NUREG/CR-5665
SI-14940000-1

A Systematic Approach to Repetitive Failures

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Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: December 1990
Date Published: February 1991

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NRC FIN L1513

ABSTRACT

This report presents a model of a systematic approach to address and correct repetitive failures. In this context, repetitive failures are the recurring inability of a system, subsystem, structure, or component to perform its intended function. The report presents a systematic method for identifying repetitive failures, selecting the failures to be investigated, determining root cause, selecting corrective actions for implementation, and monitoring of subsequent system/component performance. Appendix A provides an example of the use of this methodology at an operating nuclear generating station.

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1.0 INTRODUCTION

In response to public comment on draft Regulatory Guide DG-1001, Maintenance Programs for Nuclear Power Plants, the NRC sponsored research on issues related to improving the effectiveness of maintenance programs. This report presents the results of research directed toward developing a systematic approach to address and correct repetitive equipment failures.

In this context, repetitive failures are the recurring inability of a system, subsystem, structure, or component to perform its intended function. Repetitive failures are characterized by the repeated failure of an individual piece of equipment, repeat failures of various equipments within a system or subsystem (which result in the loss or degradation of system function), or the failures of the same or similar components in several different systems.

While there are many factors involved in achieving a successful maintenance program, two characteristics are common to many successful programs: (1) the conduct of proactive maintenance and (2) the development of a low tolerance for repetitive failures. A proactive maintenance policy is one in which the plant develops and executes extensive preventive and predictive maintenance programs to minimize the amount of corrective maintenance that is performed. It includes programs and policies that seek to identify and correct equipment problems <u>before</u> the equipment has lost its functionality.

In conjunction with this anticipatory approach to maintenance, the development of a low tolerance for failures involves an attitude in which failures are identified, prioritized, analyzed, and corrected. Repeat failures are investigated, root cause is determined, and action is taken to prevent further failures.

Thus, the successful plant develops an attitude or culture in which significant effort is expended to prevent equipment failures and to analyze those significant equipment failures that do occur and initiate corrective actions to prevent their recurrence.

To efficiently address those failures that do occur, it is advantageous to develop and execute an approach to these failures that focuses on the problems that are truly important to the safety and reliability of the plant. Such an approach systematically addresses the failures of systems, structures, and components. This approach provides a method to evaluate failures and concentrate resources on those failures (problems) that are most significant.

2.0 A SYSTEMATIC APPROACH TO REPETITIVE FAILURES

2.1 Overview

The use of a systematic approach to repetitive failures implies that the utility develop a methodical approach to address and prevent recurrence of system and/or component failures. A thorough and well thought out plan for addressing failures can contribute to long term improvements in plant operation and safety by efficiently allocating resources to the investigation and correction of those failures that are most critical to the safe, reliable operation of the plant. It can also contribute to development of a plant culture in which failures, particularly repetitive failures, are not tolerated.

Figure 2-1 is an illustration of a simple model of a systematic approach to repetitive failures. In this approach, repetitive failures are identified; failure problems are prioritized; analysis is conducted to determine root cause; improvement goals are established; corrective actions are taken; and performance is monitored against established goals. The model is depicted as a closed loop system to represent the continuing process of monitoring, corrective action and feedback.

Initially, the program starts with the monitoring of overall plant equipment performance. Monitoring activities should extend as widely as possible across the plant, but as a minimum, they should encompass the plant's critical components; including safety-related systems and components, systems and components that support safety systems, and balance-of-plant (BOP) systems and components whose failure could initiate or affect transients or accidents.

The purpose of the monitoring process is to identify repetitive system or component failures. Both systems and components should be monitored. Systems need to be monitored to identify the potential loss of equipment due to aging, corrosion, wear, design, or operational problems that may lead to loss of system function. For example, repetitive failures of components in service water or instrument air systems can be precursors to larger system failures and possible failure of supported safety functions. Component failures also need to be monitored in order to identify possible generic failure problems that may affect multiple plant systems.

Repetitive failures can be identified using information that is readily available to plant management. The number of corrective maintenance work orders or man-hours attributed to specific components can be determined by reviewing the maintenance

