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# MAINTENANCE TEAM INSPECTION RESULTS: INSIGHTS RELATED TO PLANT AGING

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## INTRODUCTION

The maintenance team inspections conducted over the past two years have provided the NRC with an abundance of information about the content and quality of utility maintenance programs. These in-depth performance based inspections have addressed areas such as:

1) overall plant performance related to maintenance,

2) management support of maintenance, and

3) the implementation of the maintenance program.

Incorporated in the inspection criteria established for these general areas are specific attributes that are related to the concept of understanding and managing aging. These include:

- root cause evaluation of equipment failure,
- trending of failure data,
- equipment qualification program implementation,
- control of spare parts,
- evaluation of test results, including post maintenance testing, and
- condition monitoring techniques.

The inspection team's judgement of how the above attributes are treated in the utility maintenance programs reflects on the ability of the plants to manage the effects of aging on safety related structures, systems and components. Therefore, a selected number of maintenance team inspection reports were reviewed with the following objectives in mind:

1. Assess the evaluations of those portions of the maintenance program determined to be important for understanding and managing aging.

2. Evaluate the weaknesses noted in utility maintenance programs which could effect the ability of the plant to manage aging.

3. Determine the types of preventive maintenance activities and condition monitoring techniques used which address plant aging.

## BACKGROUND

The maintenance team inspections have been performed in accordance with temporary instruction (TI) 2515/97, entitled "Maintenance Inspection". The purpose of this inspection is to determine the effectiveness of the total integrated maintenance process. As specified in the TI, "the goal of the inspection effort is to emphasize the use of plant experience, test and surveillance data, recent component failures, [and] PRA insights..." to identify strengths and weaknesses. Two volumes of inspection guidance supplement the TI, and direct the inspector to evaluate the maintenance/aging association. For instance, in section 4.2.1.2 of the supplemental guidance, the inspector is directed to determine the extent to which management is aware of plant aging. Similarly, section 4.2.2.7 requires the inspector to evaluate the involvement of corporate management in maintenance activities which address plant aging.

More important than these citations, however, is the assessment of maintenance program activities which reflect on the plant's ability to manage aging. Predictive and preventive maintenance programs must include condition monitoring, trending, and record keeping in order to effectively manage the effects of aging. Inadequacies found in these areas are indicative of a plant's inability to properly address aging.

At this time, 47 inspections have been completed, with 24 more scheduled to be conducted through the end of 1990. The Performance and Quality Evaluation Branch of NRR has compiled the findings from these inspections in a computerized database. With their assistance, the plants were identified where the NRC inspection teams had reported concerns about how the maintenance program accounted for the effects of aging. Ten reports were obtained which contained specific findings that the utility maintenance programs do not address aging. These 'aging' findings from the database are summarized in Table 1.

It should be noted that nine out of these ten inspections concluded that the overall maintenance programs were adequate, satisfactory, or good. Thus, despite the fact that deficiencies were found in the management of aging at these facilities, their overall maintenance programs did adequately address other NRC concerns. Based on the guidance provided to the maintenance inspection teams, a maintenance program can be judged to be good because it effectively manages current problems, but not effectively manage the long term aging effects on components, systems, and structures.

Table 1: 'Aging' Findings from Selected Maintenance Reports

| Plant | Finding |
|---|---|
| 1. Dresden 2 & 3 | Aging of electrical components not considered |
| 2. Maine Yankee | No formal program to address plant aging |
| 3. St. Lucie 1 & 2 | Limited life components not tested in PM Program |
| 4. Arkansas Nuclear One 1 & 2 | Lack of awareness of aging |
| 5. Hope Creek | Aging issue not fully addressed |
| 6. LaSalle 1 & 2 | No program to identify trends in plant aging |
| 7. Waterford 3 | No formal program to address plant aging |
| 8. Grand Gulf 1 | No program in place to address plant aging affects |
| 9. Clinton 1 | No followup of aging failures |
| 10. Indian Point 2 | Data is not used in support of Plant Aging Program |

DISCUSSION

Ten of the completed maintenance team inspection reports have been reviewed to obtain the following information related to aging:

1) weaknesses in the maintenance programs

2) maintenance program strengths

3) applied condition monitoring techniques

4) maintenance activities on specific components, systems and structures

5) NRC inspector concerns/comments

Weaknesses were found in all ten plants in the area of aging. Weaknesses were also found in areas that the NPAR Program has identified as being important to understanding and managing aging during both the original license term or for plant life extension. These are listed on a plant by plant basis and summarized following this listing.

