NOT MEASUREMENT SENSITIVE

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DOE STANDARD

GUIDELINE TO GOOD PRACTICES FOR TYPES OF MAINTENANCE ACTIVITES AT DOE NUCLEAR FACILITIES

U.S. Department of Energy
Washington, D.C. 20585

AREA MNTY

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FOREWORD

The purpose of the *Guideline to Good Practices for Types of Maintenance at DOE Nuclear Facilities* is to provide contractor maintenance organizations with information that may be used for the development and implementation of a properly balanced corrective, preventive and predictive maintenance program at DOE nuclear facilities. This document is intended to be an example guideline for the implementation of DOE Order 4330.4A, *Maintenance Management Program*, Chapter II, Element 4. DOE contractors should not feel obligated to adopt all parts of this guide. Rather, they should use the information contained herein as a guide for developing maintenance programs that are applicable to their facility.

CONTENTS

1. INTRODUCTION

1.1 Purpose

This guide is intended to assist facility maintenance operations in the review of existing and in developing new corrective, preventive, and predictive maintenance programs. It is expected that each DOE facility may use different approaches or methods than those defined in this guide. The specific guidelines that follow reflect generally accepted industry practices. Therefore, deviation from any particular guideline would not, in itself, indicate a problem. If substantive differences exist between the intent of the Guideline and actual practice, management should evaluate current practice to determine the need to include/exclude proposed features. A change to maintenance practice would be appropriate if a performance weakness was determined to exist. Development, documentation, and implementation of other features which further enhance these guidelines for specific applications, is encouraged.

Maintenance work is intended to ensure plant capacity by limiting forced downtime and returning items to service through an effective and timely first effort, consistent with plant goals. The three basic types of maintenance are corrective, preventive, and predictive. This guide describes key features of properly balanced corrective and preventive maintenance programs. Their implementation should enhance safe, reliable, and efficient maintenance operations. Additional information pertinent to the implementation of this guideline may be found in the following DOE Guidelines: *"Guidelines to Good Practice for Training and Qualification of Maintenance Personnel" "Writer's Guide for Technical Procedures," "Guidelines to Good Practices for Planning, Scheduling, and Coordination of Maintenance Activities at DOE Nuclear Facilities," "Guidelines to Good Practices for Control of Maintenance Activities at DOE Nuclear Facilities," "Guidelines to Good Practices for Postmaintenance Testing at DOE Nuclear Facilities," "Guidelines to Good Practices for Management Involvement at DOE Nuclear Facilities," and "Guidelines to Good Practices for Maintenance History at DOE Nuclear Facilities."*

Appendix J is provided for use by facility trainers who intend to provide training regarding this element.

1.2 Background

The information in this guide was developed from commercial and DOE sources. Each facility should select those details that are applicable, add any unlisted knowledge or experience that are applicable, and develop and implement facility-specific maintenance programs. Facilities that have existing documented maintenance programs should review this guide to identify details that may enhance their existing programs.

1.3 Application

The content of this guide is generally applicable to all DOE nuclear facilities. Portions of the programs outlined may not be applicable to all facilities because maintenance organizations, disciplines, titles, and responsibilities may vary among DOE nuclear facilities. Facility maintenance personnel can verify the adequacy or improve existing maintenance programs by adapting this guide to their specific facility and individual maintenance disciplines.

2. DEFINITIONS

2.1 Acronyms Used in This Standard. The acronyms used in this standard are defined as follows:

a. ALARA - As Low As Reasonably Achievable

b. DOE - Department of Energy

c. MIG - Maintenance Importance Generator

d. MJR - Maintenance Job Request

e. RCM - Reliability Centered Maintenance

f. SARUP - Safety Analysis Report Update Process

g. SNM - Special Nuclear Materials

h. SSC - Structures, Systems, and Components

2.2 ALARA (As Low As Reasonably Achievable). A radiation protection philosophy requiring that personnel exposure to radiation and radioactive material be kept not only within regulatory limits, but be maintained as low as reasonably achievable in light of current technology with appropriate consideration for economic and social factors, and benefits derived.

2.3 Corrective Maintenance. Repair and restoration of SSC that have failed or are malfunctioning and are not performing their intended function. As a rule of thumb, if the specific component (such as packing or bearing) requiring maintenance has failed, the action required to repair it should be classified as corrective maintenance.

2.4 Deficiency. Any condition that deviates from the design of a structure, system, component, or equipment and results in a degraded ability to accomplish its intended function.

2.5 Facility. Any equipment, structure, system, process, or activity that fulfills a specific purpose. Examples include storage areas, fusion research devices, nuclear reactors, production of processing plants, waste management disposal systems and burial grounds, testing laboratories, research laboratories, transportation activities, weapons development and production, standards and calibrations labs, and accommodations for analytical examinations of irradiated and un-irradiated components.

2. 6 Grace Period. A time period after the scheduled completion date in which the activity may be completed without being considered overdue. This time period is normally 25 percent of the scheduled interval.

2. 7 Maintenance. Day-to-day work that is required to maintain and preserve plant and capital equipment in a condition suitable for its designated purpose and includes preventive, predictive, and corrective (repair) maintenance.

2. 8 Maintenance Importance Generator. A computerized system using predetermined rules to compare data on an MJR and to establish relative-importance ranking for each maintenance job.

2.9 Master Equipment List. A detailed master list of equipment, components, and structures to be included in the maintenance program. This list includes both safety related and non-safety related systems and equipment.

2.10 Outage. Condition existing whenever production has stopped.

2.11 Periodic Maintenance. Preventive maintenance activities accomplished on a routine basis (typically based on operating hours or calendar time) and may include any combination of external inspections, alignments or calibrations, internal inspections, overhauls, and SSC replacements.

2.12 Planned Maintenance. Preventive maintenance activities performed prior to SSC failure and may be initiated by predictive or periodic maintenance results, by vendor recommendations, or by experience/lessons learned. These include items such as scheduled valve repacking, replacement of bearings as indicated from vibration analysis, major or minor overhauls based on experience factors or vendor recommendations and replacement of known life-span components. For example, repacking a valve due to packing leakage would be corrective maintenance, but scheduled repacking prior to leakage would be planned maintenance.

2.13 Predictive Maintenance. Predictive maintenance activities involve continuous or periodic monitoring and diagnosis in order to forecast component degradation so that "as-needed" planned maintenance may be performed prior to SSC failure. Not all SSC conditions and failure modes can be monitored; therefore, predictive maintenance should be selectively applied. Reliable predictive maintenance is normally preferable to periodic internal inspection or equipment overhauls.

2.14 Preventive Maintenance. Preventive maintenance includes periodic and planned maintenance actions taken to maintain SSC within their design operating conditions, extend its life, and is performed to prevent SSC failure. This includes technical safety requirements surveillances, in-service inspections, and other regulatory forms of preventive maintenance.

2.15 Reliability Centered Maintenance (RCM). A maintenance system that determines the most effective maintenance activity, based on an analysis of an items failure modes, failure rates, and the importance of the item to the safe operation of the facility.

2.16 Root Cause. The determination as to why a SSC failed.

2.17 Structures, Systems and Components (SSC). Physical items designed, built, or installed to support the operation of the plant.

2.18 Surveillance. Functional tests of installed equipment and/or systems to satisfy technical safety requirements.

3. PLANT MAINTENANCE

3.1 Discussion

3.1.1 The objectives of a plant maintenance program should be to improve plant safety and reliability by preventing equipment breakdown and to maintain the equipment in a satisfactory condition for normal operation and/or emergency use. Various maintenance techniques may be included in a plant maintenance program. It is necessary that the program be well-defined and periodically adjusted to ensure that equipment reliability is maintained.

3.1.2 A maintenance program has the following key elements:

- Management commitment, overview, and control are essential for the success of a maintenance program.
- Responsibilities of each group are clearly defined.
- The program is administered and implemented by dedicated personnel who are technically competent in maintenance techniques.
- The scope of the program includes equipment important to the safe and reliable operation of the plant and is directed by historical data, where possible.
- The selection of maintenance techniques is appropriate for the type of plant equipment.
- Data is carefully analyzed and trended.
- Tasks are scheduled on a routine basis and performed as appropriate.
- The program is periodically evaluated and, if necessary, upgraded.

3.1.3 A system of controlling maintenance work activities should be clearly defined based upon the Maintenance Operations Model (Appendix A), which consists of five interrelated processes applicable to each maintenance job. The processes are as follows:

- <u>Plan Maintenance Job</u>. Identify the scope of a needed maintenance job. Produce a maintenance job plan. Determine maintenance job planning category, priority, and safety concerns. Identify and procure materials, and identify other maintenance task resources. Prepare the maintenance job package.

- Schedule Maintenance Job. Calculate estimated start date and project resources for the maintenance job. Schedule and commit required resources and special tools/equipment items to allow performance of all maintenance tasks within the maintenance job.

- Execute Maintenance Job. Initiate and perform a maintenance job and collect job information as defined in the maintenance job package.

- Execute Postmaintenance Test. Verify facilities and equipment items fulfill their design functions when returned to service after execution of a maintenance job.

- Complete Maintenance Job. Perform maintenance job closeout to include completion of all documentation contained in the maintenance job package to ensure historical information is captured.

3.1.4 Appendix B (Facility Management) illustrates a comprehensive "Work Control Program" based on the requirements of DOE Order 4330.4A, *Maintenance Management Program.* The implementation of this program should ensure that the maintenance activities in nuclear facilities are conducted in a manner that preserves and restores the availability and operability of the SSC important to safe and reliable plant operation.

3.2 Scope

This program describes the components needed to establish, implement, track, and evaluate a maintenance program. The following items are addressed in this program:

a. assignment of responsibility to develop and implement a maintenance program

b. selection of equipment to be included in the program

c. selection of appropriate maintenance techniques

d. data analysis and trending

e. scheduling and tracking of maintenance tasks

f. program evaluation and upgrade

3.3 Responsibilities

3.3.1 The maintenance manager should have overall responsibility for the establishment, implementation, and performance of the maintenance program as described below:

a. developing and implementing maintenance procedures

b. coordinating maintenance with the owner/operator to establish proper plant conditions and obtaining authorizations to conduct maintenance activities

c. monitoring the overall effectiveness of the maintenance program and incorporating program changes based on plant history, performance, and industry experience

d. approving revisions to the program

3.3.2 Maintenance supervisors should have direct responsibility for execution of maintenance activities as follows:

a. ensuring maintenance results are recorded in maintenance history

b. reviewing, trending, and analyzing data to detect any degradation of equipment condition

c. coordinating with owner/operator and technical support, as required, to perform additional testing to confirm suspected deficient conditions

d. providing recommendations to the maintenance manager on needed corrective, preventive or predictive maintenance

e. recommending additions or deletions to the program

f. recommending revisions to maintenance procedures or schedules

g. providing periodic summary reports to maintenance management describing the current status of the maintenance program and summarizing problems recently identified or corrected

h. ensuring that baseline data is updated after any maintenance or modifications

3.3.3 The operations manager should be responsible for listing the equipment to be included and the alignment of plant systems and components to support the maintenance program as noted below:

a. ensuring that maintenance tasks are properly authorized

b. providing schedule and technical assistance to maintenance

c. restoring systems and components to correct operating alignment or standby modes upon completion of maintenance tasks

d. making the final equipment operability/acceptance determination, if applicable, prior to returning the equipment to service

3.3.4 The technical support manager should be responsible for assisting, as required, in the development and implementation of the maintenance program as noted below:

a. reviewing the list of equipment to be included in the maintenance program

b. recommending task intervals based on vendor recommendations, operating experience (including run time and failure history), and engineering analyses

c. involving engineering personnel (system engineer, if used) in the review and analyses of maintenance results

d. providing recommendations to maintenance managers to upgrade equipment performance (including processing design changes) or to make necessary maintenance program adjustments

3.3.5 Special consideration should be made in selecting and training the personnel responsible for obtaining and analyzing maintenance data. A dedicated staff is recommended to provide the consistency and expertise needed to fully benefit from this program. A training program should be implemented to support needed competency and to upgrade knowledge as technology changes.