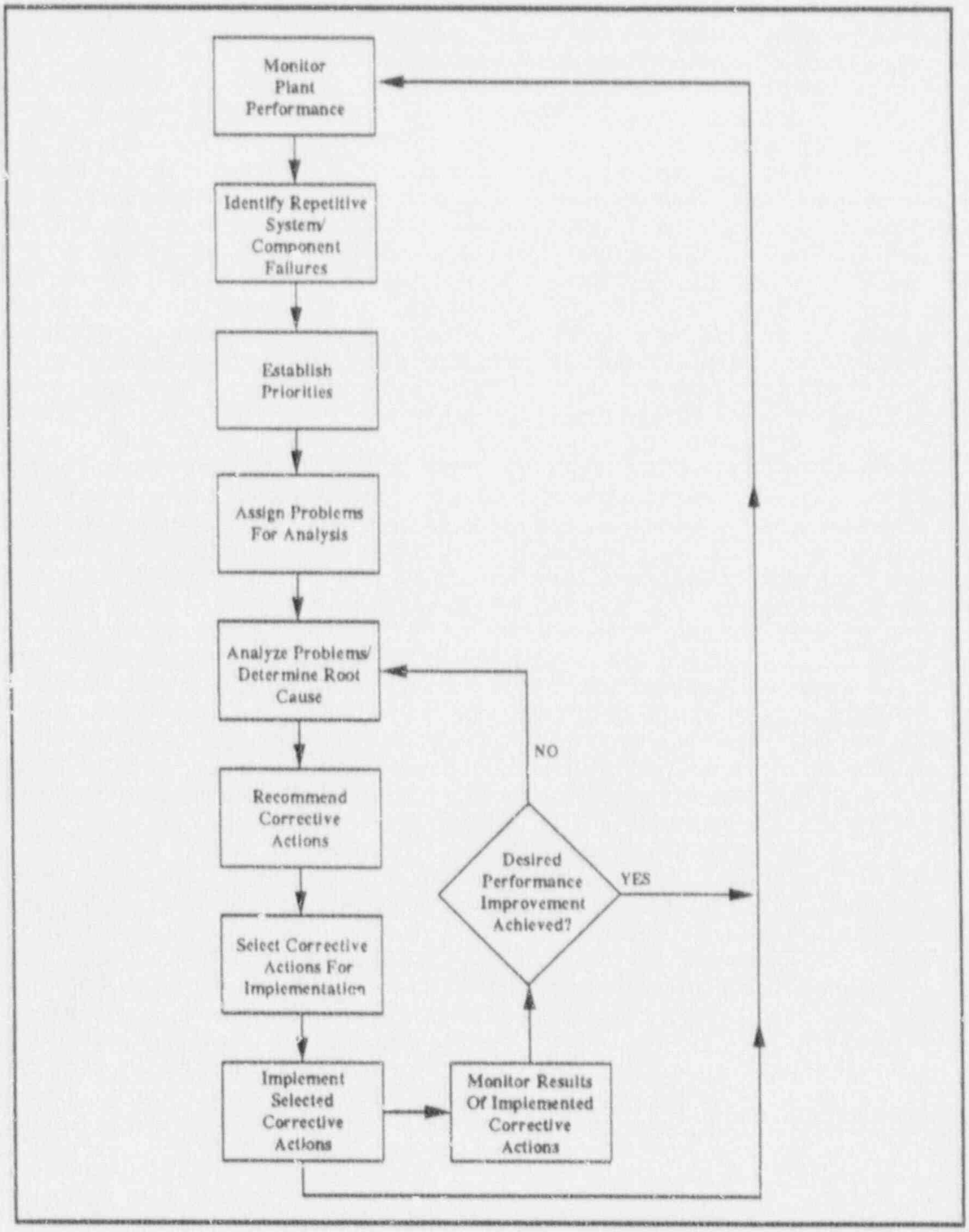


Figure 2-1. Repetitive Failure Analysis Flowchart

backlog and completed work orders. This review will generate a list of components that have experienced repetitive failures. Additionally, repetitive failures may also be identified utilizing data that are collected as maintenance performance indicators or maintenance effectiveness indicators.

Once systems and/or components with repetitive failures have been identified, the problems must be sorted by priority to allow assignment of the problems for study. Placing a priority on the problems allows the responsible managers to focus their attention and resources on the problems and failures which are considered to be most important to the operation and safety of the unit. It also provides a framework for allocation of resources within the utility. The prioritization process must account primarily for the safety significance of the equipments involved, as well as the utility's overall goals and specific unit goals.

After the failures have been identified and placed in order of priority, they are assigned for analysis. A problem may be assigned to individuals or to groups depending on the complexity of the problem and the estimate of the skills that will be required to solve the problem. When assigning the problem for analysis, the statement of the problem must be clear and the expected performance improvement must be identified. By identifying the expected performance improvement to the team as part of the assignment, the team will have a standard by which to measure possible solutions during the analysis of the problem. Possible solutions may also be suggested to the team. However, care must be taken not to prescribe the solution and inhibit the creativity of the team.

The first responsibility of the team is to collect all relevant data, analyze the problem, and determine the root cause. Based on the root cause, the team will develop a list of potential corrective actions that address the problem and the desired improvement goals.

Potential corrective actions will then have to be evaluated and prioritized in order to select those that will be assigned for implementation. Again, the candidate corrective actions will be evaluated based on the seriousness of the failure (in terms of the plant's safe operation) and the potential for improvement in safety and reliability. Other factors under consideration in selection of the corrective actions to be implemented include: (1) the length of time necessary to implement the solution; (2) the estimated cost of the corrective action; (3) the complexity of the corrective action; and (4) the nature of the change, whether programmatic or hardware.

Once the corrective actions have been evaluated and the highest priority actions have been selected for implementation, they must be assigned to the appropriate individual, department, or team. Expected actions along with a schedule and due dates should be established at this time. Actions should be completed in a timely manner in order to preclude a repeat failure while corrective actions are in progress. To this end, when long-term corrective actions are required, it may be advantageous to consider interim corrective actions when the failure has the potential for affecting plant safety. These "near- or short-term" actions are designed to minimize the potential for repeat failures or to mitigate the consequences of such a failure, and allow the plant to deal with the problem on an interim basis until the long-term corrective action can be completed.

Finally, when corrective actions have been completed, actions are taken to monitor the effects and ensure that the desired improvements have been achieved. If the problem has not been corrected, then the goals and performance must be reevaluated based on the new information. When performance goals are met, the item is closed out and routine monitoring is continued.

2.2 Monitor Equipment Performance and Identify Failures

The first step in establishing a systematic approach to failures is to determine the areas that will be monitored in order to identify candidate failures for further study and analysis. It is not possible to fully analyze every failure, therefore the objective of this step is to identify those failures that are potentially significant enough to warrant the extra attention and resources.

The performance of both systems and components should be monitored by the program. System performance provides a high-level indication of the ability of the plant to respond in accordance with its design bases. Component performance monitoring should be at a level of detail that is sufficient to guard against the potential consequences of the failure of the same or similar types of components in more than one system, i.e., generic equipment failures.

2.2.1 Primary Sources of Repetitive Failure Data

Data collected in an effort to monitor maintenance effectiveness and the maintenance process are the primary source of candidates for further analysis. Maintenance effectiveness and process indicators that may be useful in identifying repetitive failures include:

Number of maintenance man-hours by system or component, Number of maintenance work orders by system or component,

Maintenance backlog (by system),

NPRDS reports, and

Control Room instruments out of service.

For example, the number of maintenance work orders written against a system can be utilized to identify systems that are experiencing repetitive failures. By sorting the data into systems and ranking the systems by the number of work orders that have been generated against each system over a period of time (e.g., one month, one quarter, or one year), those systems that have experienced the most failures are easily identified. Systems with failure numbers that are significantly above the norm would be candidates for further evaluation.

Similarly, maintenance work orders should be sorted to identify repeated failures of individual components within a system or to identify "generic" failures across systems.

Sorting can be done by numbers of work orders or by number of man hours worked. Sorting by numbers of work orders identifies those equipment and systems that have failed the most times, while sorting by man hours worked identifies the equipments and systems that have required the most effort and the longest down time to repair.

2.2.2 Alternate Sources of Repetitive Failure Data

A second source of repetitive failure problems is the plant's overall program for goal setting and performance monitoring. Failure to achieve an overall performance goal or an adverse trend in a performance can often be the result of repetitive failures in plant systems or components. Periodic evaluation of shortfalls in plant performance in achieving its goals may identify these failure problems. Similarly, evaluation of adverse trends prior to reaching a goal shortfall can contribute to a proactive approach which seeks to sustain a high level of performance.

Plant performance goals that are typically monitored and are potentially excellent sources for identifying repetitive failures are:

Safety system unavailability,

Number of inadvertent safety system actuations, Number of plant scrams at power,

Capacity factor,

Lost generation,

Forced outage rate,

Number of Licensee Event Reports, and

Number of Plant Incident Reports/Deviation Event Reports.