In a similar manner, maintenance program strengths, condition monitoring techniques, and specific maintenance activities being conducted at the plants as described in the maintenance team inspection reports are listed and discussed in separate sections. Finally, some general comments and observations made by the inspection team related to the maintenance/aging management correlation are presented. These illustrate some maintenance program activities which concerned the inspection team.

Maintenance Program Weaknesses

Nuclear power plant maintenance programs should include activities which will be effective in detecting and mitigating the effects of aging. The ten maintenance team inspection reports which are discussed in this report contain findings indicating that aging is not being properly addressed. These are presented in this section, along with other findings or observations also indicative of a potential inability to manage aging.

a. Dresden

- Plant aging consideration for electrical components had not been addressed. (p.44)
- Lack of "as-found" condition and "maintenance cause" was considered a weakness because trending, rework identification, and root cause analysis would be hindered. (p.13)
- A trend program based on equipment histories had not been established. (p.46)

b. Maine Yankee

- No formalized program exists that addresses plant aging considerations. (p.21)
- Engineering weaknesses included the lack of the system engineer concept, no failure trending analysis involvement, minimum input to corrective and preventive maintenance procedures. (p.5)
- Trending is done only on an individual component basis and NPRDS is not used. (p.6)
- "The lack of incorporation of PRA considerations into the maintenance program is considered a weakness." (p.25)

c. Arkansas Nuclear One

- "The apparent lack of awareness of plant aging is considered a weakness. It appears to be attributable to an unimplemented equipment trending program." (p.3)
- "Maintenance history, component failure analysis, and trending were determined to be weak." (p.2)
- "There was a lack of awareness of plant aging of nonsafety related equipment as evidenced by numerous problems with the instrument air system." (p.9)
- Electrical, mechanical, and I&C groups have made little progress in identifying equipment data to be trended. (p.10)
- "The NRC inspectors found weaknesses in both the licensee's program for root cause analysis and its implementation." (p.11)
- "The role of probability risk analysis was noted to be nonexistent in the maintenance process." (p.18)

d. St. Lucie

- Known limited life components are not included in the PM Program - specific reference to NPAR and electrolytic capacitors. (p.13)
- Vendor recommendations were not properly incorporated into procedures for mechanical maintenance. (p.64)
- The sensitivity to minor deficiencies needs to be increased. (p.64)

e. Hope Creek

- Plant aging issues have not been fully addressed. (p.12)
- The inspection team was critical of the oil sampling and analysis procedure for the EDGs. (p.29)

f. LaSalle

- Did not have an established program to identify subtle trends in plant aging or common mode failures in electrical components. (p.18)
- Set point drift problems not adequately evaluated to eliminate root cause. (p.22)
- Diagnostic program for motor-operated valves of a narrow scope and considered to be behind the industry. (p.5)

g. Waterford

- No formal program had been initiated to address plant aging awareness. (p.15)
- Inadequate attention to ISI and IST results. (p.18)
- "The NRC inspector considered the licensee's program for lubricating MOVs inadequate for preventing the mixing of greases of different soap bases in MOV main gear boxes." (p.14)
- No programmatic mechanism to assure that system engineers were made aware of pertinent industry operating experience. (p.13)
- Post maintenance testing of compressors not being performed. The capacity of this equipment was between 50% and 65%. (p.35)
- "There were few component-specific corrective maintenance procedures for mechanical components. (p.4)