3.4 Guidelines

3.4.1 Selection of Equipment

A detailed master list of equipment, components, and structures to be included in the maintenance program should be developed by a maintenance technical support and owner/operator team. The master list should be adjusted as dictated by experience, cost effectiveness, and maintenance history records of equipment performance. The following should be considered for selecting equipment to be included in the program:

a. equipment affecting personnel safety

b. equipment affecting safe and reliable plant operation

c. equipment specified in code, regulatory, or technical safety requirements

3.4.2 Procedure Preparation for Maintenance Tasks

Procedures should be developed for each piece of equipment identified in section 3.4.1. The procedures should describe the maintenance activities to be performed in sufficient detail so that the maintenance is performed properly. DOE *"Writer's Guide for Technical Procedures"* provides guidelines for writing maintenance procedures.

3.4.3 Preventive Maintenance (PM)

3.4.3.1 It is reasonable to implement PM activities for components that demonstrate failure modes caused by "wear out" or degradation due to application, use, time, age, and etc. The effectiveness of the program, however, also depends on how well each scheduled activity detects deterioration and prevents failure.

3.4.3.2 A good PM program should be an evolutionary process. It should start with the scheduling of routine tasks done based on such items as regulatory and technical safety requirements, codes and standards, vendor recommendations, plant and industry experience with similar equipment, engineering analysis of equipment performance, systematic analysis through predictive maintenance, history records of equipment performance, cost/benefit analysis, capacity need, and schedule use. It should be revised as additional history and trends indicate.

3.4.3.3 Interval of PM Tasks

The initial interval of PM tasks to be performed should be established to maximize equipment reliability based on just-in-time considerations.

3.4.3.4 Scheduling and Tracking PM Performance

a) A master schedule should be prepared based on the assigned interval determined per Section 3.4.3.3. The master schedule should include PM tasks intervals throughout the year.

b) PM work control documents (refer to DOE *"Guidelines to Good Practices for Planning, Scheduling, and Coordination of Maintenance Activities at DOE Nuclear Facilities" and "Guidelines to Good Practices for Control of Maintenance Activities at DOE Nuclear Facilities")* should be prepared for each task. They may be either hard-copy duplicates or computer-generated copies.

c) PM tasks should be capable of being quickly sorted and listed by system and system condition required to perform the task. This should aid in planning work items, especially when being performed during forced outages and changes in operating conditions, and also aid in scheduling PM tasks by system/subsystem to increase overall equipment capacity.

d) Preventive maintenance should be scheduled at appropriate intervals and where practical scheduled with corrective maintenance and surveillance, and ISI/IST test activities on the same equipment and with other related maintenance.

e) Grace periods should be specified in the PM program.

f) Delays in the performance of scheduled PM tasks beyond the defined grace period should require escalating approval. For example, approval should be obtained from department supervisors, operations managers, maintenance and technical support managers, and the plant manager, depending on the length of time that the task is to be delayed and the potential risk involved.

g) Appropriate craft supervision should be encouraged to recommend changes in PM task interval based on real-time observations and conditions. These changes should be approved by the operations, maintenance, and technical support managers.

h) The maintenance manager should report monthly to the operations manager any associated problems with scheduled PM tasks, including the number exceeding the grace period.

3.4.3.5 Performance of PM Tasks

PM tasks should be performed using procedures or instructions and controlled by methods such as task cards or detailed PM job requests. Coordination should be established in advance among other maintenance groups and plant departments (e.g., operations, radiological protection, and QC/QA). Good work practices, such as pre-job briefings, quality craftsmanship, observations, data recordings, cleanliness, correct tool use, and history update are essential to the PM task.

3.4.3.6 PM Program Evaluation

An evaluation of the PM program should be conducted annually by the maintenance manager with assistance from the applicable/affected operations, technical support, and engineering groups. This evaluation should address the overall effectiveness of the program in improving plant and/or equipment availability, as well as reducing the cost of maintenance. This evaluation should consider PMs that are being performed unnecessarily or excessively, thereby consuming valuable and limited resources that may otherwise be used to upgrade other maintenance programs. Additionally, excessive PM may increase item deterioration, radiation exposures, maintenance errors, and rework. Items to be considered in the evaluation should include, but not be limited to the following:

a) adequacy of PM procedures as deemed by craftsperson feedback - Appendix C provides an example of a craftsperson feedback form.

b) quality assurance audit reports and self assessment findings

c) failure trend reports for plant and industry equipment

d) licensee event reports

e) non-conformance reports

f) material deficiency reports

g) causes for deferrals

3.4.3.7 PM Program Improvement

Using the results of the PM program evaluation presented in Section 3.4.3.6, the following improvements should be addressed and implemented as appropriate:

a) adjustment of PM task interval

b) redefinition of PM activities

c) addition or deletion of PM activities

d) adjustment of spare parts stocking levels

e) propose design changes

f) identification of special tools

g) revised PM program and/or PM task procedures

h) replacement of cost/labor intensive items

NOTE: Appendix D contains an enhanced PM program which may be used for the development or revision of plant specific PM programs.

3.4.4 Predictive Maintenance

3.4.4.1 Predictive maintenance should be integrated into the overall preventive maintenance program so that "just-in-time" planned maintenance may be performed prior to equipment failure. Not all equipment conditions and failure modes can be monitored; therefore, predictive maintenance should be selectively applied. Reliable predictive maintenance is normally preferable to periodic internal, inspection or equipment overhauls. In addition, corrective maintenance efficiency may be improved by directing repair efforts (manpower, tooling, parts) at problems detected using predictive maintenance techniques.

3.4.4.2 Predictive maintenance should be limited to components and systems that are significantly important to the safe and reliable operation of the plant. The program should collect, trend, and analyze data and initiate planned actions for degrading equipment. The effectiveness of the program is dependent on the accuracy of equipment degradation rate and time to failure assessment.

3.4.4.3 Management commitment, control, and overview are essential for the success of a predictive maintenance program. This section contains a summary of key principles and program elements for a predictive maintenance program. The example program is provided to assist plant personnel in the development and implementation of a predictive maintenance program. Although the key elements of the program are applicable to all plants, some of the details may need to be modified to reflect individual plant conditions and needs.

3.4.4.4 Selection of Predictive Maintenance Techniques

a) Many different predictive maintenance techniques are used throughout the industry. The following is a description of some predictive maintenance techniques that may be used:

- Vibration Monitoring and Diagnostics - a technique used for the monitoring and analysis of plant rotating equipment - This technique is used to analyze displacement, velocity, and acceleration parameters to predict the need to correct problems such as bad bearings, poor alignments, or improper balance.

- Lubricating Oil Analysis, Ferrography, and Grease Analysis - techniques used for the early detection of lubricant breakdown and abnormal wear

  1) Lubricating oil analysis monitors the actual condition of the oil itself. Parameters measured include viscosity, moisture, "additive" package and the presence of other contaminants.

  2) Ferrography is a technique used to analyze oil for metal wear products and other particulate. Trending and analyzing the amount and type of wear particles in a machine's lubrication system may pinpoint where degradation is occurring.

3) Grease analyses are techniques used to detect changes in lubrication properties of grease. Sensory tests such as color, odor, and consistency are most often applied to greases. A penetration test is sometimes used to quantify grease consistency. Grease analyses are often performed on samples obtained from motor-operated valves.

- Bearing Temperature Trending/Analysis - a technique used to measure and trend temperatures of critical machinery bearings to predict failure - Changes in bearing temperature may indicate wear due to loss of lubrication, excessive vibration, or intrusion of foreign material into the rotating assemblies. Bearing temperature analysis is often performed in conjunction with the vibration monitoring and lubricating oil analysis/ferrography programs.

- Infrared Thermography - a technique based on the fact that the infrared radiation emitted by a source varies with its surface temperature - Infrared surveys may be performed on heat - producing equipment such as motors, circuit breakers, batteries, load centers, and insulated areas to monitor for high resistance, loose connections, or insulation breakdown. Additionally, this technique may be applied to pinpoint condenser air in-leakage locations and valve leaks.

- Acoustical/Ultrasonic Testing - a technique used to measure acoustical emissions from components such as valves and heat exchangers - This technique is used to monitor valves for leakage and heat exchangers for proper flow rates. In addition, ultrasonic testing may detect weld crack propagation and check for piping erosion/corrosion effects.

- Motor-operated Valve Testing - a technique used to measure and analyze key motor-operator parameters such as running current, voltage, stem thrust, limit and torque switch set-points, and valve stroke times - This technique is extensively used to provide accurate indication that the motor-operated valve operates as designed under actual system conditions of temperature, flow, and pressure. Motor-operated valve testing is also used to trend performance to identify degrading conditions.

- Radio Frequency Monitoring - a technique used to detect, internal arcing of an electrical generator - Generator arcing is caused by component failures such as stator winding insulation failure, conductor fatigue failure, or voltage breakdown because of reduced clearances between components that are at different voltages. The arcs cause short-duration current pulses containing measurable radio frequency signal components.

- In-leakage Detection - a technique using helium detectors to locate pathways for the ingress of contaminants into steam, condensate, and feedwater systems - This technique has proven to be effective in detecting air in-leakage into condensers, valves, and flanges.

- Insulation Resistance (Meggering) - a technique used to measure leakage currents in electrical insulation - This technique is used in monitoring degradation of electrical insulation of motors, generators, and cables.

- Polarization Index - a technique used to measure the mechanical integrity of insulation - This technique is used to monitor degradation of electrical systems by measuring the ratio between one-minute and 10-minute readings for insulation resistances.

- Electric Circuit Monitoring - a technique used to determine the condition of a circuit and aid in fault location - This technique performs basic measurements such as inductance, capacitance, and resistance, and measures distance through time domain reflectometry. Electric circuit monitoring is effective in determining the condition of electrical connections, contacts, terminations, moisture damage, and damaged insulation and its location.

- Plant Performance Monitoring - in addition to the predictive maintenance techniques already described, various other methods may be used as a predictive approach to monitoring plant performance, including the following:

  1) Eddy current testing is commonly used to monitor heat exchanger tube wall thickness.

  2) Temperature differential is used as a means of monitoring heat exchanger performance.

3) Flow measurements monitor heat exchanger and pump performance.

4) Unit heat rate is used to measure plant steam cycle efficiency.

Appendices E, F, and G provide examples of three procedures that implement techniques proven to be successful in selected applications: vibration monitoring, lubricating oil analysis, and infrared monitoring (thermography).

Appendix H provides examples of the predictive maintenance techniques applicable to various plant components.

3.4.4.5 Data Review, Trending, and Analysis

a) The predictive maintenance coordinator should compare recently acquired data with previous history data to detect any indicated change in equipment condition trends. If degradation indicates integrity of operating equipment may be endangered, or if action criteria is being approached, the predictive maintenance coordinator should initiate one or more of the following actions:

   1) Coordinate with the data originator to determine whether corrective action has been initiated.

   2) Validate the trend analysis/conclusion.

   3) Request additional testing or monitoring be performed to confirm the suspected deficient condition. Any of the various predictive maintenance techniques available may be used to obtain additional confirmatory information, if appropriate.

   4) Initiate action (via a maintenance job request) to have the defective equipment scheduled for repair.

   5) Recommend revisions to preventive maintenance procedures and/or schedules, if appropriate.

   6) Acquire new equipment baseline data to verify correction of problems and to establish new reference points.