When a plant goal is not met or when a goal is met but the statistics indicate a decreasing trend in performance, it is natural to follow-up to determine the underlying causes of the performance problem.

2.2.3 Monitoring Frequency

Data that are being monitored for the identification of plant equipment problems should be reviewed frequently enough to allow identification of potential problems before they can seriously affect plant operation. However, reviews should not be so often that they strain resources or cause priorities to be shifted frequently.

Since a majority of the data that are being used to monitor plant operations are associated with maintenance performance, potential failure problems will most likely be identified during the periodic reviews of these data. Many of these, particularly work order and man-hour breakdowns, are reviewed on a monthly and/or quarterly basis. During these reviews any anomalies or adverse trends should be noted and questioned. As a minimum, the selected areas should be reviewed annually in coincidence with the review of the past year's performance and the establishment of the following year's goals.

In addition to establishing the periodic review of plant performance as a discrete activity, it is also important to recognize that some areas, such as Plant Incident Reports and Licensee Event Reports, are monitored on an ongoing basis to identify individual incidents or failures of "high relative importance." These are failures of components or systems that are serious enough individually that a recurrence of the failure would be unacceptable from a safety or operational standpoint. These types of failures should be added to the program for evaluation and ranking as they occur.

As an example, periodic reviews of Plant Incident Reports might identify a number of failures in the plant's differential transmitters that resulted in operational difficulties but did not cause a serious plant transient or plant trip. In this case, the individual incidents of failure did not cause a serious problem, but the recurrence of failures associated with the same type of instrument would be indicative of a more serious, potential generic problem that may warrant further investigation. Similarly, a single failure of a differential pressure transmitter that results in the loss of a steam generator's water level and a subsequent plant trip may warrant immediate investigation to determine the root cause of the failure and whether or not the potential for failure in other similar transmitters exists.

Figure 2-2 provides an example of a monitoring plan that might be included in a plant's program to address repetitive failures.

2.3 Establish Priorities

Once the system and component failures that warrant further evaluation have been identified, the next step is to rank the problems prior to assigning them to teams. This ranking is necessary to provide the input into the resource allocation decisions that must be made when assigning the problems to teams and later, when evaluating the costs of implementing the proposed corrective actions. The ranking also focuses attention on those problems that have been identified as the most important to the achievement of the plant's operational and safety goals.

Where the plant or utility has an existing system for evaluating and ranking projects, the problems that have been identified can be integrated into this system or they may be evaluated using a separate system. The ranking process could include inputs from any or all of the following:

Overall plant performance goals,

Probabilistic Risk Assessment (PRA)/Individual Plant Evaluation (IPE),

Reliability Centered Maintenance (RCM) studies,

Plant Safety Analyses/Technical Specifications, and

Costs in man-hours, dollars, exposure, or lost generation due to recurring failures.

MONITORING PLAN

1. The following areas of plant operations shall be included in the plant's overall performance monitoring plan. Reports associated with each of the areas shall be reviewed in order to identify:

   a. Repetitive component or system failures

   b. Goals that were not met due to equipment performance problems

   c. Adverse trends in performance

   d. Significant component or system failures

2. The following maintenance process indicators shall be reviewed quarterly for potential equipment performance problems as follows.

   a. The number of corrective maintenance work orders generated in the past year for each safety-related system and component will be totaled. Systems and components will be ranked in order from the highest to lowest number of corrective maintenance work orders. The ten systems that have sustained the highest number of repetitive failures, i.e. the highest number of work orders, and the ten components with the highest number of failures will be further evaluated.

   b. The number of man hours of corrective maintenance work generated in the past year for each safety-related system and component will be totaled. Systems and components will be ranked in order from the highest to lowest number of man hours worked. The ten systems that have sustained the highest number of repetitive failures, i.e. the highest number of man hours, and the ten components with the highest number of failures will be further evaluated.

   c. NPRDS Component Failure Analysis Reports (CFAR) will be reviewed annually. Safety-related components that have displayed failure rates that are 25% greater than the industry average will be further evaluated.

3. The following plant performance goals shall be formally reviewed on an annual basis to identify potential equipment performance problems.

   a. Safety System Unavailability for:

      (1.) High Pressure Coolant Injection

      (2.) Low Pressure Coolant Injection

      (3.) Safety Injection

      (4.) Emergency Diesel Generators

   b. Inadvertent Safety System Actuations

   c. Forced Outage Rate

   d. Capacity Factor

4. Licensee Event Reports (LERs) and Plant Incident Reports (PIRs) shall be reviewed annually to identify repetitive equipment problems that have resulted in multiple reports. Additionally, LERs and PIRs that have resulted from failures that are indicative of the potential for serious component or system performance problems shall be included in the program for evaluation as they occur. (Note: This is in addition to and/or in conjunction with the normal follow-up that would be required for a PIR or an LER.)

Figure 2-2. Sample Monitoring Plan

Figure 2-3 provides a sample of a ranking form that might be utilized to evaluate the competing problems. It is meant to be illustrative of the types of inputs that could be used and the weighting factors that might be assigned to the categories, and is not all inclusive. There are many factors that might be included in ranking the problems. Each utility and plant will need to develop and select inputs and weighting factors that fit within their existing systems for evaluating alternatives and allocating resources. For example, other factors that might be considered in ranking the problems include meeting a specific plant performance goal (such as safety system unavailability), or meeting an overall corporate goal to improve the plant's core melt frequency.

No matter what process is used for ranking the problems at a plant, the process itself enforces a discipline on the organization which serves to focus attention and resources on those failures that have been defined as most important to the success of the plant. This is a key factor in reaching and maintaining a high level of plant performance.

2.4 Assign Problems for Analysis

Once the repetitive failure problems have been identified and ranked, the process of matching the problems to the available resources can begin. The number of problems that can be analyzed is dependent on the complexity of the problems and the available resources, both manpower and money.

Before a problem is assigned to a team, a clear definition of the problem and the expected improvement in performance should be provided. Both of these are logical outputs of the previous steps in the process, particularly the improvement goal. A clear statement of the problem is necessary to ensure that everyone has an understanding of the problem and its consequences.

During the identification of performance shortfalls and ranking of problems, information was gathered that will help to develop the improvement goals. For example, the PRA analysis that was used in the ranking process will indicate the performance improvement that is necessary. It is important to determine the improvement goals at this stage so that the team will have proper direction for its efforts and will have a yardstick to measure potential corrective actions.