h. Grand Gulf

- "A noted weakness in the program was that there was no specific program in place to address plant component aging...." (p.17)
- "...maintenance requirements for non-safety related equipment based upon the service life of the constituent parts of that equipment had not been established." (p.17)
- "Areas identified as weaknesses elsewhere in this report such as root cause analysis, maintenance, and component trending, ...are in part due to weaknesses in the System Engineering Group." (p.21)
- "The use of PRA concepts is non-existent in the GGNS maintenance program." (p.22)
- The description of the problem and the corrective action on the work request were too cryptic to be useful for equipment history. (p.40)

i. Clinton

- "There was no formal method to assess the corrective action for these types of failures to determine the extent that the operability of other identical components could have been subjected to common mode 'Plant Aging' failure." (p.15)
- "The inspectors concluded that the system engineers' involvement was weak in the MWR process, root cause analysis, field system and component walkdowns,...." (p.15)
- The licensee had not established goals for measuring the effectiveness of maintenance. (p.5)

j. Indian Point 2

- Management has no effective indicator available to monitor plant aging or the effectiveness of site maintenance to impact plant aging. (p.11)
- "The licensee's maintenance program also lacks a thorough incorporation of vendor maintenance recommendations into the preventive maintenance program." (p.14)
- "While environmental (EQ) required maintenance was defined, a program with procedures to implement, schedule, and track this EQ required maintenance was not yet in place." (p.16)
- A systematic method does not exist for defining equipment maintenance requirements for inclusion in the PM program. (p.16)

Maintenance Program Weakness - Summary

The maintenance program weaknesses which were identified in more than one of the inspection reports are summarized in Table 2. Each of these relates to some degree to the ability of the licensee to manage the effects of aging.

Table 2: Summary of Maintenance Program Weaknesses

| Observation | # of Plants |
|---|---|
| Management of Aging Not Addressed (see Table 1 for details) | 10 |
| Inadequate trending | 5 |
| Inadequate root cause analysis | 4 |
| System engineer program deficiency | 4 |
| PRA considerations not included | 3 |
| Maintenance history not maintained | 3 |
| Vendor recommendations not considered | 2 |
| No method to identify PM requirements | 2 |
| Insufficient diagnostic maintenance | 2 |

Maintenance Program Strengths

In the course of the maintenance team inspections, the inspectors recorded positive observations in the programmatic and equipment-specific aspects of the utility maintenance programs. Those aspects necessary for managing aging which were documented in the reports have been extracted and are discussed below. Reference citations pertain to the page numbers of the applicable inspection report.

a. Dresden

- Maintains a setpoint trending program for bistables. (p.21)
- Employs a time series analysis of equipment failures to determine preventive maintenance requirements. (p.43)

b. Maine Yankee

- Service life information is being gathered on safety related electrical equipment and associated parts; technical efforts are being conducted on mechanical and electrical issues which affect plant aging. (p.21)
- Licensee has an aggressive work schedule and program for motor operated valves. (p.61)

c. Arkansas Nuclear One

- The preventive maintenance improvement project was determined to be a definite strength. The entire PM concept had been reevaluated and restructured from new procedures to implementation. (p.2)
- Motor operated valve diagnostic testing is significantly greater than the industry norm. (p.2)

d. St. Lucie

- All of the instruments used to obtain data for operator logs are included in the calibration program. (p.54)
- Based on a circuit breaker failure analysis, PM was initiated on all similar breakers in the control rod drive system. (p.49)

e. Hope Creek

- Numerous performance indicators are available for management to assess the status and effectiveness of maintenance. (p.4)
- The maintenance management information system (MMIS) is used by system engineers to analyze completed corrective maintenance to determine any action requirements and inputs to the station performance trending/monitoring program. (p.24)

f. LaSalle

- Has implemented a Problem Assessment Data Sheet (PADS) program to facilitate the systematic root cause and failure analysis of systems and components. (p.28)
- Trends of results were evident for predictive maintenance in the areas of vibration data and lube oil samples. (p.30)

