire generator rotor.

3. OMM 46 - Recommendations for Providing Improved Control of Generator Hydrogen Gas Moisture Content - contains recommendations for the replacement of single tower gas dryers with dual tower gas dryers. The dual tower gas dryers provide for continuous operation in a drying mode by automatic switching between dryer tanks. Since these dryers have their own built-in blower motor, drying of the gas continues even at unit standstill.

AC Equipment–Information Bulletin 107A - Revised: June 13, 1990

Generator Rotor Coil Support Ring Operation, Handling and Inspection

In recent years there has been growing concern in the power generation industry regarding the potential for failure of generator rotor coil support rings (RCSR's). Considerable evidence of stress corrosion cracking of various manufacturer's RCSR's has been found which has necessitated their replacement as a precaution to prevent catastrophic failures and subsequent property damage and personal injury.

A-C Equipment Services Corporation has experienced very little evidence of stress corrosion cracking on our RCSR's. However, a catastrophic failure of an Allis-Chalmers RCSR in January 1990 has presented additional facts for consideration. Most of the A-C Equipment Services Corporation RCSR's are an 8-6-4 material designation (8% manganese, 6% nickel, 4% chromium) which appear to be somewhat less susceptible to stress corrosion than some other materials. Most of the discussion of stress corrosion of RCSR centers around the 18-5 material (18% manganese, 5% chromium) which has been widely used. A-C Equipment Services Corporation has replaced a number of the 8-6-4 RCSR's with the 18-5 material in past years. It has been our position that the lower stress levels of the RCSR's that are used on the Allis-Chalmers units and the lower yield strength requirements of the material used makes these RCSR's less susceptible to stress corrosion than those of other manufacturers. There is a new RCSR material available designated 18-18 (18% manganese, 18% chromium) which is reported to be immune to stress corrosion cracking.

A-C Equipment Services Corporation has experienced some fretting and resulting fatigue cracks on a specific design of RCSR which employs multiple shrink fits; the rotor body to RCSR, the end disc to RCSR and the end disc to the rotor body. This is designated as our Tight-Tight-Tight design (T-T-T).

Even though wide spread problems have not been experienced with the Allis-Chalmers rotor coil support rings, it is A-C Equipment Services Corporation's recommendation that **all** RCSR's be removed from the generator rotor for inspection by our latest methods. Any inspections that have been performed by A-C Equipment Services Corporation on RCSR's since 1980 have been done with our latest methods and need not be reinspected until the recommended interval has expired.

A-C Equipment Services Corporation has developed special eddy current inspection methods to detect indications in non-magnetic RCSR's. In addition we recommend that a Zyglo dye penetrant inspection be performed on these rings.

Preparation for inspection requires removal of the rotor from the generator stator, removal of all interfering parts of the rotor, disassembly of the RCSR from the rotor and removal of surface coatings, insulation and end discs from the RCSR's.

Inspection of the critical regions in the RCSR bores by Non-Destructive Testing (NDT) methods from the external surfaces while on the rotor may have limitation. Therefore, it is necessary to remove RCSR's from the rotor to inspect the critical bore surfaces in order to evaluate their actual condition.

The indications that are detected by these inspection techniques can generally be removed by local grinding and dimpling. The design of these RCSR's can tolerate this dimpling and allow the rings to be returned to service in most all cases.

In addition to the basic inspection recommendations and indication removal, the following items are recommended in handling and operation of RCSR's.

1. We recommend reinspection of all RCSR's in 10 years from date of last inspection regardless of moisture or corrosion conditions. If high moisture levels are encountered during service of 8-6-4 or 18-5 rings, an inspection of the RCSR's should be made within 1 year of the incident.

2. Reinspection intervals of 18-18 RCSR's have not been definitely established due to the short time that this material has been in service in generator units. However, A-C ESC would recommend a reinspection of 18-18 rings, off of the rotor, after 10 years of service. An ultrasonic inspection on the rotor should be performed after 5 years of service to obtain baseline data for future inspections.

3. All magnetic RCSR's should also be removed and inspected using magnetic particle examination using fluorescent magnetic media and dye penetrant (Zyglo).

4. RCSR's which have had deep defects removed, should be reinspected in 5 years from date of last inspection to verify that defects have not reappeared.

5. In geographical areas that have a very humid climate, RCSR's should be reinspected in 5 years from date of last inspection. The potential for stress corrosion cracking would be greater in the humid climate areas.

6. The RCSR's of units that are in storage or in a non-operational or standby state appear to be more susceptible to stress corrosion cracking. This is most probably due to a greater exposure to moisture. The RCSR's of these units should be

inspected before returning the units to service. If this class of units is to be operated at infrequent intervals and reinspection would be a handicap, a replacement of the RCSR's with the 18-18 material should be considered.