With a statement of the problem and the desired improvement identified, the problem is ready to be assigned to a problem solving team. The size and composition of the team should be commensurate with the scope and complexity of the problem. For example, a simple problem with a single type of instrumentation may

PROBLEM RANKING FORM

Instructions: Circle the letter of the item which completes each of the phrases. In some cases, more than one item may be circled. Justification for each choice should be attached on a separate sheet. Justification for each ranking should not exceed one short paragraph. When each of the evaluation factors has been completed, determine the total ranking value at the bottom of the form.

1. Problem. ____
____
____
____
____

2. This problem involves the failure of:

    a. Safety-related systems or components (20 points)

    b. Balance-of-plant systems or components that provide essential support to safety-related systems or components (15 points)

    c. Balance-of-plant systems or components whose failure may result in a plant and/or turbine trip (15 points)

    d. Balance-of-plant systems or components (5 points)

3. This problem results in:

    a. The exposure of the general public to a controlled radioactive release (15 points)

    b. Greater than 250 mrem of exposure to plant personnel (15 points)

    c. Greater than 50 mrem of exposure to plant personnel (10 points)

    d. An increase of greater than 500 square feet in the plant's contaminated areas (10 points)

    e. An increase of greater than 100 square feet in the plant's contaminated areas (5 points)

4. This problem causes:

    a. Capacity factor loss of more than 0.5% (10 points)

    b. Expenditure of greater than 1500 man-hours to make repairs (15 points)

    c. Expenditure of greater than $50,000 for repairs (15 points)

5. Determine the ranking factor for this problem.

SUM: 2. ________
3. ________
4. ________

TOTAL ________

Figure 2-3. Sample Problem Ranking Form

be assigned to the instrumentation & controls (I&C) department or to an individual I&C engineer. However, a complex problem may require the assignment of a multi-disciplinary task force in order for the team to have the necessary technical expertise to address the entire problem.

The makeup of the team may also be affected by the scope and complexity of the anticipated corrective actions. If it is suspected that the problem with repeated failures of a salt water pump will involve the development of a new training program, it may be advantageous to assign a training instructor to the problem solving team in the beginning. This will promote problem solving and provide the trainer with a comprehensive picture of the problem (and its importance to the plant's operations and goals) when the assignment to develop and conduct the new training course is made.

The team should be provided with the statement of the problem, the improvement goals, and a schedule. The schedule should allow for effective feedback to the responsible manager(s) and for timely completion of the task. The time allotted to determine the root cause of the problem and to recommend solutions should be established based on the safety significance and criticality of the failure that is being analyzed. Other factors under consideration when establishing a schedule are the plant's operational and outage schedule, the complexity of the problem, the availability of the resources needed to analyze the problem (e.g., outside laboratories), and the competing assignments of the task force members.

2.5 Analyze Problem and Recommend Corrective Actions

Once a team has been assigned, its responsibility is to analyze the component and/or system failure(s) and determine the root cause(s); that is, the cause(s) of the failure(s) which when corrected will minimize the probability of recurrence. The team may use formal root cause analysis techniques; such as Programmatic Root Cause Analysis, Kepner-Tregoe Analysis, Management Oversight and Risk Tree (MORT), and Cause-and-Effect Analysis, or they may use more informal methods. In arriving at a conclusion, the team may utilize inputs from engineering studies, laboratory analyses, manufacturer's recommendations, plant machinery history, preventive and predictive maintenance records, and field mechanic's or technician's knowledge to analyze the situation. A key ingredient to the success of the team in arriving at a solution will be the depth of the analysis to determine the cause of the failure. Figure 2-4 provides a short list of some categories and subcategories of root causes that are commonly identified, however the actual root cause will necessarily be much more detailed.

TYPICAL ROOT CAUSE CATEGORIES

Personnel Error

- Failure to Follow Procedures
- Miscommunications
- Training/Knowledge Deficiency
- Lack of Attention
- Supervisory Deficiency
- Programmatic Deficiency
- Human Factors Deficiency
- Improper Tools
- Inadequate Retest

Procedural Error

- Incomplete Information
- Inaccurate Information
- Lack of Procedure
- Poor Format or Presentation
- Conflicting Information
- No Clearly Defined Acceptance Criteria

Equipment Failure

- Design Deficiency
- Maintenance Deficiency
- Manufacturing Deficiency
- Wear Out
- Installation Error
- Inaccessibility for Maintenance

External Causes

- Wind
- Lightning
- Tornado
- Flood
- Inclement Weather

Figure 2-4. Typical Root Cause Categories

When the team is satisfied that it has identified the actions that could have been taken to prevent occurrence of the failure, then it can proceed to the development of recommended corrective actions. Recommendations should focus on the elimination of the root cause and thus, the failure. If it is not possible to eliminate the potential for the failure to recur, then the corrective actions will need to focus on mitigation of the failure.

Possible corrective actions may take the form of any combination of the following:

New/Revised Operating Procedures,

New/Revised operator training,

New/Revised Maintenance Procedures,

New/Revised maintenance training,

Additions/Revisions to the Preventive Maintenance Program,

Additions/Revisions to the Predictive Maintenance Program,

Equipment replacement,

Simple design changes, and/or

Complex design changes.

2.6 Select Corrective Actions for Implementation

Once the potential corrective actions are identified, they must be evaluated to determine which of the actions should be implemented. One of the key inputs to the decision analysis is the team's best estimate of whether or not the proposed corrective actions achieve the improvement goals that were originally specified. Other factors that should be considered at this time include:

Ease of implementation of the corrective action versus the achievement of the established improvement goals,

Resources (manpower, cost, and schedule) required to implement the corrective actions, Time necessary to implement the corrective action, and

Design bases and regulatory requirements.

Ease of implementation versus achievement of the desired improvement in performance is an important consideration at this stage. In many cases, it may be possible to obtain all or most of the desired gains by implementing a corrective action that is quick and easy to install. In this case, an improvement in performance that is slightly below that which was originally desired may be acceptable. Similarly, an inexpensive fix may be acceptable if it achieves most of the desired improvement.

Another consideration is the time necessary to implement the desired corrective actions. In some cases, the optimal solution to the problem may involve a design change that requires a large effort to design and install. With no short-term solutions available that are completely adequate, it may be necessary to implement some short-term actions to lower the probability of a recurring failure or to mitigate the consequences of a failure. This would be an interim action that would help to provide time while the long-term corrective actions were being developed.

Again, the potential corrective actions should be ranked and evaluated within the context of the plant's normal program for allocating resources and establishing goals. By weighing the desired performance improvements against the possible corrective actions and the "costs" of implementing those improvements, the plant can decide which corrective actions will ultimately be implemented.