3.4.4.6 Scheduling of Predictive Maintenance

a) The interval that predictive maintenance tasks are performed may vary depending on such factors as those listed in Section 3.4.3.2. In addition, the relative importance of the equipment to overall plant operations may be factored into determining an appropriate interval. It should be recognized that predictive maintenance tasks should be managed and scheduled as part of the overall plant preventive maintenance program. Example priorities for taking action based on predictive maintenance results are as follows:

   1) Safety-related (Priority A): Designation of equipment whose failure would compromise safety and/or impose limiting conditions for operation (LCO).

   2) Capacity Threatening - Not Spared (Priority B): Designation of equipment whose failure would result in total or partial capacity loss.

   3) Capacity Threatening - Spared (Priority C): Designation of equipment whose failure would result in partial or total loss of capacity if backup equipment is unavailable or fails.

   4) Support Equipment (Priority D): Designation of equipment whose failure would result in eventual reduction of unit efficiency, safety, or reliability.

   5) High-maintenance Items (Priority E): Designation of equipment that has a high incidence of failure.

b) A master schedule should be prepared based on the assigned interval dictated by Section 3.4.3.3 and the priorities denoted in item "a" above.

c) Work control documents should be prepared for each predictive maintenance task.

d) Grace periods should be specified in the predictive maintenance program (normally 25 percent of the scheduled interval); however, tasks should normally be performed as scheduled, and grace periods should be used only when approved unavoidable conflicts arise.

e) If the performance of scheduled predictive maintenance has the potential of exceeding the grace period, the operations manager and the maintenance manager, or designees, shall be informed and be directly involved in the decision process.

f) Only operating equipment or equipment in standby should be placed in predictive maintenance monitoring. Such monitoring should be rescheduled at a time consistent with normal plant and equipment operations.

3.4.4.7 Program Evaluation and Upgrade

a) Failures of equipment included in the predictive maintenance program should have detailed root cause investigations to determine why the program did not detect degradation before the failures occurred.

b) All personnel should be alert for possible inputs to the predictive maintenance program that may be beneficial in improving plant reliability and performance. These comments may result from work performed by corrective maintenance or modification activities. Inputs should be forwarded to the predictive maintenance coordinator.

c) Proposed additions or modifications to the predictive maintenance program should be evaluated for applicability, potential benefit, and cost-effectiveness.

d) Techniques proposed for use within the predictive maintenance program should be evaluated for applicability, potential benefit, and cost-effectiveness. Appendix I provides an example form for evaluating proposed predictive maintenance program changes.

e) Periodic summary reports (e.g., monthly) to operations and maintenance management describing the current status of the predictive maintenance program and summarizing problems recently identified or corrected should be provided by the predictive maintenance coordinator. This report is useful for management to assess program effectiveness.

f) An overall evaluation of the predictive maintenance program should be conducted annually by the maintenance manager. This evaluation should address the overall effectiveness of the program. Items to be considered in the evaluation are procedure adequacy, in-plant and industry operating experience, quality assurance audit reports and self assessment findings, failure trends, licensee event reports, non-conformance reports, material deficiency reports.

g) Based on the above evaluations and input, the following examples of predictive maintenance program changes should be considered:

   1) adding or deleting equipment in the program

   2) adding or deleting predictive maintenance activities on a particular piece of equipment

   3) identifying the need for new, upgraded, or additional monitoring equipment and software

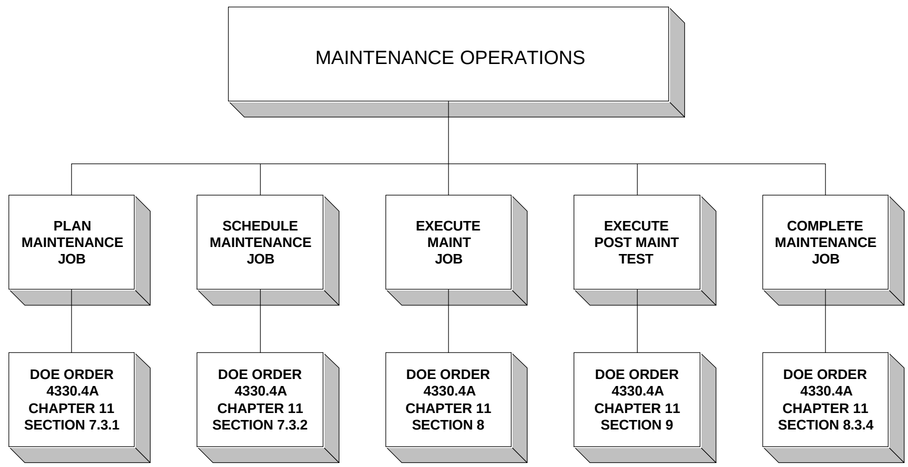
   4) proposing plant design changes

   5) adjusting task intervals

h) The predictive maintenance program evaluation and upgrade also may be integrated into the overall preventive maintenance program review.

APPENDIX A
MAINTENANCE OPERATIONS MODEL

APPENDIX A



The Maintenance Operations Model incorporates five interrelated processes applicable to each maintenance job. These five processes are Plan Maintenance Job, Schedule Maintenance Job, Execute Maintenance Job, Execute Postmaintenance Testing, and Complete Maintenance Job.

The Plan Maintenance Job process is identifying the job scope; producing a job plan; determining the planning category, priority, and safety concerns; identifying and procuring parts, materials, and supplies; identifying other task resources required; and preparing the work package. This process was developed based on DOE Order 4330.4A Chapter II Section 7.3.1.

The Schedule Maintenance Job process is calculating estimated start date and project resources required for job; scheduling and committing required resources and special tools/equipment to allow performance of all job tasks associated with the job. This process was developed based on DOE Order 4330.4A Chapter 11 Section 7.3.2.

The Execute Maintenance Job process is initiating and performing the job; and collecting job information as defined in the work package. This process was developed based on DOE Order 4330.4A Chapter II Section 8.

The Execute Postmaintenance Testing process is verifying facilities SSC fulfill their design functions prior to return to service after execution of the job. This process was developed based on DOE Order 4330.4A Chapter II Section 9.

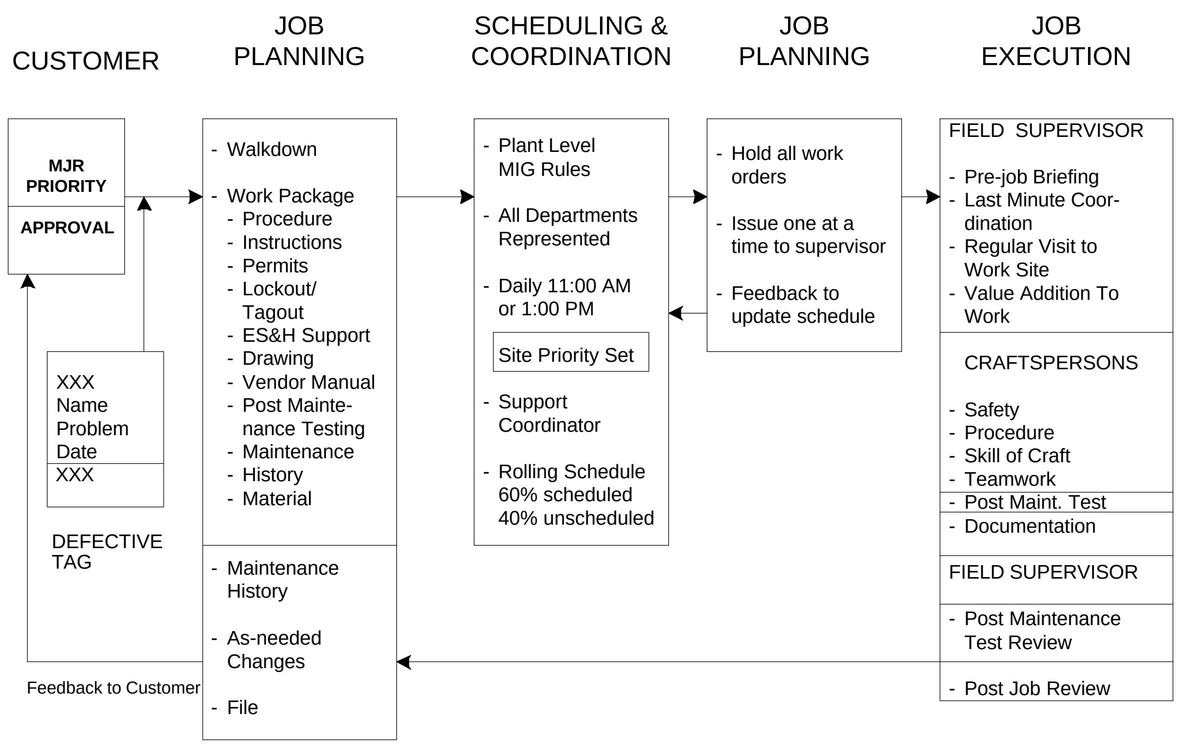
The Complete Maintenance Job process is performing job closeout to include completion of all documentation contained in the work package to ensure historical information is captured. This process was developed based on DOE Order 4330.4A Chapter II Section 8.3.4.

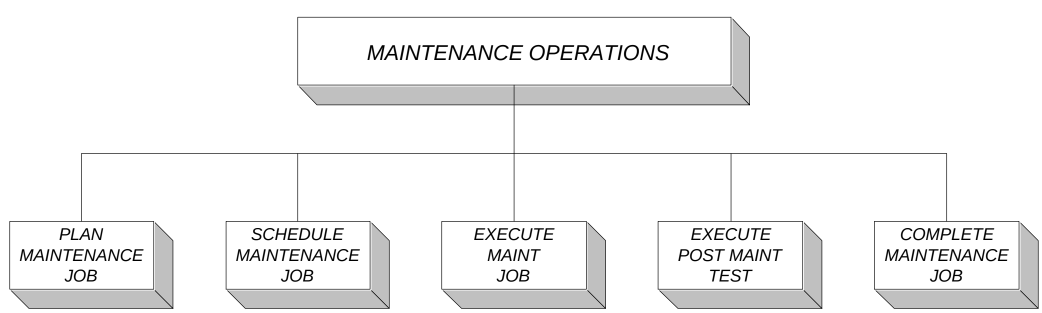
APPENDIX B
FACILITY MANAGEMENT

APPENDIX B

FACILITY MANAGEMENT

MAINTENANCE WORK CONTROL PROCESS FOR 4330.4A IMPLEMENTATION





APPENDIX C
PM DOCUMENT VALIDATION AND FEEDBACK FORM

APPENDIX C
PM DOCUMENT VALIDATION AND FEEDBACK FORM

Route to: Maintenance Manager

MJR NUMBER __________
PROCEDURE NO. __________
COMPONENT TAG NUMBER __________
COMPONENT DESCRIPTION __________
PM TASK NUMBER _________________

SAFETY CLASS SR ___ QR ___ NNS ___
EQ __________
DISCIPLINE _______________
CRAFTSPERSON ____________________

		YES	NO	N/A
1.	Is the materials and tools equipment list complete and adequate?	___	___	___
2.	May PM task be performed as written?	___	___	___
3.	Does the procedure reflect the current "as-built" plant configuration?	___	___	___
4.	Are referenced parts/equipment correctly identified and easily located?	___	___	___
5.	Are graphic illustrations accurate, legible, and easy to understand, and do they indicate enough illustrative detail to adequately perform the PM task?	___	___	___
6.	Do data sheets follow sequentially with the procedure book?	___	___	___
7.	Are prerequisites, precautions, and limitations clearly identified?	___	___	___
8.	Are tag numbers, nomenclature, and units/symbols identical to those displayed on the components or instruments?	___	___	___
9.	Is PM frequency adequate?	___	___	___
10.	Are step, caution, and note statements easily understandable?	___	___	___
11.	Are changes to maintenance job request required?	___	___	___
12.	Are manpower/manhour requirements adequate?	___	___	___
13.	Is concurrent maintenance correctly identified?	___	___	___

Editorial/Grammatical errors identified: ____

Recommended changes to format, flow, or technical content: __________________________

____

Resolution/Justification: ____

Resolution by: ____________________ ________________________ _____________
Signature Printed Name Date

APPENDIX D
PREVENTIVE MAINTENANCE PROGRAM ENHANCEMENT

APPENDIX D
EXAMPLE METHODOLOGY
PREVENTIVE MAINTENANCE PROGRAM ENHANCEMENT

1. PURPOSE

The purpose of this document is to provide guidance that may be used to enhance an existing preventive maintenance (PM) program by improving the reliability of plant components and systems while optimizing resources. The implementation of this guidance should help ensure that PM tasks for important components are applicable for the types of expected failures and are effective in controlling the failures.