g. Waterford

- Has applied lessons learned of past equipment problems and repairs to PM Program to enhance reliability and availability. (p.31)
- A root cause evaluation of all failures is conducted with a view toward extending the operating life of a component, or quantifying failure information in order to better predict when a component will fail again. (p.32)
- All maintenance activities on both safety related and BOP equipment were stored in the computer data base and in the NPRDS; the computer data base appeared to be an excellent basis for maintenance trending. (p.31)

h. Grand Gulf

- The Independent Safety Evaluation Group (ISEG) reviews plant operations and maintenance experiences; evaluating and trending those experiences, reporting to NPRDS, and making recommendations to plant management. (p.21)
- The Station Information Management System is a tool that will improve component trending analysis. (p. 29)

Summary of Maintenance Program Strengths

Table 3 summarizes these maintenance program strengths identified in the maintenance team inspection reports which could be incorporated into a program to address plant aging.

Table 3: Summary of Maintenance Program Strengths

| Observation | # of Plants |
|---|---|
| Evaluation of failures for further action | 6 |
| Trend program in effect | 4 |
| Gathering service life data | 2 |
| Effective PM program | 2 |
| Aggressive MOV program | 2 |

Condition Monitoring Techniques

As part of the review of the maintenance team inspections, information about the condition monitoring techniques that were observed were recorded. These are listed below along with the page reference from the applicable report.

a. Dresden

- Detection of loose connections by using thermography. (p.15)
- Vibration analysis and lube oil analysis used. (p.15)
- MOV diagnostic performed using "VOTES", Valve Operator Testing and Evaluation System. (p.18)
- Sonic test equipment used to detect instrument air leaks. (p.15)

b. Maine Yankee

- MOV diagnostic testing performed using MOVATs. (p.61)

c. Arkansas Nuclear One

- MOV diagnostic tests (MOVATs). (p.2)
- Vibration and loose parts monitoring system; however, found by the inspection team to be inoperable. (p.17)

d. St. Lucie

- "The licensee has had several successes in both the vibration and thermography areas." (p.28)
- The cause of unplanned shutdowns are analyzed - critical system parameters are then monitored and trended to prevent future shutdowns. (p.31)

e. Hope Creek

- Calibration data is evaluated and noise analysis conducted for pressure transmitters. (p.32)

f. LaSalle

- The electrical maintenance monitoring included vibration analysis of motors, analysis of EDG lubrication oil, and thermography. (p.16)
- Oil samples from electric motors and transformers were analyzed, but the results were not trended. (p.18)
- Performance monitoring of heat exchangers and erosion/corrosion pipe monitoring in early stages of implementation. (p.4)

g. Waterford

- All safety related and most BOP mechanical components are included in the vibration monitoring program. (p.36)
- Items trended include flow rates, pressures, temperatures, and instrument setpoint drift. (p.36)

h. Grand Gulf

- Trending of motor megger readings, specific gravity for batteries, lube oil analysis, and vibration. (p.34)

i. Clinton

- Electrical maintenance included monitoring techniques such as vibration analysis, motor oil samples, and thermography to detect loose electrical terminations. (p.7)

j. Indian Point 2

- The licensee has implemented several commendable efforts at predictive maintenance including the use of thermography to find problem spots and valve stroke time trending to trigger preventive maintenance. (p.16)

Summary of Condition Monitoring Techniques

An important aspect in any maintenance program is the ability to assess the condition of the equipment. In each of the inspection reports, the team provided examples of the predictive maintenance practices. That is, those parameters that were being monitored in order to detect degradation of the equipment or system prior to a failure are described. Table 4 lists the techniques highlighted in the inspection reports.