2.7 Implement Selected Corrective Actions

Corrective actions that have been selected for implementation should then be assigned to individuals, departments, or teams for implementation. Schedules and milestones should be established based on the complexity of the corrective actions, available resources, and the importance of the implemented corrective action to the safe operation of the plant. The schedule and milestones should be reviewed periodically to ensure that adequate progress is being made. Adjustments to the schedule and/or the resources assigned should be made in order to ensure the timely implementation of the corrective actions.

2.8 Monitor Results of Implemented Corrective Actions

Following the implementation of corrective actions, the performance of the affected systems and/or components should be monitored to determine whether or not the improvement goals have been met. Implementation plans should include sampling or monitoring plans that are designed for this purpose. Early feedback on the success of the corrective actions in solving the performance problems is desirable. This will allow timely changes to be made to the corrective actions in the cases in which the performance improvement goals are not met. Similarly, if short-term corrective actions result in meeting the desired equipment performance, early monitoring may allow the longer term actions to be postponed, modified, or canceled.

In cases where the corrective actions do not result in achieving the desired improvements in performance, the information gathered in this monitoring phase should be added to the existing information about the problems. The problem solving team should then reanalyze the problem based on all the available data. Corrective actions should be revised and new actions initiated when appropriate. The new information may also result in changes to improvement goals as the entire problem is reevaluated.

New and revised corrective actions are then evaluated and the implementation plan adjusted accordingly. As the revised corrective action plan is implemented, follow-up activities continue until acceptable improvement goals are met. Only then are the corrective actions and the problem closed out.

APPENDIX A

A REPETITIVE FAILURE PROGRAM

1.0 INTRODUCTION

This appendix describes some of the aspects of a systematic approach to repetitive failures as practiced at an operating nuclear generating station. Section 2 provides examples of station procedures and practices and relates them to the elements of the repetitive failure analysis model. Section 3 describes two examples of the use of this approach in correcting plant performance problems.

2.0 ASPECTS OF A REPETITIVE FAILURE PROGRAM

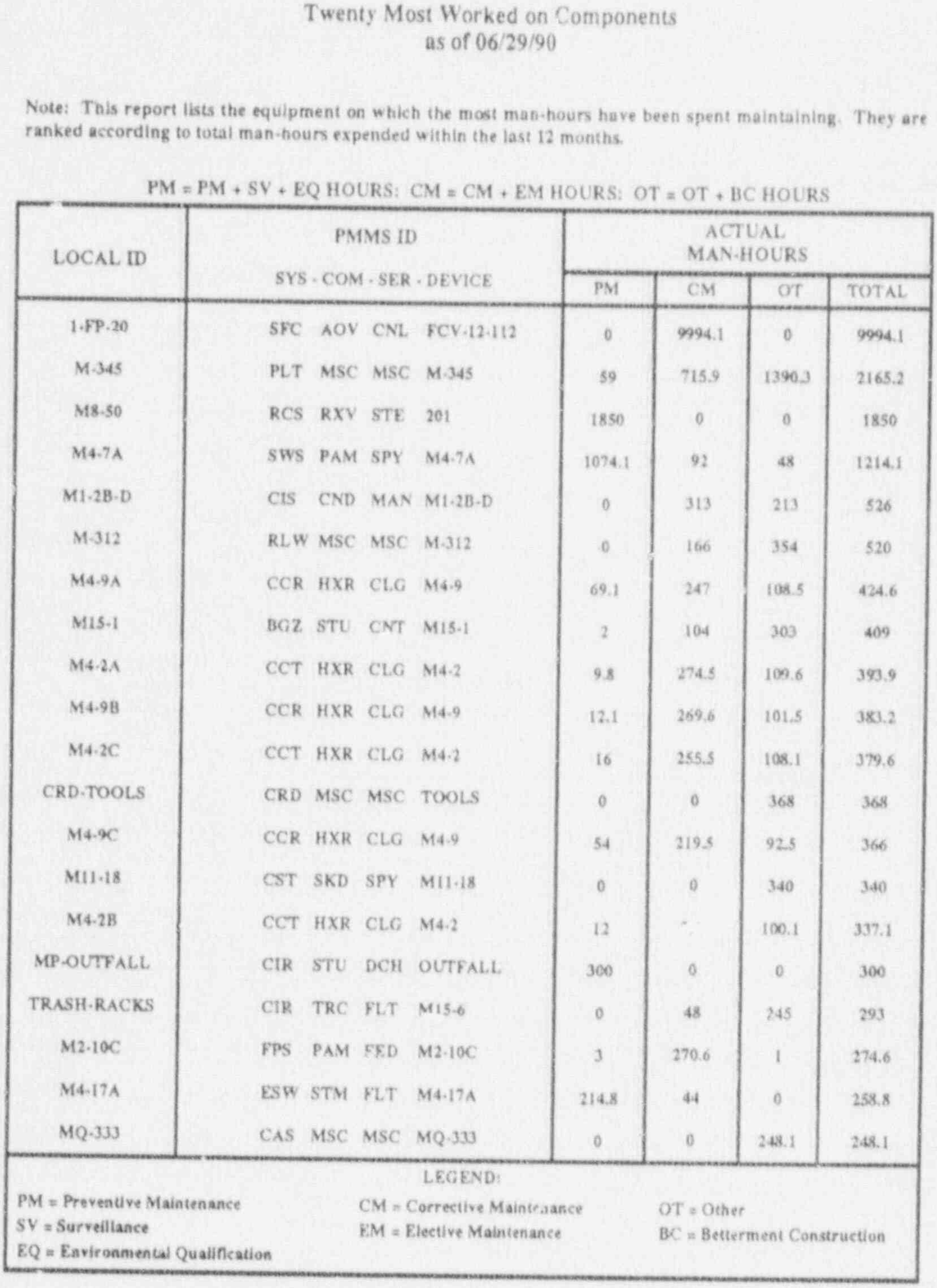
2.1 Monitoring and Identification of Repetitive Failures

A primary means of identifying repetitive failures at this station is provided by the Production Maintenance Management System (PMMS). This is an automated work order system that affords the station the ability to generate maintenance performance data that are readily usable in identifying repetitive failures.

Performance reports are prepared and submitted monthly (abbreviated version) and quarterly. Among the reports that are produced are listings of the 20 most worked on components and the 10 most worked on systems. The components and systems are ranked by the number of man-hours expended in the past twelve month period. These listings can be utilized to generate potential repetitive failure problems for further analysis. Figures A-1 and A-2 are examples of the quarterly listings.