2. SCOPE

This document describes the elements necessary to enhance a preventive maintenance program. The following items are addressed:

- overview of enhancement method
- problem component analysis
- problem component selection
- system analysis
- system selection and prioritization
- data collection
- system and subsystem boundary determination
- determination of system and subsystem function(s)
- determination of functional failures
- functionally critical equipment selection
- analysis strategy for critical and noncritical equipment
- determination of failure modes and effects
- history review
- preventive maintenance task selection and implementation

- logic tree analysis
- preventive maintenance living program

3. DEFINITIONS

3.1 APPLICABLE - The characteristic of a PM task when it is capable of improving the reliability of the component by modifying the way a component fails and its failure rate.

3.2 COMPONENT - A piece of equipment, such as a pump, valve, motor, or instrument that is normally assigned a unique equipment identifier.

3.3 COMPONENT FAILURE - Loss of ability of a component to perform one or more of its functions.

3.4 CONDITION-DIRECTED TASK - A task performed when component performance or condition reaches a limit (either predefined or determined by engineering evaluation) measured by performance or condition monitoring test where continued satisfactory operation cannot be ensured.

3.5 CONDITION MONITORING - Tests and inspections that may be accomplished on an unobtrusive basis to identify a potential failure. Condition monitoring includes established predictive maintenance techniques.

3.6 CORRECTIVE MAINTENANCE - Repair and restoration of equipment or components that have failed or are malfunctioning and are not performing their intended function.

3.7 DOMINANT FAILURE MODE - The most probable failure mode of a component during its design life.

3.8 ECONOMIC LIFE LIMIT - The time a component is expected to remain in-service before the need for replacement of the component based on cost-effectiveness to reduce the frequency of age-related failures.

3.9 EFFECTIVE - The capability of a PM task to improve component reliability to a given level under cost, implementation, and other constraints.

3.10 FAILURE - See definition of functional failure.

3.11 FAILURE CAUSE - The physical mechanisms or reasons that produced the failure.

3.12 FAILURE EFFECTS - The consequences of a failure.

3.13 FAILURE-FINDING TASK - A task performed to discover hidden failures when no other tasks are judged to be applicable and effective in detecting degradation in component performance.

3.14 FAILURE MODE - The particular type or manner of failure. A failure mode describes what may or has happened as opposed to what caused it to happen. For example, a motor-driven pump fails to run or a circuit breaker fails to open are different kinds of failure modes.

3.15 FAILURE MODE AND EFFECTS ANALYSIS (FMEA) - A technique used to determine significant failure modes of critical components by analyzing the effect of the failure on a system or the plant and the likelihood of the failure mode to occur.

3.16 FAILURE RATE - The actual or expected number of failures for a given type of component in a given time period. For example, the failure rate of a capacitor may be specified as the number of short circuit failures per million capacitor hours. While the failure rate of an item is often a function of time, it also may depend on such factors as the number of operating cycles or environmental conditions.

3.17 FUNCTION - The actions or requirements that a component or system should accomplish, sometimes defined in terms of performance capabilities.

3.18 FUNCTIONAL FAILURE - A failure that results in a loss of component or system function(s). The failure may be active or passive, evident or hidden.

3.19 IMPLAUSIBLE FAILURE - A failure from a rare or unexpected failure mechanism during the service life of the component while operating under normal or emergency conditions.

3.20 FUNCTIONALLY CRITICAL, EQUIPMENT (FCE) - Equipment whose failure results in a loss of system function or whose frequency and severity of failure have an adverse impact on plant operation. FCE may be an individual component or an entire subsystem.

3.21 MASTER EQUIPMENT LIST (MEL) - A detailed master list of structures, systems, and components (SSC) to be included in the maintenance program. The list should include both safety-related and nonsafety-related SSC.

3.22 MEAN-TIME-BETWEEN-FAILURES (MTBF) - The average or expected value of operating time between failures of a repairable item.

3.23 PREVENTIVE MAINTENANCE - Predictive, periodic, and planned maintenance actions taken to maintain a component within design operating conditions and extend its life. Preventive maintenance actions may include operator rounds, engineering walkdowns, and management inspections.

3.24 PROBLEM COMPONENT - A component whose past failures have caused a significant adverse impact on safety system availability, electrical generation, or maintenance cost.

3.25 RELIABILITY - The probability that a component or system should perform its functions for a specified period of time when used within established operating parameters.

3.26 RUN-TO-FAILURE - A maintenance strategy to allow selected components to operate until failure without performing preventive maintenance on the components.

3.27 SURVEILLANCES - Functional tests of installed components and/or systems to satisfy technical safety requirements.

3.28 WEAROUT - The normal degradation process that is a function of operating time.

4. RESPONSIBILITIES

The position titles listed below are the minimum levels of responsibility for conducting a PM program enhancement effort. It is recognized that titles and organizational responsibilities may be different for specific plants. Responsibilities for each element of the enhancement effort should be assigned to those listed and other participating individuals to ensure smooth and timely implementation of the effort. These responsibilities should include review and approval authority of the documentation and recommendations of the analysis along with specific responsibilities for implementation of the recommendations.

Industry experience indicates that the project coordinator and analyst/reviewer positions should be dedicated on a full-time basis to the enhancement effort to achieve timely and consistent results.

Maintenance Manager

Responsible for the implementation of the PM program enhancement effort. Approves additions, deletions, or adjustments to PM tasks.

Technical Support Manager

Responsible for recommending PM task frequencies and program changes based on vendor recommendations, equipment trends, plant and industry operating experience, engineering analysis, cost-effectiveness, and failure analysis. Also responsible for recommending changes as a result of plant or component modifications.

Operations Manager

Responsible for ensuring that operations personnel report component abnormalities that may need to be addressed by the PM program. Also assists in system selection and identification of system and component functions and failure effects.

Project Coordinator

Responsible for directing and coordinating efforts of the analyst/reviewers and the interface with other groups such as technical support and maintenance groups. Also responsible for the development and application of consistent definitions and guidelines needed to implement the enhancement process.

Analyst/Reviewer

Responsible for reviewing SSC requirements, characteristics, and history to determine PM or operational tasks needed to maintain or achieve desired levels of component reliability.

5. OVERVIEW OF ENHANCEMENT METHOD

Before the enhancement effort is started, the objectives to be achieved should be clearly established by management. In establishing the objectives, the status of the existing PM program should be considered. For example, objectives a plant may establish to enhance a weak PM program may focus more on equipment reliability and documentation of the basis for existing tasks. A plant with a well-established PM program may have an objective to improve utilization of resources and optimization of selected technical safety requirements for PM activities.

It is important that all groups involved in the development or performance of PM tasks become familiar with the stated objectives and participate in some portion of the analysis effort. This should produce more comprehensive results, enhance ownership of the program, and facilitate implementation of changes to the existing PM program.

The PM program enhancement method provides two analytical processes, problem components analysis and system analysis. Each process is followed by PM task selection and implementation. The final element of the enhancement method is establishment of a living PM program that is continually updated, based on actual equipment performance, to maintain its effectiveness.

Problem component analysis is described in Section 6. This analysis focuses on improving reliability of problem components by determining failure modes and implementing any needed PM tasks or design changes.

System analysis is described in Section 7. This analysis focuses on improving overall reliability of plant systems by determining failure modes and implementing PM tasks or design changes. This analysis improves the use of resources by identifying existing PM tasks and technical safety requirements that may be redundant or unnecessary. Additionally, this analysis identifies noncritical components that may be evaluated to determine if assigned PM tasks are cost-effective with respect to resources and radiation exposure or consequences of failure. The review of noncritical components often provides the greatest opportunity to optimize the use of available resources.

Following completion of Sections 6 or 7, selection and implementation of applicable and effective PM tasks are performed as described in Section 8, "Preventive Maintenance Task Selection and Implementation." Selection of condition monitoring (predictive maintenance) tasks is emphasized before selection of time-directed PM tasks. If an applicable and effective PM task cannot be determined, the process involves an evaluation to determine the feasibility of a design change or other corrective actions.

Maintaining an effective PM program is described in Section 9, "Preventive Maintenance Living Program." Experience gained from plant operations, maintenance, and the installation of design changes dictates frequent review of the enhancement analysis and revision of the PM program to maintain program effectiveness.

6. PROBLEM COMPONENT ANALYSIS

This section describes a process that may be used to analyze problem components and identify any PM activities that may improve component reliability. The type and level of maintenance performed on a component should be based on its importance to the plant with respect to nuclear safety and reliability. The effort to enhance a PM program should start by focusing on these components. Although several analytical techniques may be used, the technique described in this section is a functional failure analysis that is commonly used in reliability-centered maintenance programs. The analysis described in this section includes the following:

- problem component selection
- component boundary determination
- component history review
- selection of analysis technique
- determination of functional failures
- determination of failure modes and effects

After the problem component analysis is complete, selection and implementation of applicable and effective PM tasks may be performed as described in Section 8, "Preventive Maintenance Task Selection and Implementation."

6.1 Problem Component Selection

Problem components are usually known and acknowledged as plant problems.

They may be identified as those components whose past failures have caused significant adverse impact on safety system availability or maintenance cost, or those components with a high rate of initiating reactor scrams, power reductions, or unplanned days off-line. It is important to start the enhancement effort by focusing on these components so that timely improvements in component reliability may be realized.

An unacceptable failure rate is a factor in determining problem components; however, the consequences of the component's unreliability are more important factors. Problem components should usually be determined through existing programs for engineering analysis of plant performance. These analyses would include review of plant availability and event reports, limiting conditions for operation logs, outage reports, maintenance history, and component failure analysis reports. The components identified using this process should be confirmed by interviews with various managers and key operations and maintenance personnel.

The components identified should be prioritized according to their impact on the plant. Impact on resources may also provide valuable input to prioritization. Any method acceptable to plant management may be used to quantify the component's impact on the plant. Plant management should review and concur with the priorities before the detailed analysis is initiated.

Efficiency may be gained if similar components are grouped together for the analysis. The criteria for grouping components should be that the components have similar functions, failure effects, and operating environments. Although it may be helpful to review failure history of all components with the same manufacturer and model number, selection and assignment of the same PM tasks to all of those components may lead to unnecessary tasks being assigned.

6.2 Component Boundary Determination

A boundary for the selected components should be established to ensure that associated devices are appropriately considered in the analysis. The boundary for a component should be established as a logical grouping of devices or components based on the function of the component. All attendant devices necessary for the component to perform its system function should be included within the boundary. For example, if a spray valve is identified as a problem component, then the valve operator, valve positioner , and current-to-pressure converter should be included in the boundary. Accurate and inclusive boundary determination is important because the unreliability of the valve may be caused by seemingly unrelated failures of these devices or it may be determined that the unreliability is primarily due to only one of the devices, in which case, the boundary may be redrawn to focus the analysis on that device.