Table 4: Condition Monitoring Techniques

| Technique | # of Plants |
|---|---|
| Vibration analysis | 7 |
| Thermography | 5 |
| Lube oil analysis | 4 |
| MOV diagnostics | 4 |
| System parameters | 2 |
| Noise analysis, erosion/corrosion monitoring, insulation resistance of motors, and specific gravity of batteries | 1 |

Maintenance on Specific Components

Several of the maintenance team inspection reports described maintenance activities or a lack of maintenance for specific components which were evaluated or observed. Of particular interest here are citations associated with components or systems studied in the NPAR Program.

a. Dresden - None specifically identified.

b. Maine Yankee

- Cleaning and inspection of motor control centers. (p.35)
- Refurbishment of 83 General Electric AK-25, 480 volt circuit breakers. (p.37)
- Cleaning and inspection of battery chargers and inverters. (p.38)
- Upgrade of power semiconductors and cable for battery chargers. (p.38)

c. Arkansas Nuclear One - None specifically identified.

d. St. Lucie

- Lack of PM on molded case circuit breakers.
- PM Program to inspect and test capacitors in inverters and battery chargers - specific reference to NPAR. (p.13)
- No PM of instrument air filter regulators - changed when they become clogged. (p.15)
- Replaced station battery recently due to 'copper contamination'. (p.11)
- Discrepant condition involved peeling tape on electrical splices. (p.11)
- Significant fuse and fuse holder degradation due to corrosion. "Since the plants are located in a salt air environment, the team was concerned that corrosion in the electrical circuits could be a potential problem." (p.49)
- Control rod drive system molded case circuit breakers were placed in the PM Program due to setpoint problems. (p.49)

e. Hope Creek

- Performs regular insulation and winding resistance tests on transformers. (p.30)
- EDG generator end PM involves checking the condition of the coils, rotor-stator air gap, collector rings, and brush rigging. (p.30)

f. LaSalle

- EDG operational parameters trended. (p.18)
- Melamine torque switches used in Limitorque MOVs failed due to 'post mold shrinkage', which was affected by temperature and age. (p.29)
- Upgrade of SOVs on the EDG fuel oil system included the utilization of improved internals such as Viton 'O' rings instead of EPDM 'O' rings. (p.20)

g. Waterford

- PM on 4160 volt switchgear requires torquing of all limit switches, auxiliary switches and switch tie-bolts. (p.29)
- Reactor trip breakers (General Electric AK-2-25) are returned to GE every five years for refurbishment. (p.27)
- "Components of the operators for air operated valves were not in a preventive maintenance program." (p.5)

h. Grand Gulf - None specifically identified.

i. Clinton

- Nitrogen pressure was not being maintained on the electrical penetrations. (p.23)

j. Indian Point 2

- Capacitors are periodically replaced on the Foxboro rack equipment. (p.16)
- An 18 month PM inspection is performed by Westinghouse and plant personnel on the reactor trip breakers (DB-50s). (p.33)

General Comments

In each of the inspection reports, observations are made by the team which provide insights into the philosophy of the maintenance program from NRC's perspective. Those that relate to aging are summarized below:

a. Dresden

- An 'alert level' of 2 corrective work requests on a component in 6 months had been established. The inspection team was concerned that this does not identify trends common to a specific model number, or longer term trends. (p.25)

b. Maine Yankee

- The NRC inspection team suggests a more active use of NPRDS to identify trends and assist in failure analysis. They also indicated that coordination of MOV work is critical due to multiple tasks. The NRC inspection team noted that prior to 1987, PM work items had more deferrals than presently, indicating that PM was not a high priority. (p.65)

c. Arkansas Nuclear One

- The inspectors noted that several hundred engineering activity requests are being evaluated by the utility for substitution of components no longer manufactured or available. (p.18)

d. St. Lucie

- The team does not consider the ASME Section XI vibrational surveillance a substitute for vibrational analysis performed as part of a good PM Program. (p.38)

- Components with 4 or more failures in 12 months are identified; components from the NPRDS are identified when their failure rate is 1.6 times the industry average. (p.30)

e. Hope Creek

- Periodic reports are obtained from NPRDS comparing failure data for HCGS with industry averages. A detailed failure analysis is performed if a high rate is obtained - "significance factor". (p.10)

- The reliability centered maintenance program has been formulated for Hope Creek. When implemented, it will provide a more formal means of addressing plant aging issues and the decision processes relating to maintaining, upgrading, or replacing equipment. (p.14)

f. LaSalle

- Measure of maintenance effectiveness included backlog and PM/CM ratio. Did not include number of LCOs or power reductions.