7. If the unit under consideration is a hydrogen cooled unit, hydrogen dryers **must be** installed to minimize the amount of moisture present in the system. These dryers **must be** kept in service at all times and should be functioning properly. Instrumentations to measure dew point of the hydrogen atmosphere should be installed and working. The hydrogen dew point should not exceed the hydrogen cooler inlet water temperature.

8. Air cooled generators should be equipped with heating devices to keep internal generator temperature at least 10°F above ambient during shutdown periods. This should prevent condensation of moisture within the generator and keep this moisture from coming in contact with the RCSR's.

9. Special care and handling provisions must be taken when a generator is disassembled to protect the RCSR from moisture or corrodents. A-C Equipment Services Corporation can provide guidelines for these special provisions if desired.

Although the Allis-Chalmers design of RCSR's has not experienced significant stress corrosion attack, the owners of Allis-Chalmers generators should consider replacement of RCSR's with the 18-18 material. If an extended life is planned for the unit, the replacement of the RCSR with rings of 18-18 material will eliminate any concern for future stress corrosion cracking and associated failure. Replacement with 18-18 RCSR's should also be seriously considered where difficulty in maintaining dry environment is experienced.

AC Equipment Specification 85-195-305

Care and Handling of Rotor Coil Support Rings (RCSR'S)

1.0 This instruction covers the handling and care of rotor coil support rings (RCSR's) in the course of inspection, handling, machining and storing of RCSR's in the shops at A-C Equipment Services Corporation.

2.0 Prior to inspection and work in the shop, RCSR's must be cleaned using acceptable solvents such as NU-way, available from:

Nuway Manufacturing Co., Inc.
2435 Wheeler Road
Bay City, MI 48706
PHONE: 1-800-346-4093

Surfaces can be cleaned and polished using various grades of flapper wheels and scotch brite pads. Final finish must be 32 RMS or better.

3.0 In the course of shop operations, RCSR's should be covered with waterproof paper board or fabric at all times between work operations, with the RCSR's on a closed pallet.

3.1 Rings are to be uncovered in the lathe only when the rings themselves are being indicated, polished or machined.

3.2 Rings are always to be supported in hard rubber or copper. Rings are never to be in direct contact with wood, steel, concrete or plastic sheeting.

3.3 Rings are to be rigged with clean nonmetallic slings that are used for this purpose only. Slings are to be stored in a clean fabric bag and slings should be handled only when wearing clean cotton gloves.

3.4 Anytime a ring must be handled or touched, clean cotton gloves should be worn to prevent the transfer of moisture and perspiration to the ring surface.

3.5 Rings are to be draped whenever work is not being conducted on them with light bulbs under the drape. Temperature of the ring must not be less 10°F above ambient temperature. Surface temperature of the ring is to be checked with a surface pyrometer not less than twice each shift. Rings that will stand idle form more than two hours when being worked upon must be stored as described herein.

3.6 Every effort must be made to keep rings clean and dry.

3.7 Only non-chlorinated solvents or marking agents will come into contact with rings.

3.8 For transport from one building to another, RCSR's must be completely enclosed inside waterproof covers.

3.9 If there will be no activity for a month or more, the RCSR's must be lightly coated with Tectyl 511 (00-315-461-00-019) and enclosed until work is resumed, at which time the covering is to be removed and the Tectyl coating wiped off with a cloth dampened with kerosene or mineral spirits. RCSR's should be cleaned with the same solvent before coating.

4.0 Long term storage of two months or more requires boxing and enclosing per 03-130-887 and keeping indoors in a heated location. When RCSR's are taken out of storage they must be zyglo and eddy current inspected prior to putting into service.

5.0 RCSR's left on rotors in storage must be protected by enclosing the rotor and keeping it above ambient with light bulbs or heaters. If the RCSR's are not painted, they should be lightly coated with Tectyl 511, taking care to keep it out of the rotor internals by plugging and/or taping any access openings.

6.0 At any point in the above where liquid moisture is observed on a RCSR it must be immediately removed by wiping and the source determined and eliminated. The area must be inspected and verified to be defect free.

ABB Power Generation, Ltd. - Recommended Practices

During Operation

The temperature of the cooling water in the stator winding has to be above the dew point of the surrounding gas during all operating conditions.

While Offline

1. Install humidity monitor and continuously check humidity.

2. Install stand still heating, if necessary.

During Outages

With rotor in stator:

1. Install humidity monitor and continuously check humidity.

2. Install stand still heating, if necessary.

With rotor out of stator:

Apply air dryer.

While in Storage

Storage more than 10 days: Enclosure (tent) for protection to keep the field temperature above the dew point (air dryer or heating) to prevent condensation. Short storage: Put on alu-strips and coat with silicon.

Additional Comments

Cleaning: Use only halogen- and sulfur-free cleaner.

GEC Alsthom - Recommended Practices

During Operation

Dryers for large H_2 cooled generators. External painting of retaining ring

While Offline

Automatic electric heating. Dryer or drying products in closed circuit.

During Outages

Heating blankets rolled around the rings.

While in Storage

Tight packing as long as possible. Heating blankets after opening.