If a larger component, such as a main feedwater pump, is selected, the boundary for the pump, which may be considered a subsystem of the feedwater system, may be established as described in Section 7.4, "Subsystem Boundary Determination," and analyzed using the guidance described in Section 7, "System Analysis."

When establishing the component boundary, also consider the devices associated with an equipment identifier since maintenance and operating history is usually most easily retrievable using those identifiers.

6.3 Component History Review

All appropriate operating characteristics, requirements, vendor maintenance recommendations, and history records of a component should be identified and considered in analysis of the component. History review and data collection may be time-consuming depending upon the individual plant's facilities. They are efforts that are performed throughout the analysis process. The information collected should be compiled into a data package to facilitate future use, reference, and ready access. All documentation developed during the analysis of components should be retained for use in the analysis described in Section 7, "System Analysis."

The data sources listed in Attachment A should provide the design and operating information needed to determine component functions and to perform the component analysis. The information needed includes the following:

- design specifications
- operating requirements

- theory of operation and operating limitations
- maintenance and surveillance requirements
- internal and external commitments

Component functions, requirements, and commitments should be listed on a form similar to Attachment B.

After the function and requirements of the component are established, its history and all the activities routinely scheduled for the component should be reviewed. At least two operating cycles, covering approximately three years, of corrective and PM data, along with any surveillance data, should be evaluated. History for components performing identical functions in similar environments for multi-unit sites should be included. Data older than two cycles may be of limited value since it may not reveal any new failure modes or the cause of the failure may have been subsequently resolved. When reviewing the history of the components, the analyst should attempt to identify the following:

- failure modes
- failure causes and mechanisms
- failure rates as compared to the industry if easily retrievable and available

Much of the information collected may be validated and additional perspective gained from interviews with key operating, maintenance, engineering, and vendor personnel. Information gained by interviews should be compared with the history data to ensure all known failures and reliability problems are identified for analysis.

6.4 Selection of Analysis Technique

There are several analytical techniques that may be used to determine the root causes and corrective actions for component performance problems. Each technique has its advantages and should be used when the circumstances best fit those advantages. Existing plant programs for root cause analysis should be considered and used appropriately in resolving component performance problems. Unacceptable levels of corrective maintenance noted on a component may indicate a problem with maintenance work practices, inadequate procedures, spare parts, or inappropriate design. Corrective actions for the causes of these problems should be addressed on a case-by-case basis rather than considering additional PM tasks.

Component reliability problems that do not have human performance factors may best be resolved by using the functional analysis technique commonly used in reliability-centered maintenance programs. The functional analysis technique, as applied to components, is described in Sections 6.5, "Determination of Functional Failures"; and 6.6, "Determination of Failure Modes and Effects."

The functional analysis technique establishes the following:

- component functions
- component failure modes
- effects or consequences of the failures

It should be recognized that analysis of component performance problems usually results in addition of PM activities. It also should be noted that the results of the component analysis may be modified when the system containing the component is analyzed. Documentation developed during the component analysis should be retained and available for use in the system analysis, described in Section 7.

6.5 Determination of Functional Failures

This section describes the method for determining component functions and how the component may fail.

From the data collected during the component history review, the functions of the component should be determined and recorded. Functions are actions or requirements the component should accomplish to support its overall system function. It is important that all functions of the component be identified since preserving these functions is the primary objective of the PM tasks that should be selected.

After the component functions are determined, the next step is to identify the likely failures that may cause loss of one or more component functions. These are called functional failures. A functional failure exists when a component ceases to provide a required function whether the function is active or passive, evident or hidden. Some functional failures may be considered to be implausible. Examples of implausible failures are those that result from a rare or unexpected external occurrence or from an unexpected or unlikely failure mechanism. Although they are noted, implausible failures are not considered for further analysis.

6.6 Determination of Failure Modes and Effects

The failure modes of the selected component and the effects or consequences of failures need to be determined. Performing the failure mode and effects analysis (FMEA) is a significant element of the problem component analysis. The significance of the failure modes is then established to determine which modes need to be evaluated for PM task enhancement or design changes.

6.6.1 Failure modes are the types or ways a component may fail. They may be determined by reviewing the component's operating characteristics and how it functions in the system.

6.6.2 Determine the plausible causes of each failure mode. Plant history may provide additional information useful in determining the failure causes.

6.6.3 Determine the effects of the failure modes and evaluate them at the local, system, and plant level to determine their effect. Local effects are those that may be noted in the general vicinity of the failure. System effects are problems that inhibit system functions or operations. Plant effects are problems that impact more than one system or limit plant operation or power generation. The following are examples of effects:

- local effect - provides a local alarm or results in leakage or unusual noise
- system effect - causes loss of redundant equipment
- plant effect - results in a power reduction or transient

When evaluating components with redundant trains, consider the consequences of the failure mode as if the redundant train was not available.

NOTE: There are other methods for considering redundant equipment. The method described above may result in increased system reliability.

Input and interviews from the operations staff and training materials also may be used to identify failure effects.

6.6.4 If a failure mode only has a local effect, then no other analysis is needed for that failure mode. Failure modes that have a plant effect and a high likelihood of failure are considered significant and should be evaluated for PM task or design changes. Failure modes that have a system effect are evaluated to determine the significance of the failure effects and if the likelihood of occurrence is high. The following questions may be used to determine if the failure modes are significant:

- Does the failure mode cause loss of a safety or system function?
- Is the failure mode likely to occur?

NOTE: Probability of occurrence of a failure is a consideration used in several elements of the analysis. Specific probabilities or the criteria to be used should be established by the plant.

- Does the failure mode adversely affect plant availability or result in a power reduction?
- Could the failure mode result in personnel injury or significant component damage?
- Does the failure mode result in high use of maintenance resources?
- Does the failure mode result in significant radiation exposure to accomplish repair?
- Does the failure mode impose excessive demand on other components, considering a reasonable repair time, (e.g., on-off cycling, uneven load distribution, or exceeding capacity ratings) that may shorten the service life of other components?

6.6.5 If the answer to any of the above questions is "yes," the failure mode should be addressed by a PM task or be evaluated for a possible design change to eliminate or control the failure mode. If the answers to the questions are "no," and the likelihood for failure is also low, then the failure mode is considered to be insignificant since the consequences may be tolerated. If a failure mode may be tolerated, it is not essential to perform a PM task to mitigate the failure cause. If all failure modes may be tolerated, the component should be considered for run-to-failure operation, and the existing PM tasks for the component should be evaluated for possible deletion.

If the failure mode should be addressed by a PM task, select a task as described in Section 8, Preventive Maintenance Task Selection and Implementation."

6.6.6 Before the FMEA is approved, it should be reviewed by knowledgeable technical support and maintenance personnel to ensure the analysis was comprehensive and technically accurate. FMEA reviews may be performed in meetings with the appropriate personnel to expedite the review and gain insight for future analysis.

7. SYSTEM ANALYSIS

This section describes a process that may be used to analyze plant systems to improve system reliability and optimize use of resources. The purpose of a system analysis is to identify critical components whose failures should be controlled or eliminated to preserve important system functions. Additionally, this section provides a strategy for analyzing noncritical components. The steps of the analysis to determine necessary PM tasks are described in the following sections:

- System Selection and Prioritization - This section describes selection and prioritization of plant systems based on importance to nuclear safety, reliability, and cost.

- Data Collection - This section describes the sources and types of data that should be collected to perform the analysis.

- System and Subsystem Boundary Determination - This section describes the method for determining boundaries and interfaces of systems and subsystems.

- Determination of System and Subsystem Function(s) - This section provides guidance for determining the functions of systems and subsystems.

- Determination of Functional Failures - This section provides a method for determining likely component failures that may cause the loss of system or subsystem function(s).

- Functionally Critical Equipment (FCE) Selection - This section provides guidance for determining critical components and instrumentation that may cause important system functions to fail.

- Analysis Strategy for Critical and Noncritical Components - This section describes the analytical method for determining component failure modes, causes, and failure consequences of the functionally critical components and discusses run-to-failure strategy for noncritical components.

- Determination of Failure Modes and Effects - This section describes how to determine the failure modes and effects of the failures for FCE.

- History Review - This section describes the sources and data that should be reviewed to ensure all failure modes and causes are identified.

7.1 System Selection and Prioritization

This section describes two methods for selecting and prioritizing plant systems to be analyzed. There are many methods that have been used effectively. Each plant should establish criteria and select a method that best meets its specific objectives. The actual method selected is not critical to the enhancement effort. Of more importance is to choose a method, document the method and its results, and proceed with the system analysis.

Systems should be selected and prioritized using input from plant personnel and management. The selection and prioritization process should include representatives from operations, maintenance, and technical support and include managers, supervisors, and appropriate craft personnel. During the process, the following factors should be considered:

- importance to nuclear safety
- potential for improved system or plant availability
- historical and potential maintenance costs
- manpower and resource requirements

Other sources of information that may be helpful in the selection and prioritization of plant systems include the following:

- probabilistic risk assessments (PRA)
- individual plant examinations (IPE)
- regulatory concerns
- equipment failure trending data
- radiation exposure history
- maintenance history

- plant-life extension and aging studies
- personnel safety statistics

The following are two methods that may be used to select and prioritize plant systems:

7.1.1 Method 1

A system prioritization survey may be performed by developing a list of important criteria. Select and request managers, supervisors, engineers, and knowledgeable craftspersons to complete the survey for each system considered for enhancement. Each system should be evaluated by assigning weighting factors from 1 to 10 to each criterion (i.e., 1-lowest, 10-highest) and then determining an overall importance value for each system by summing the factors.

The importance values provided by all personnel performing the evaluations should be summed for each system, and each system should be ranked in descending order. The systems with the highest ranking should be the ones considered when selecting the system to be evaluated first.

7.1.2 Method 2

This method is directed at improving nuclear plant safety through improvement to overall plant performance by focusing on system availability data (i.e., unplanned shutdown days and unplanned outage extension days) and the results of system prioritization surveys as they are described in Step 7.1.1. The survey and unavailability data are then scaled to reflect their relative magnitude. Next, the scaled values are multiplied by a weighting coefficient and summed to yield a composite score. These scores are then ranked in descending order.

Some suggested weighting coefficients are shown below:

Unplanned days off-line (UDOL) = 1.0
Surveillance unavailability hours (LCO) = 0.04 (Mode 1)
In-plant survey = 0.1

Unplanned days off-line include scrams, forced outages, and outage extension days. Surveillance unavailability hours include time spent in limiting conditions for operation (LCO) action statements resulting from maintenance surveillance testing and corrective maintenance.

The following formula may be used to determine system ranking for a single or two-unit plant:

NOTE: LCO hours for multi-unit sites may be considered as shown in the formula.

System score = 1.0 * [UDOL]
+ 0.04 * [LCO (Ul) + LCO (U2)]
+ 0.1 * [Survey results]

Where: U1 = Unit 1; U2 = Unit 2; * = multiply

NOTE: The formula may be modified for a specific PM program enhancement objective by changing or adding additional factors along with appropriate weighting coefficients. For example, a plant with a well-established PM program and a strong performance record may have an objective to optimize resources by selecting systems with a large number of PM tasks for possible reduction while not affecting safe and reliable operation of the system. To consider the impact of the existing PM effort, a factor may be added to the formula that represents the number of existing PM tasks per system or cost to perform the tasks. Tle weighting coefficient selected should be representative of the importance placed by management on that factor of the formula.

7.1.3 The system selection and prioritization process should be used for the plant systems deemed most important for nuclear safety, reliability, or economics. Plant management should review and approve the systems selected and their ranking. If two or more systems have equal ranking, plant management should decide the final ranking that establishes the sequence in which the systems should be evaluated.