- Trend definition: 3 failures of component in a 12 month period. Same for all components and does not consider safety impact. (p.30)

g. Waterford

- The licensee maintains a history file for all components, and conducts a root cause evaluation of all failures. This is done with a view toward extending the operating life of a component, and quantifying failure information in order to better predict when a component will fail again. (p.32)

- The licensee plans to further improve the trending and predictive maintenance program by consolidating the various trending systems into one program, and use of enhanced trending software. (p.36)

h. Grand Gulf

- Most PM requirements were generated from startup testing. Systems and components did not receive equal treatment. (p.18)

i. Clinton

- 'Aging' was listed as the root cause for 312 safety related equipment failures in last two years. This was questioned by the inspection team since Clinton is a relatively new plant. (p.15)

j. Indian Point 2

- The licensee is planning to develop a "Daily On-line Retrieval Information System - DORIS" to maintain a running record of data obtained from logs, PM, and surveillance test results. "...the inspection team considers that implementation of a DORIS type program... could significantly enhance development of the predictive maintenance program." (p.35)

## CONCLUSION AND RECOMMENDATIONS

The ten reports which have been reviewed provided information on how utility maintenance programs are addressing the aging of components, systems, and structures. This information includes the attitude of management towards the aging issue as well as the status of maintenance program attributes which address the detection or mitigation of degradation caused by aging. Those attributes which were of interest to this review include failure root cause analysis, trending of data, and condition monitoring techniques.

In general, the findings of the NRC inspection teams indicate that aging is not being adequately addressed in the maintenance programs at the ten plants which were reviewed. Most of these plants have, or are incorporating, more sophisticated techniques and tools in their maintenance programs which can be used in an effective aging management program. However, the aging issue is apparently not a high priority, and therefore is not receiving sufficient attention.

On the regulatory side, it is important to note that in each of the ten reports, inadequacies were reported related to the management of aging. However, in nine of the ten cases, the overall maintenance program was considered to be 'good', 'satisfactory', or 'effective'.

Because of the insights learned from this limited review, all of the maintenance team inspection reports are being systematically reviewed. A matrix of practices related to detecting and mitigating the effects of aging is being developed, along with a more detailed evaluation of utility practices and attitudes towards the managing of aging.

REFERENCES


1. Report 50-237/88029(DRS), 50-249/88030(DRS); Dresden Nuclear Power Station - Units 2 and 3 Maintenance Team Inspection Report, 4/4/89.

2. Report 50-461/89003; Clinton Power Station Maintenance Team Inspection Report, 5/10/89.

3. Report 50-309/88-80; Maine Yankee Atomic Power Company Maintenance Team Inspection Report, 1/18/89.

4. Report 50-313/88-36. 50-368/88-36; Arkansas Nuclear One Maintenance Team Inspection Report, 2/7/89.

5. Report 50-335/89-24 and 50-389/89-24; St. Lucie 1 and 2 Maintenance Team Inspection Report, 1/10/90.

6. Report 50-354/89-80; Hope Creek Generating Station Maintenance Team Inspection Report, 1/31/90.

7. Report 50-373/89010(DRS), 50-374/89010(DRS); LaSalle County Station, Units 1 and 2 Maintenance Team Inspection Report, 6/27/89.

8. Report 50-416/88-21; Grand Gulf Maintenance Team Inspection Report, 1/4/88.

9. Report 50-382/89-01; Waterford Steam Electric Station, Unit No.3 Maintenance Team Inspection Report, 3/14/89.

10. Report 50-247/89-80; Indian Point Station Unit No.2 Maintenance Team Inspection Report, 8/20/89.