Additionally, once a cycle, the utility prepares lists of repetitive work for the preceding operating cycle. For this list, the lower threshold is <u>four</u> or more combined corrective maintenance work orders associated with an equipment. These lists are then evaluated by the departments to identify problems and potential solutions.

Another method that the utility uses to identify repetitive equipment failures is the Nuclear Plant Reliability Data System (NPRDS) Component Failure Analysis Report (CFAR). Quarterly NPRDS reports, which are attached to the quarterly PMMS report, are prepared by the station's NPRDS Coordinators. These reports contain a CFAR analysis of the components that exceed the default significance criteria. The analysis includes a technical



Twenty Most Worked on Components
as of 06/29/90

Note: This report lists the equipment on which the most man-hours have been spent maintaining. They are ranked according to total man-hours expended within the last 12 months.

PM = PM + SV + EQ HOURS: CM = CM + EM HOURS: OT = OT + BC HOURS

LOCAL ID	PMMS ID SYS - COM - SER - DEVICE	ACTUAL MAN-HOURS			
		PM	CM	OT	TOTAL
1-FP-20	SFC AOV CNL FCV-12-112	0	9994.1	0	9994.1
M-345	PLT MSC MSC M-345	59	715.9	1390.3	2165.2
M8-50	RCS RXV STE 201	1850	0	0	1850
M4-7A	SWS PAM SPY M4-7A	1074.1	92	48	1214.1
M1-2B-D	CIS CND MAN M1-2B-D	0	313	213	526
M-312	RLW MSC MSC M-312	0	166	354	520
M4-9A	CCR HXR CLG M4-9	69.1	247	108.5	424.6
M15-1	BGZ STU CNT M15-1	2	104	303	409
M4-2A	CCT HXR CLG M4-2	9.8	274.5	109.6	393.9
M4-9B	CCR HXR CLG M4-9	12.1	269.6	101.5	383.2
M4-2C	CCT HXR CLG M4-2	16	255.5	108.1	379.6
CRD-TOOLS	CRD MSC MSC TOOLS	0	0	368	368
M4-9C	CCR HXR CLG M4-9	54	219.5	92.5	366
M11-18	CST SKD SPY M11-18	0	0	340	340
M4-2B	CCT HXR CLG M4-2	12	[illegible]	100.1	337.1
MP-OUTFALL	CIR STU DCH OUTFALL	300	0	0	300
TRASH-RACKS	CIR TRC FLT M15-6	0	48	245	293
M2-10C	FPS PAM FED M2-10C	3	270.6	1	274.6
M4-17A	ESW STM FLT M4-17A	214.8	44	0	258.8
MQ-333	CAS MSC MSC MQ-333	0	0	248.1	248.1

LEGEND:

PM = Preventive Maintenance
SV = Surveillance
EQ = Environmental Qualification
CM = Corrective Maintenance
EM = Elective Maintenance
OT = Other
BC = Betterment Construction

Figure A-1. Example Listing of "Twenty Most Worked on Components"

Ten Most Worked on Systems
as of 06/29/90

Note: This report lists the systems on which the most man-hours have been spent maintaining. They are ranked according to total man-hours expended within the last 12 months.

PM = PM + SV + EQ HOURS: CM = CM + EM HOURS: OT = OT + BC HOURS

SYSTEM	ACTUAL MAN-HOURS			
	PM	CM	OT	TOTAL
Spent Fuel Cooling (SFC)	6	10140.2	0	10146.2
Control Rod Drive (CRD)	3130.8	119.2	714	3964
Heating Ventilation and Cooling (PLT)	60.5	980.1	1618.3	2658.9
Service Water (SWS)	1268.1	1133.8	195	2596.9
Liquid Rad Waste (RLW)	253.6	1146.1	614	2013.7
Reactor Coolant (RCS)	1880.2	26.3	0	1906.5
Miscellaneous Plant Equipment (PLM)	791	172.2	318.2	1281.4
Turbine Building Closed Cooling (CCT)	102.5	812.2	317.8	1232.5
Reactor Building Closed Cooling (CCR)	145.2	758.1	302.5	1205.8
Condensers (CON)	41.5	838.6	267.5	1147.6

LEGEND:

PM = Preventive Maintenance
SV = Surveillance
EQ = Environmental Qualification
CM = Corrective Maintenance
EM = Elective Maintenance
OT = Other
BC = Betterment Construction

Figure A-2. Example Listing of "Ten Most Worked on Systems" evaluation and brief discussion of the component.

Finally, the utility uses a system of management by objectives to establish goals and objectives for station performance. Goals, including those reported quarterly to the Institute of Nuclear Power Operations (INPO), are established in such areas as capacity factor, forced outage rate, and number of Licensee Event Reports. Performance indicators are reported quarterly, and an annual review of performance is conducted. Failure to meet a goal results in analysis of the cause of the performance shortfall.

2.2 Assigning Problems for Analysis

At the station, problems are assigned to the department that is primarily responsible for the equipment or system. Both the maintenance (mechanical and electrical) and the instrument & controls departments have engineers on staff. For small problems that are entirely within the scope of the department, these engineers will be assigned to work on the problems individually.

Should the problem be more complicated, involve a significant amount of time, or involve a plant design change, the problem will be assigned to a team. The team generally will include an engineer or technician from the responsible maintenance department, an engineer from the plant's engineering department, and representatives from other plant departments, when appropriate.

Within the station, problem assignments are tracked and controlled using a formal routing system. This system is used to open, assign, distribute, track, and close out problem assignments. The assignments carry explicit instructions and due dates that may only be modified with the approval of the originator of the assignment.

Problems that require significant expenditures of engineering man-hours for design or significant expenditures of capital money require the initiation of a project assignment. Project assignments are the mechanism that is utilized by the utility to identify and control tasks that are performed by the corporate engineering staff.

Project assignments are assigned "in-service" dates and are controlled by the corporation's overall system for prioritizing and allocating resources, which will be discussed below.

2.3 Assigning Priorities

Assignments within the station are made informally based on a number of factors, including the safety significance of the problem, its effect on plant reliability, and its effect on the ability of the plant to meet its performance goals.

Project assignments are ranked and prioritized using a formal evaluation system. The evaluation system provides the process for developing a prioritized list of project assignments. Recommendations for the projects that will be worked by the corporate staff are based on a number of considerations including: the priority of the project, the available budget, outside commitments and station goals.