It may be advisable to begin the enhancement effort by conducting a pilot study of one system. If a pilot study is to be conducted, it may be best to start with a system that has an unacceptable failure rate. Another criteria that may be used for the pilot study is that a relatively simple system containing mechanical, electrical, and electronic components be selected so all major technical disciplines may gain experience from the study. The primary objective of the pilot study is to refine techniques and establish guidelines for analysis of future systems. It should be recognized that the number of systems selected for detailed evaluation determines overall scope of the PM program enhancement effort and the resources needed.

7.2 Data Collection

Once systems are selected, the analyst should collect design, operational, and maintenance information in order to develop a data package for the system and components. This ensures the operating characteristics, requirements, and history of the system and associated components are known and considered in the analysis. The data package should provide the analyst with the information needed to determine system functions, equipment failure modes, failure causes, and failure rates. The information for the data package may be obtained from sources such as those shown in Attachment A. The information needed includes the following:

- design specifications
- operating requirements
- theory of operation and operating limitations
- maintenance and surveillance requirement
- internal and external commitments
- routinely scheduled PM and surveillance activities

Although the data collected may have many uses, collecting and assimilating the information is a time-consuming effort and is performed continuously throughout the process. To facilitate retrievability, use, and updating of the data collected, a computer data base may be used for easy access by all analysts and other users. If a computer program is not available for electronic approvals of analysis documentation, computer-generated forms may be used to obtain the necessary reviews and approvals.

7.3 System Boundary Determination

The next step in the enhancement process is to define the boundaries of selected systems. The boundary of a system should include everything necessary for the system to accomplish its function(s). Defining system boundaries is an important step, and once established, boundaries should be documented and maintained throughout the remainder of the process. To assist in defining system boundaries, the analyst should refer to the boundary or system interfaces identified during a design basis review, if one is available. Using information already developed provides an opportunity to minimize the cost and resources needed.

7.3.1 Using a copy of the single-line schematic drawings and the piping and instrument drawings (P&ID) of the selected system, define the system boundaries as follows:

7.3.1.1 Draw boundary lines such that controlled components and their associated controllers and instrumentation are within the system boundary.

7.3.1.2 Piping boundaries for a system should be drawn at a valve, with the valve included if its function is for isolation of the system.

7.3.1.3 Air-operated valves should include the instrument air system back to the first isolation valve off the instrument air header and the local instrumentation (e.g., positioners, current-to--pneumatic converter and solenoid valves). For the instrument air system, the valves, regulators, and piping serve the same function and should be analyzed as part of the instrument air system.

7.3.1.4 Multiple trains in a system or redundant components within a system should be included within the same system boundary.

7.3.1.5 When a system contains a heat exchanger, the heat exchanger should be included with the system that is being cooled.

7.3.1.6 Specific components that are dedicated to a particular system should be included within that system boundary. For example, the level and flow instrumentation in the main steam system that provides signals only to the feedwater control logic should be included in the feedwater system and not in the main steam system.

7.3.2 There are some special boundary points that may need to be established. For example, in order to define functions where control logic is involved, the analyst may find it convenient to extend a system boundary beyond that shown on a given drawing to include instrument sensors that drive the system logic. It should be recognized that system drawings are sometimes not sufficient to show instrumentation logic and electrical boundaries.

7.3.3 It may be helpful to color code the P&IDs to show the boundaries and each component that should be addressed in the enhancement effort. In addition, it also may be helpful to develop a list of components within the boundary to track their analysis.

7.3.4 A copy of the marked-up system drawings should be included in the final documentation package.

A comparison and review of major drawings should provide assurance that all components in the selected systems were included in the process and that important components were not excluded when system boundaries were established.

7.4 Subsystem Boundary Determination

This section provides a method to determine subsystem boundaries by partitioning the selected system. The boundary for a subsystem should be established as a logical grouping of devices based on the functions of the system being analyzed. All instruments and components that are necessary for the subsystem to perform its system function should be included within the subsystem boundary. These new boundaries partition the system under analysis into subsystems. Some of the guidance for defining system boundaries as described in Section 7.3 is also applicable to the subsystem boundary determination process. For example, redundant trains of components should be included in the same subsystem. The subsystem should be further partitioned into separate trains for analysis to consider the possibility that one train may perform a function(s) the other train does not perform. This step of partitioning into subsystems should be completed for all functionally significant components within a selected system.

Subsystem boundary interfaces also should be identified. These interfaces include significant mechanical, electrical, and pneumatic inputs/outputs and/or control signals such as the following:

- Inputs cross the boundaries moving into a component of the subsystem. Examples of inputs include fluids, gases (e.g., air), electrical power, instrument signals, and steam. These inputs are necessary for the component to function properly. In this process, inputs are always assumed to be present and available when needed.

  NOTE: The assumption that these inputs are present and available when needed precludes the need for using a fault tree analysis to analyze multiple failures. For example, if the supply breaker is included in a subsystem, a fault tree analysis would be appropriate to analyze failures of the breaker along with failures of other subsystem components. If a fault tree is not used, the breaker should be analyzed as a separate subsystem or when the distribution system is analyzed.

- Outputs cross the boundaries moving out of the component into other components or systems. These outputs are directly related to the function(s) that should be preserved.

- A component interface block diagram may be used to illustrate inputs and outputs.

7.5 Determination of System and Subsystem Functions

This section describes a method to determine the primary and auxiliary functions of a system and subsystem and the ways these functions may fail. Determining functions is an important step in this method since preserving these functions is the objective of the PM task that should be selected.

7.5.1 Function definitions describe what the system or subsystem should accomplish. Functions may be determined from the following:

- system and subsystem interfaces that should be supported

- internal interfaces that the system or subsystem should provide as input to another subsystem

- internal interfaces that the system or subsystem provides to support itself

Examples of primary functions include the following:

- normal and emergency cooling flow

- auto-start signal to another system

- compressed air at a sufficient pressure for downstream components to operate properly

- control room alarms, indications, and recordings

7.5.2 Determine the function(s) of each system and subsystem by reviewing plant system descriptions, Final Safety Analysis Reports (FSARs), P&IDS, Technical Safety Requirements (TSRs), operating procedures and instructions, abnormal operating procedures, emergency operating procedures, and design basis documentation. If functions, such as providing a vent or drain path, are determined not to be important to the overall purpose of the system or subsystem, then these functions may be omitted. Omission of specific functions (or other assumptions) should be noted in the data package along with the technical basis for the omission. System or subsystem function(s) should be listed on a tabulation form.

7.5.3 When determining system and subsystem functions to analyze, the analyst should consider that a system and subsystem typically perform a number of auxiliary functions in addition to their primary function(s). The analyst should carefully review the auxiliary functions of system and subsystem to identify those functions that should be preserved. Auxiliary functions may include the following:

- Maintain pressure boundary integrity.
- Provide indication required by technical safety requirements.
- Automatically shut down components.
- Provide input signals for local instrumentation.
- Provide miniflow protection for pumps.

7.6 <u>Determination of Functional Failures</u>

This section describes a method for determining likely component failures that may cause the loss of system or subsystem function(s). A functional failure exists when a component ceases to provide a required function whether the function is active or passive, evident or hidden. Some functional failures identified may be judged to be implausible. Examples of implausible failures are those manufacturing defects that escaped detection during installation and operational testing, the result of an unexpected failure mechanism, or a failure that requires a rare or unexpected external occurrence.

The definition of what constitutes a failure is of primary importance. A clear distinction should be made between degraded performance and functional failure. Whenever a failure is defined by some level of performance, condition, or dimension, the appropriate standards should be stated to provide the basis for establishing whether a failure has occurred. For example, heat exchanger tube fouling may cause water temperature to exceed an allowable temperature. This would be considered a failure. Any temperature below the allowable value, but above the normal operating temperature, would be considered degraded operation. Component performance standards are determined from descriptive and operating information sources such as plant technical safety requirements, operating procedures, and design requirements.

7.7 Functionally Critical Equipment Selection

After functional failures are identified, functionally critical equipment (FCE) is identified by analyzing the functional failures. Functionally critical equipment are components within a system or a subsystem that meet the following criteria:

- components whose failure results in a system functional failure
- components whose failure frequency and severity have an adverse impact on plant operation

Selection of FCE may be performed by analyzing the effects of a failure of the component on the system functions. If failure of the component may cause a loss of system function, the component is considered as FCE. In addition, the results of a PRA or other model may indicate that a component is functionally critical. The following items also should be considered in the selection and prioritization of FCES:

- individual plant examination
- importance to nuclear safety
- safety system functional inspections
- operating and maintenance history
- plant operating experience
- component failure analysis report (CFAR)
- radiation exposure attributed to maintenance on the component

- commitments associated with the component
- cost of repair
- mean-time-between-failures
- input from vendors and other supplier programs (e.g., technical bulletins and notices)

A list of all FCE should be compiled, this list should be useful in assigning priorities and should provide a mechanism for tracking and documenting the status of subsequent analysis.

7.7.1 Instrument Matrix

This section describes a method of identifying functionally critical instruments. A system may contain hundreds of instruments and the analysis of these instruments may be a formidable task. Many instruments perform important system functions that should be preserved by a PM task. However, some of these functions may not be identified during an analysis of system functions or during development of a FMEA on FCE that has associated instruments. To assist in identifying functionally critical instruments, a matrix should be developed and used to identify the functions of the instrument and their importance in maintaining system functions. This technique of using a matrix has proven to be successful for evaluating instruments and provides a good checklist to ensure that all functions of the instrument are identified for analysis.

7.7.1.1 All instruments contained in the system should be listed on a matrix containing an instrument function. The functions to be listed on the matrix are listed below:

F I - provides a component, system, or plant trip function

F 2 - provides automatic control or interlock

F 3 - safety-related display instrumentation (e.g., as defined in technical safety requirements and the FSAR)

F 4 - supports technical safety requirements

F 5 - provides alarm, indication, or recorder information to the control room

F6 - instrument monitored on operator rounds

F7 - provides computer input

NOTE: Explanation of the types uses of the input should be noted on the matrix.

F8 - instrumentation that is used to continuously monitor system, component, or plant performance or design parameters (e.g., accumulator pressure indication)

F 9 - used for manual system operation

F10 - required for general indication

F11 - no required function

NOTE: The functions of the instrument should be clarified during an interview to ensure the classification is correct.

Instruments that should be listed on the matrix are those process devices that sense, switch, convert, indicate, and transmit such parameters as flow, level, pressure, temperature, PH, and conductivity.

7.7.1.2 The matrix should be distributed to appropriate operations, technical support, and maintenance personnel. Each individual should complete the matrix by placing an "X" in the designated column if the instrument performs that function. Other characters may be used to provide additional information on the instrument's function. For example, it may be helpful to use a "C", "S", or "P" to denote a component, system, or plant function. An asterisk (*) may be used if the instrument is found to provide a significant system function.

7.7.1.3 After each instrument has been analyzed, the matrix should be returned to the analyst. The results of all the responses are combined into a master matrix. Based on the collective responses, the analyst determines the importance of each instrument. The first three functions (Fl, F2, and F3) listed on the matrix are important system functions. Instruments that implement these functions are typically associated with other FCE. Instruments that perform functions F4 through F9 of Section 7.7.1.1 should be considered for an FMEA based on the instrument's use, its required accuracy, and consequence of its failure.

7.8 Analysis Stategy for Critical and Noncritical Components

The two analysis strategies presented in this section are the failure modes analysis of: (1) critical and (2) noncritical components.

7.8.1 Noncritical Component Strategy

The strategy for noncritical components is to evaluate existing PM tasks and the components, considering the consequences of deleting the tasks. The analysis of noncritical components often provides the greatest opportunity to optimize use of resources by identifying unnecessary or inappropriate PM tasks.