C

PARTIAL LIST OF HARDWARE SUPPLIERS

Dual-Tower Gas Dryers

LECTRODRYER
P.O. Box 2500
Richmond, Kentucky 40475
606 624-2091

Pneumatic Products Corporation (PALL)
4647 S.W. 40th Avenue
Ocala, Florida 32674
904 237-1220

Westinghouse Electric Company
(Similar to LECTRODRYER)
Contact Local Sales Representative

Dew Point & Humidity Monitoring Equipment

Panametrics, Inc.
Process Instrument Division
221-T Crescent St.
Waltham, MA 02154
617 899-2719

Alnor Instrument Company
7555 N. Linder Avenue
Skokie, IL 60077
708 677-3500

VAISALA Inc.
Sensor Systems Division
100 Commerce Way
Woburn, MA 01801
617 933-4500

D

COMPILATION OF UTILITY SURVEY COMMENTS

Following is a compilation of comments received on the questionnaire:

Would like specific recommendations and examples for each category (of retaining ring operation).

Beaver Valley Power Station (Duquesne Light Company) has a spare set of 18-5 rings in good shape on hand (67-inch, Westinghouse).

1) Have other members installed real-time dew point monitors? What has been the operating experience?

2) Have other members installed blowers to provide H2 gas flow through dryers with the T-G unit at rest?

We are currently considering upgrading existing single tower hydrogen dryers to a dual tower design as well as installing dryers on those units which do not have dryers. We are also considering the installation of continuous dew point monitors.

Arizona has an extremely dry climate, and the units are indoor units. Most of our exposure is hydrogen cooler leaks. Effects of cooler leaks are minimal since hydrogen pressure is greater.

Would like information on mfg./model, of instrumentation being used and/or should be used to measure dew point, humidity, temp., etc. as well as problems encountered, cautions, good practices, user actual experiences for these instruments.

Present plan is to change out all our remaining 18-5 rings over the next 5-6 years. We would then have all retaining rings either magnetic steel or 18-18 material.

When rotor work is being done, a large plastic enclosed framework used in conjunction with dehumidifying equipment is a prudent measure.

A comprehensive review of our nuclear units is being finalized. It incorporates the latest developments in inspection/qualification techniques, unit specific PRA, and cost/benefit study of alternatives.

- For air cooled generators, it is important to maintain the heater strips for a warm environment to avoid moisture condensation.
- Follow OEM guidelines.
- Pay attention to liquid detectors and investigate all alarms.
- Provide as much shelter from weather as possible while rotor is removed.

Monitoring of alterrex 18-5 rings could be advantageous in future as accumulative water damage continues.

Provide on-line dew point measuring instrumentation on all units, but particularly on those using 18-5 RR material, with alarm setting and recommendation for operator action.

With units offline:

— maintain dry hydrogen gas environment, or

— dry air environment, or

— dry nitrogen blanketing

For long term storage:

— use environment controlling storage bags with dew point monitors and gas/air dryers.

A. We are following the OEM guidelines on the generators and avoid moisture at all times.

B. Our intention is to change all retaining rings during the upcoming major outages on all units. This will be done over the next 6 years.

Have changed Unit 2 retaining rings to new 18-18. Unit I still 18-5.

Is it good practice to paint retaining rings between inspections? Provide design information for dew point monitoring instrumentation.

I think you do more damage and put yourself at risk by removing and inspecting 18-5 rings. Leave the rings in place unless you're going to replace them.

For gas turbines, current preventative maintenance procedures are as follows:

a. Make sure the heaters are working.

b. Protect the rotor while the heaters are out of service.

c. No use of water or chlorinated solvents during rotor cleaning

Approximately 80% complete replacing 18-5 rings with new 18-18 rings.

We are using the Pall gas dryer on Unit 3. It seems to be doing a good job.

We perform NDT (such as dye penetrant, magnaflux) on retaining rings approximately every 5 years.

The new generator has 18-18 retaining ring material. No 18-5 material in present unit.

Commonwealth Edison developed a detailed guideline to be followed by the operating people. This guideline provides recommendations on how to provide protection against moisture exposure under all situations. This guideline is available for your reference.

Have plans to install dew point alarms in gas supply systems and in generator end bell access cover. Are considering self-circulating gas dryers for our one cycling unit. Will eventually develop operating procedures for dew point alarm conditions which should include purge and drain without shutting down. May include changing VAR conditions to heat rotor prior to shutdown.

a) Replace with 18-18 rings.

b) Our gas turbine application of environmental control for retaining rings includes several items, including the following:

    1) Generator stator heaters off, or malfunction is alarmed into the control room.

    2) Any start-up of the unit must include a minimum 2 hours operation time to build up residual heat to replace the warm air evacuated during the ramp up to speed.

    3) Additional collection ring and excitation compartment heaters are being proposed.

    4) Conversion to a TEWAC, totally enclosed water-to-air, is being studied.

Follow manufacturer's guidelines.