Projects are initially prioritized according to four factors: the effects of the project (on safety), gain value, source of the requirement, and cost factor. The initial screening form is shown in Figure A-3. The originator of the project assignment completes the initial screening form with the help of other engineering disciplines, when necessary. The procedure contains an explanation of the criteria for each of the attributes within the category, and supporting documentation for the choices is attached to the form.

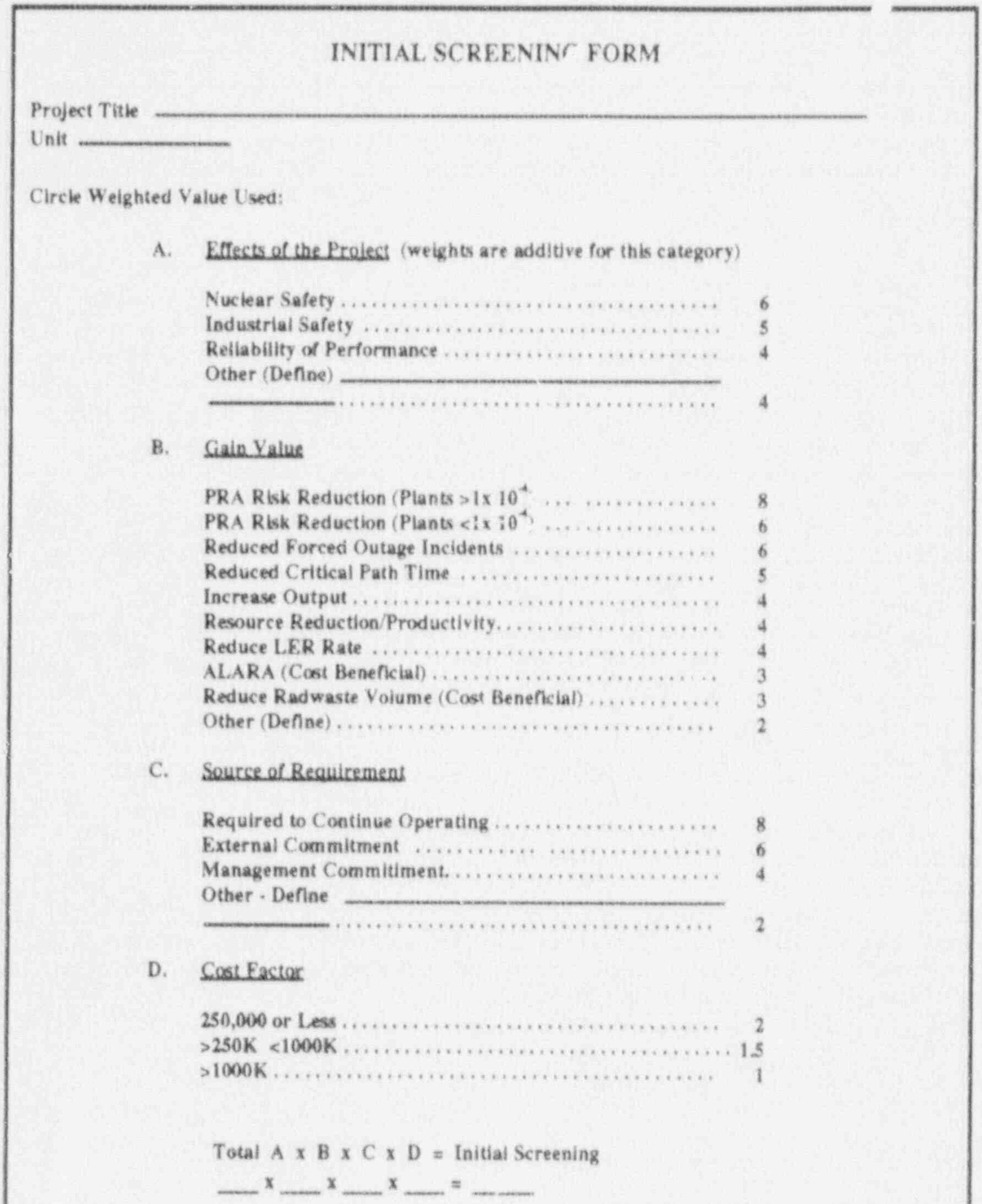
The result of the initial screening is a number from 8 to 1,792 with the highest number representing the highest priority project. The project's priority number is determined by selecting the weighted value for each of the four categories and then multiplying the four values together. The weighting values in category 1 (effects of the project) are added together to obtain the weighting value for the category.

2.4 Root Cause Determination and Recommended Corrective Actions

Station personnel have been trained in root cause analysis techniques and the root cause investigation process is described in a station procedure. The procedure covers the data collection, analysis, corrective actions, documentation, and follow-up requirements. Corrective action recommendations are made for each root cause that is found. The procedure requires that sufficient information be provided to define the scope of the recommended corrective actions and that the recommendation include a time frame in which the corrective actions should be made. Follow-up is an integral part of the root cause analysis process.

2.5 Selecting Corrective Actions

Corrective action recommendations that result from investigations conducted at the station are normally selected for implementation by the cognizant managers, either individually or as a group. The selections are based primarily on the evaluation of the root cause and best judgment of the potential for the recommended action to correct the root cause.



INITIAL SCREENING FORM

Project Title ______________________________

Unit ____________

Circle Weighted Value Used:

A. Effects of the Project (weights are additive for this category)

Nuclear Safety	6
Industrial Safety	5
Reliability of Performance	4
Other (Define) ______________________	4

B. Gain Value

PRA Risk Reduction (Plants >1x 10^{-4}	8
PRA Risk Reduction (Plants <1x 10^{-4})	6
Reduced Forced Outage Incidents	6
Reduced Critical Path Time	5
Increase Output	4
Resource Reduction/Productivity	4
Reduce LER Rate	4
ALARA (Cost Beneficial)	3
Reduce Radwaste Volume (Cost Beneficial)	3
Other (Define)	2

C. Source of Requirement

Required to Continue Operating	8
External Commitment	6
Management Commitiment	4
Other - Define ______________________	2

D. Cost Factor

250,000 or Less	2
>250K <1000K	1.5
>1000K	1

Total A x B x C x D = Initial Screening

____ x ____ x ____ x ____ = ______

Figure A-3. Example of the Initial Screening Form

Corrective actions that result from project assignments are typically beyond the scope of the station's resources. These actions are prioritized and scheduled using the company's formal ranking model. This model encompasses a two-step process for ranking projects and a step for integrating the project into the overall project schedule.