After the list of FCE has been identified and analyzed, the noncritical components should be reviewed and evaluated. An analysis of the PM programs for noncritical components may justify the deletion or modification of existing tasks or provide an economic basis that should allow the component to run-to-failure. The analysis of noncritical components may also result in a reduction of maintenance man-hours, spare part inventories, and radiation exposure. In addition, this should allow maintenance personnel to concentrate their efforts on components that are important to plant operation and safety.

A minimum review of noncritical components should consist of a review of the maintenance history, total PM tasks, and vendor information for the component. This review should identify recurring or highly probable failure modes. If the failure rate of the noncritical component is high and its repeated failures are not cost-effective, then effective PM tasks or design changes may be used to control the failure rate. Noncritical components with an acceptable failure rate and whose failure consequences are economically tolerable should be considered for run-to-failure operation.

7.8.2 Critical Component Strategy

The strategy for critical components is to identify significant failure modes by using an FMEA. Significant failure modes are failure modes that have a high likelihood of occurrence and that also have an adverse effect on a system or the plant.

7.8.3 Determination of Failure Modes and Effects

This section discusses how to determine the failure modes and effects of FCE failures. Performing the FMEA is a significant element of the system analysis. After the FMEA is completed, the significance of each failure mode is established to determine which modes should be evaluated for PM tasks or design changes.

7.8.3.1 Failure modes are the types of failure or ways a component may fail. They may be determined by reviewing the component's operating characteristics and how it functions in the system. Each failure mode should be recorded on a tabulation form.

7.8.3.2 The plausible causes of each failure mode should be determined. Plant history may provide additional information to determine the causes. The failure causes should be recorded on the FMEA tabulation form.

7.8.3.3 The effects of the failure modes should be determined. Failure modes should be evaluated at the local, system, and plant level to determine their effects. When evaluating components with redundant trains, consider the consequences of the failure mode as if the redundant train was not available.

NOTE: Considering the consequences of a component failure as if redundant equipment is not available is a conservative assumption that should result in failures of most redundant safety components being classified as single failures of safety system functions. As such, these failures should be evaluated since they meet the criteria of loss of safety system function. There are analytical techniques used to determine the consequences of failures of redundant components. These techniques are typically used in probabilistic risk assessments that quantify risk and reliability. Although usually manpower-intensive, using these techniques may reduce the number of redundant components that require an FMEA or change the priority of the components to be evaluated.

Local effects are those that may be noted in the general vicinity of the failure. System effects are problems that inhibit system functions or operations. Plant effects are problems that impact more than one system, constrain plant operation, or limit power generation.

7.8.3.4 If a failure mode has only a local effect, then no other analysis is needed for that failure mode. Failure modes that have a plant effect and a high likelihood of failure are considered significant and should be evaluated for PM tasks or design changes. Failure modes that have a system effect are evaluated to determine their likelihood of failure and the significance of the failure effects. The following questions may be used to determine if the failure modes with a system effect are significant:

- Does the failure mode cause loss of a safety or system function?

- Is the failure likely to occur?

  NOTE: Probability of occurrence of a failure is a consideration used in several elements of the analysis. Specific probabilities or the criteria to be used should be established by the plant.

- Does the failure mode adversely affect plant availability or result in a power reduction?

- Could the failure mode result in personnel injury or significant component damage?

- Does the failure mode result in high maintenance costs?

- Does the failure mode result in significant radiation exposure to accomplish repair?

- Considering a reasonable repair time, does the failure mode impose excessive demand on other components (e.g., on-off cycling, uneven load distribution, or exceeding capacity ratings) that may shorten the service life of other components?

The following are examples of effects:

- local effect - provides alarm

- system effect - causes degradation of system flow

- plant effect - reactor power limitation or transient

Input and interviews from the operations staff and training materials may be used to identify possible failure effects. The effects of each failure mode should be recorded on the FMEA tabulation form.

7.8.3.5 If the answers to any of the above questions are "yes," the failure mode should be addressed by a PM task or be evaluated for a possible design change to eliminate or control the failure mode. If the answers to the questions are "no," and the likelihood for failure is also low, then the failure mode is considered to be insignificant since the consequences may be tolerated. If a failure mode may be tolerated, it is not essential to perform a PM task to mitigate the failure. If all failure modes may be tolerated, the component was incorrectly selected as FCE and the component should be considered for run-to-failure operation. Existing PM tasks for the component should be considered for possible deletion.

If the failure mode should be addressed by a PM task, indicate "yes" in the column marked "significant mode" of the FMEA tabulation form and select a PM task as described in Section 8, "Preventive, Maintenance Task Selection and Implementation"

7.8.3.6 Before the FMEA is approved, it should be reviewed by knowledgeable technical support and maintenance personnel to ensure the analysis was comprehensive and technically accurate. FMEA reviews may be performed in meetings with the appropriate personnel to expedite the review and gain insight for future analysis.

7.9 History Review

The history review plays a vital role in the PM program enhancement effort. For the system analysis process, the review should be conducted after the FMEA. This helps to avoid biasing the outcome of the analysis to only agree with the results of the history review. This may result in overlooking some failure modes or inadequately addressing some components.

After the FMEA is completed, the history and all the activities routinely scheduled for the component should be reviewed. At least two operating cycles, approximately three years, of corrective and preventive maintenance data along with any surveillance data should be evaluated. History for components performing identical functions in similar environments for multi-unit sites should be included. Data older than two cycles may be of limited value since it may not reveal any new failure modes or the cause of the failure may have been subsequently resolved. When reviewing the component's history, the analyst should attempt to identify the following:

- failure modes

- failure causes and mechanisms
- failure rates as compared to the industry if easily retrievable and available

Although plant data is weighed more heavily, failure data from other sources should also be used. Newer plants may have to rely more on industry experience. This data should be reviewed closely to determine that failure modes and causes are plausible and coded correctly. DOE Notices and Bulletins are valuable sources of failure information. Component failure analysis reports should be used and failure rate data may be helpful in evaluating failure history. Unacceptable levels of corrective maintenance noted on a component may indicate problems with maintenance work practices, inadequate procedures, spare parts, or inappropriate design. Corrective actions for these causes of problems should be addressed on a case-by-case basis rather than considering additional PM tasks.

Much of the information collected may be validated and additional perspective gained from interviews with key operating, maintenance, engineering, and vendor personnel. Information gained by interviews should be compared with the history data to ensure all known failures and reliability . problems are identified for analysis.

8. PREVENTIVE MAINTENANCE TASK SELECTION AND IMPLEMENTATION

This section discusses the selection and implementation of applicable and effective PM tasks. To accomplish this effort, significant failure modes identified from the FMEA are evaluated using a logic tree analysis to classify the importance of the failure modes. This information is then used to recommend applicable and effective PM tasks or design changes. The recommended PM tasks are compared to the existing PM tasks to determine if the new tasks should be implemented or if the existing tasks should be modified or deleted. This section also discusses development of an integrated project plan to implement the recommended PM tasks.

8.1 Logic Tree Analysis

A decision or logic tree analysis (LTA) process, may be used to determine the importance of each significant failure mode and aid in the selection of applicable and effective preventive maintenance tasks. The logic tree requires the analyst to answer "yes" or "no" to a series of questions. These answers should determine the decision path. The analyst starts by evaluating if the failure mode is visible or evident to the operating crew. The analyst then determines the consequence and importance of the component functional failure. After determining the consequences and importance of the failure, an applicable and effective PM task is selected or a design change may be necessary. The following questions may be used in the logic tree process:

(1) Is the occurrence of a failure evident or visible to the operating crew while performing their normal duties?

This question divides failures into two groups, evident and hidden:

Yes - Those failures that are obvious to the operators during their normal day-today activities. It is not necessary that the operators know precisely what is wrong, only that something is wrong and that they may take the steps required to repair the component.

No - Those failures that are discovered when operation of infrequently used equipment is attempted or when protective, standby, or backup systems fail to operate on demand. These failures are called hidden failures and may be especially critical to safe and efficient operation.

(2) Does the failure cause a loss of function or secondary damage that has a direct and adverse effect on the safety of the plant?

NOTE: Considering the consequences of a failure of safety system components as if redundant equipment is not available is a conservative assumption that may result in many components being classified as having a safety consequence. There are analytical techniques used to determine the significance of failures of redundant components. These techniques are typically used in probabilistic risk assessments that quantify risk and reliability. Although usually manpower-intensive, using these techniques may reduce the number of components that require FMEA or change the priority of the components to be evaluated.

This question divides the functional failure into two groups, safety and nonsafety:

Yes - Those failures that directly affect operating safety. Safety relates to essential functions needed to protect the health and safety of the public. These should be direct threats, not improbable combinations of events that have minor impact on operating safety or are highly unlikely.

No - Those failures that do not impact the operating safety as described above. These failures have economic or operational impacts that restrict the operator from using installed equipment.

(3) Does the failure cause a power reduction greater than 10 percent or result in a forced outage?

NOTE: The amount of power reduction or other operational impact should be established by plant management.

This question divides the nonsafety-related failures into two groups, operational and economic:

Yes - Those failures that directly impact operations and power generation. These failures affect the ability of an operations-critical system to perform its primary function.

No - Those failures that impact support functions or result in a power reduction less than 10 percent, or those failures with a purely economic impact.

(4) Does the failure cause a plant scram?

This question divides failures that impact operations into two groups, scram initiator and operational impact:

Yes - Those failures that result in a plant scram.

No - Those failures that result in a forced outage, a power reduction less than 10 percent, or other operational impact.

8.1.1 Using the LTA, categorize each failure mode according to its consequence and importance to the operation of the plant. The importance classes are described below:

Class A (Safety) - Failure modes that affect personnel and/or reactor safety. Scheduled maintenance is required and shall reduce the likelihood and severity of the failure to an acceptable level; otherwise, the component/system should be redesigned.

Class B (Scram initiators) - Failure modes that may cause plant scrams. Scheduled maintenance or a design modification is required to reduce operational costs and limit challenges to safety systems.

Class B2 (Operational Impact) - Failure modes that result in a forced outage, power reductions less than 10 percent power, or other operational impact. Scheduled maintenance or a design modification is necessary to reduce operational and corrective maintenance cost.

Class C (Economics) - Failure modes that affect support functions and do not cause a power reduction greater than 20 percent. Scheduled maintenance or a design modification is necessary to reduce the corrective maintenance cost.

Class D (Hidden failures) - Failure modes of standby or infrequently used components that do not affect personnel and/or reactor safety and are not evident to the operating crew. Scheduled maintenance is necessary to reduce the likelihood of multiple failures to an acceptable level. Hidden failures are reclassified using the LTA as either A, B1, B2, or C to establish priority of task selection.

Significant failure modes should be addressed in the following order: A, B1, B2, and C. This information should be used in the selection of applicable and effective PM tasks.

8.1.2 Preventive Maintenance Task Selection

This section describes the method for selecting applicable and effective PM tasks to control the failures of significant failure modes. The PM task selection portion of the LTA is used in this method.

Four basic categories of PM tasks are described below. Special emphasis should be placed on selecting condition-monitoring tasks when they are applicable. If a failure mode provides any indicators of degradation of a component, baseline values should be set for the degradation and a regular monitoring program established for the component. When scheduling permits, multiple tasks should be combined into single activities. The following are the categories of PM tasks:

- TIME-DIRECTED TASK - A task performed solely on the basis of a fixed time schedule, safe life limits, or economic life limits (e.g., change the air filters in the instrument air system every 30 days). The scheduled replacement of a component at its end-of-life is a time-directed replacement task. A time-directed task may be ineffective if not performed at an appropriate interval. For example, a premature overhaul not only wastes resources but also increases the risk of human error during the removal, overhaul, and reinstallation process. In addition, premature overhauls may result in unnecessary radiation exposure and excessive equipment unavailability.