Once the project scope (scope of work, cost estimate, and man-rem estimate) has been determined, the project is ranked using an analytical ranking model (ARM). The ARM evaluates projects based on four attributes: public safety, personnel safety, economic performance, and personnel productivity. Formal analysis of each of the attributes is conducted in this phase. For example, the public safety attribute is analyzed by the Probabilistic Risk Assessment group in this phase.

Following the completion of the ARM ranking, the project undergoes a prioritization screening. This process ranks the project based on its ARM results and consideration of additional factors, such as: cost/benefit analysis, installation man-rem expenditure estimates, and external commitments. Low ranking projects are recommended for cancellation at this point.

Projects that remain are then combined into an integrated implementation schedule. This is a multi-cycle schedule that attempts to optimize the use of personnel and financial resources while recognizing the corporation's operational goals.

2.6 Implementing Corrective Actions

Corrective actions that are within the scope of the station's resources are assigned and controlled as follow-up actions to the original assignment. Typically, the assignments are made using the station's formal routing system, including specific actions and due dates. The more important assignments may also be included in the individual department's goals, which are established by the management by objectives program.

Corrective actions that are the result of project assignments are implemented according to the integrated schedule. This schedule is routinely reviewed by station and corporate managers. Due dates and implementation schedules are prepared, and explanations must be provided for failing to miss an assigned due date.

3.0 EXAMPLES

3.1 Gas Turbine Generator Governor Replacement

One of the emergency power supplies for the unit is a gas turbine generator. It is designed to auto-start under emergency conditions and can supply 12 Mwe to an emergency bus. The originally installed governor system was a 1960's design and utilized electro-hydraulic control.

Over time, aging of the relays and components in the control system and in the timing sequence logic had resulted in an increasing number of failures during the gas turbine starting sequence. This resulted in more than a half dozen start failures of the gas turbine during 1982 and 1983.

Initially, the station's response was to: replace a number of key relays in the staring circuit, add preventive maintenance tasks, increase the frequency of testing, and add an 8-channel brush recorder system. The recorder system allowed the technicians to monitor the performance of key components in the starting sequence and to make adjustments and/or replacements prior to the occurrence of a start failure.

Subsequently, the gas turbine's performance was satisfactory. However, in 1985 a single starting failure occurred and in 1986, two start failures were experienced. Consequently, a project assignment for the replacement of the governor control system was initiated. The project called for the replacement of the electro-hydraulic control system with a modern microprocessor-based system.

The project assignment was evaluated using the project prioritization system and was approved for design and installation. The basis of the decision was: (1) a study that predicted an increase in gas turbine reliability of 8 percent following the replacement, (2) a Probabilistic Safety Study that identified gas turbine failures as contributing to over 8 percent of the probability of a core melt, and (3) a predicted decrease in the calculated core melt frequency due to station blackouts following the replacement. All these items contributed to meeting the corporate goal for reducing core melt frequency.

Design work was completed during 1987 and 1988, and the new governor system was installed during the unit's 1989 refueling outage.

3.2 Mechanical Pressure Regulator Failures

The reactor pressure at this boiling water reactor is controlled by an electric pressure regulator with a mechanical pressure regulator as a backup. In February 1986, a malfunction of the mechanical pressure regulator (MPR) caused reactor pressure to oscillate over a range of approximately 20 psi and resulted in a reactor scram. In May 1986, the reactor was manually scrammed at 10 percent power during a shutdown when operators observed pressure fluctuations following a transfer to the MPR. In August 1986, the

MPR failed a third time with no consequence to plant operation.

Investigation of the incidents was assigned to an engineer in the instrument and controls department. It was determined that a primary contributor to the problem was scale buildup on the MPR's pressure dampening valve. This buildup was the result of a leak that had developed in the bellows for the pressure regulator's sensing line. Additionally, it was felt that the MPR's output piston stroke time needed adjustment and that the MPR feedback link required adjustment to be more responsive.

As corrective action, the pressure sensing valve was cleaned and the sensing line flushed with demineralized water. A planned maintenance action item was generated to disassemble and inspect the pressure sensing valve during plant shutdowns (approximately once every six months). As a follow-up action, the MPR was disassembled and rebuilt during the following refueling outage. A vendor engineer was contracted to supervise the rebuilding effort. All components were measured and restored to the original design dimensions, seals were replaced, pistons honed, and ball joints replaced.

Corrective actions were also taken to improve the ability of operators to monitor and control the pressure regulating system. A meter was added to the control room panels in order to allow the operators to anticipate the action of the pressure regulator during transfer operations. Also, the pressure regulator's control room meters were modified to improve the human factors performance of the control switches and the meters. Procedure changes were implemented and special training conducted using the plant simulator. Finally, a transfer of the system from the electric pressure regulator to the mechanical pressure regulator was scheduled to be accomplished on a weekly basis as part of the control room routine. This provides for routine exercising of the system and affords the operators the opportunity to conduct the transfers and manipulate the system.

Since the implementation of the corrective actions, no recurrence of the pressure regulator problems has occurred.

Glossary

Generic equipment failure - The failure of the same or similar types of components in more than one system.

Repetitive failure - The recurring inability of a system, subsystem, structure, or component to perform its intended function.

NRC FORM 335
(2-89)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC. Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-5665
SI-14940000-1

2. TITLE AND SUBTITLE

A Systematic Approach to Repetitive Failures

3. DATE REPORT PUBLISHED

MONTH	YEAR
February	1991

4. FIN OR GRANT NUMBER

5. AUTHOR(S)

David J. Odland

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Sonalysts, Incorporated
215 Parkway North
Waterford, CT 06385

9. SPONSORING ORGANIZATION – NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

This report presents a model of a systematic approach to address and correct repetitive failures. In this context, repetitive failures are the recurring inability of a system, subsystem, structure, or component to perform its intended function. The report presents a systematic method for identifying repetitive failures, selecting the failures to be investigated, determining root cause, selecting corrective actions for implementation, and monitoring of subsequent system/component performance. Appendix A provides an example of the use of this methodology at an operating nuclear generating station.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

maintenance
repetitive failures

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page)

Unclassified

(This Report)

Unclassified

15. NUMBER OF PAGES

16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC
PERMIT No. G-67

120555 [illegible] 13 [illegible]
US N [illegible] CA [illegible] 1 1AN1CH1 [illegible] W1 A1
DIV [illegible] F [illegible] IA [illegible]
TPS [illegible] PDR- [illegible] LICATIONS SVCS
[illegible]
WASHINGTON
DC 20555

NUREG/CR-5665

A SYSTEMATIC APPROACH TO REPETITIVE FAILURES

FEBRUARY 1991