- CONDITION-MONITORING TASK - A task that is used to gather data so that component condition or performance may be monitored and evaluated in order to perform planned maintenance, a condition direct task, prior to equipment failure. Condition monitoring tasks are selected according to the parameters required to describe equipment performance.

- CONDITION-DIRECTED TASK - A task performed on an as-needed basis when the condition or performance of the component has reached a predefined limit or standard. This is normally a restorative task that is performed prior to failure, such as changing a pump seal when leakage reaches five gallons per minute. In some cases, the component's performance shall be baselined. Baselining involves measuring specific parameters during routine operation so they may be compared to established values, levels, and limits of performance that are indicative of normal, abnormal, or unacceptable conditions.

- FAILURE-FINDING TASK - A task performed to discover a hidden failure. The intent of the task is not to monitor and anticipate failure as with a condition-monitoring task but rather to find a failure after it has occurred, at which time corrective maintenance may be performed. An example of this is a surveillance test that starts and runs the diesel--generators every 30 days. If the test results in the discovery of a failure, then corrective action should be taken.

8.1.2.1 The LTA uses a series of questions to identify applicable and effective PM tasks for preventing or detecting failures. There are three sections of the LTA. One section addresses operational and safety classifications of failure modes while the other sections address economic and hidden failure modes.

Select tasks by answering each of the LTA questions "yes" or "no".

NOTE: Since many existing tasks are based on technical safety requirements, the surveillance test program should be used when practical to gather condition-monitoring data.

8.1.2.2 Identify, describe, and record the recommended PM tasks and record the bases for the recommended task.

8.1.2.3 This section describes how PM tasks are determined to be applicable and effective.

All PM tasks recommended from the LTA shall be evaluated to ensure that they meet applicability and effectiveness requirements. Each PM task should be evaluated considering the failure it prevents. The applicability of a task depends on its ability to change the way a component fails and its failure rate. Applicability requirements are different for condition-monitoring and time-directed tasks. The requirements for selection of a condition-monitoring task include the following:

- The task shall be able to detect a component's degraded condition or performance.

- The failure shall be plausible and capable of being detected using condition-monitoring techniques.

- The failure shall be predictable as it progresses from a potential failure to a functional failure.

The applicability requirements for time-directed tasks include the following:

- The failure does not have detectable parameters or the parameters cannot be measured.

- The component should be in operation for the specified period of time.

- The task shall restore the component's condition and reduce the likelihood of failure to an acceptable level.

Effectiveness requirements for a task depend on the consequences and cost of the failure (i.e., operational, safety, or economic), To be effective, a task selected for a failure mode with safety consequences shall reduce the likelihood of failure within cost and implementation consideration. An example of an implementation consideration is the impact of performing a task "on-line," thereby increasing the time a system is unavailable (i.e., LCO time), or performing it during an outage with the associated impact on outage workload and duration. A task to identify hidden failures with safety consequences, a failure-finding task, shall reduce the likelihood of a multiple failure, also within identified constraints. The hidden failure shall be discovered before another failure occurs that would result in loss of a system function or a safety system challenge.

NOTE: The effectiveness of a new PM task should be dependent on the existing material condition of the component. If a component is in a degraded material condition (eg., a safety-related motor operating with excessive vibration), it may fail before the new PM task is able to prevent the failure as designed because much of the service life of the component has been expended. The component may need to be repaired, overhauled, or replaced to establish an acceptable material condition baseline. The new PM should then be effective in controlling the expected failure mode.

For failure modes that have operational or economic consequences, the selected task shall be cost-effective (i.e., the cost of preventive maintenance shall be less than the cost of the operational loss and/or cost of repair). Cost-effectiveness is evaluated by performing an economic trade-off study. This study should compare the cost of performing the proposed task (e.g., labor, materials, and spare parts) with the cost of the consequences of not performing the task. The present-value cost of the PM shall be less than the present-value cost of not doing the task. The cost-effectiveness of a recommended PM task should be evaluated before the task is implemented.

8.1.3 Task Interval Determination

This section discusses considerations for establishing the intervals for PM task performance. Although the LTA analysis is rigorous in selecting maintenance tasks, it does not address task intervals. The interval for each maintenance task is evaluated on the basis of the failure mode it prevents. The interval for a condition-monitoring task depends on its ability to measure and detect a reduction in the component's condition or performance before a failure occurs. The same is also true of failure-finding tasks assigned to components with potential hidden failures.

The requirement for the first interval for condition-monitoring tasks or inspection is that the interval be long enough so that some physical evidence of deterioration may be detected. Subsequent intervals shall be short enough to ensure that further degradation is detected before failure occurs, so that planned or condition-directed maintenance may be performed to prevent the impending failure.

After the applicability and effectiveness of the conditioning-monitoring task is established, a condition-directed task restoring the degraded condition-detected by the condition-monitoring task may be determined and prepared.

The initial intervals for time-directed tasks are conservatively selected based on operating and/or vendor information. These intervals should be adjusted according to the component's reliability and as-found condition based on review of PM task results and the component's maintenance history.

The following questions may be of assistance in determining appropriate task interval for time-directed and condition-monitoring tasks:

- How frequently does the failure mode occur that the task is designed to prevent?
- How much time elapses between initiation of degradation and functional failure?
- Can the failure progression or component degradation be measured adequately?

8.2 Preventive Maintenance Task Comparison

Once the PM task selection process is complete, a task-by-task comparison of the selected, applicable, and effective tasks is made with existing activities and vendor recommendations. The comparison should include all existing PMs, surveillance tests, in-service inspection tests, performance tests, and calibrations for the component being analyzed. Operator rounds or other routine inspections are often overlooked as recognized tasks, but they also should be recorded. After they are recorded, these tasks and activities may be compared to vendor-recommended activities, inspections, and tests.

It is important to establish the basis of the vendor PM recommendations to help resolve any differences between the recommendations and PM tasks. For example, were the vendor recommendations based on continuous or intermittent operation of the equipment? The source or requirement for each PM task should be determined and listed. Assistance from the groups responsible for tracking commitments may be helpful in identifying these requirements. Examples of sources include the following:

- technical safety requirements
- vendor technical manuals and bulletins
- DOE technical documents
- insurance requirements
- in-service inspection (ISI) requirements
- plant operating and maintenance experience
- other commitments

The contents of newly defined PM tasks are compared with existing tasks. Any newly selected task not addressed by an existing task should be proposed as a new PM task. Any existing task not supported by the analyses should be considered for deletion as an unnecessary task. Caution should be exercised before deletion of any task. Prior to deletion, a review should be performed to ensure the deletion does not invalidate a commitment or an assumption made in the analysis process. If a commitment may be impacted by deletion of the task, then consideration should be given to requesting a change to the commitment.

Similarity of task content may indicate the need to combine activities. Frequency of task performance should be compared and adjustments to the frequency recommended if a review of the component's history indicates a change is warranted. Some of the selected tasks may be different in content or frequency from technical safety requirements. For these situations, collection of operating data and the bases developed during the analysis process may be of use in supporting a change request to the technical safety requirements.

Proposed deletions should be reviewed by personnel responsible for tracking commitments before the task is approved for deletion.

All data that has been used to determine the recommended PM task should be properly recorded and stored so that it may be easily retrieved, used, and referenced for future selections.

8.3 Task Review and Approval

The next step is to review and approve the recommended PM tasks and associated implementing actions. Prior to approval, each PM task should be thoroughly reviewed to validate the results of the LTA and to ensure the task may be properly and economically performed. This review should involve operations, maintenance, technical support, and other personnel who are familiar with the PM program goals, objectives of the enhancement effort, the analysis techniques, and the specific component. The review also should determine all actions needed to put the task into effect. Examples of these actions may include the following:

- adjusting PM task schedules
- revising PM instructions
- ordering new spare parts or adjusting inventory levels
- purchasing or leasing diagnostic equipment
- requesting deviation from commitments
- updating vendor manuals
- revising operation and maintenance procedures
- training personnel

The task should be approved by the appropriate manager after it is verified to be technically sound and implementable. Approval of the task also should include approval of the actions needed to implement it. Often, approval of an implementing action is at a higher management level than approval of the specific PM task (e.g., request to deviate from a commitment). For these cases, the implementing action shall be approved and completed before the task may be performed.

8.4 Task Implementation

The implementation process should begin as PM tasks are approved. Implementation includes completing all the actions each organization shall take to put the approved tasks into effect.

Experience has shown that implementation of the analysis results often requires more effort and management involvement than that needed to actually perform the analysis. Therefore, an integrated project plan should be developed that assigns responsibilities, resource requirements, commitment dates, and status reporting requirements. The plan is needed to ensure all efforts are coordinated and completed within the desired time frame. The project plan shall be monitored periodically by management to ensure milestones are met and the enhancement objectives are being achieved.

In addition, follow-up interviews should be conducted with operations, maintenance, and technical support personnel to ensure all responsible individuals understand and support the implementation and results of the analysis. Problems identified by these interviews should be expeditiously resolved and reviewed for generic consequences to maintain effective use of resources and timely progress.

9. PREVENTIVE MAINTENANCE LIVING PROGRAM

After a PM enhancement effort has been implemented, appropriate adjustments need to be made periodically to the program because of changes in plant design, operating conditions, regulatory commitments, and as-found component conditions. This "living program" concept should ensure that components critical to plant safety and operation remain reliable. The primary objectives of the living program are to minimize future component failures, optimize PM tasks and use of resources, identify program expansion needs, and satisfy regulatory and industry concerns.

9.1 Task and Program Review

To gain the maximum benefit from the enhancement effort, appropriate review, feedback, and update processes need to be incorporated into the PM program to ensure that the program effectively addresses changing plant and equipment conditions. These processes should be routine functions of appropriate organizations.

Evaluation of data from the following sources and implementation of appropriate adjustments need to be performed to maintain the effectiveness of the PM program:

- equipment failure trending
- root cause analysis of component failures resulting in plant events
- craft feedback reports
- predictive maintenance analysis
- plant and system performance monitoring
- preventive and corrective maintenance history
- surveillance test optimization studies
- radiation exposure history of PM performances
- equipment design modifications

During the evaluation of the data from the sources listed above, the following items should be considered:

- equipment failure characteristics (e.g., failure rates, causes, and mechanisms) to validate FMEAs
- as-found equipment conditions and task intervals
- installation of new equipment for program scope changes
- operating and maintenance procedure changes for PM task content changes
- plant effects caused by failure of noncritical components

Results of the evaluations should be used as the basis for appropriate adjustments to PM task content and frequency. Other actions that also may be needed to keep the PM program current include the following:

- Revise the program scope.
- Revise the analysis.
- Update documentation.
- Perform a new analysis.
- Select a different task.
- Provide training.
- Delete tasks.
- Revise procedures.

An example of an adjustment to the PM program is replacing time-directed PM tasks with condition-monitoring tasks when the as-found condition of the components indicates that the intervals of the PM task may be increased and that a condition-monitoring task is applicable. This is a typical change that may result in improved use of plant resources. Also, PM tasks for components with commitment- or regulatory-specified intervals, along with the corrective maintenance history of the components, should be reviewed periodically to determine if the performance or frequency of the PM tasks is detrimental to the reliability of the components.

9.1.1 Task Frequency Optimization

This section describes one method for optimizing PM task frequency. Preventive maintenance task frequencies need to occasionally be adjusted to achieve optimal results. One method effectively used to change frequencies for nonsafety-related components involves direct observation of the "as-found" condition of equipment during PM activities. The use of this process may result in an increase or a decrease in PM task frequency. The following method to optimize task frequency may be implemented without a substantial increase in craft or supervisory man-hours.

9.1.1.1 The "as-found" condition of equipment is recorded as a "score" from 1 to 9 (1-lowest, 9-highest) during routine PM activities. This score is determined by the supervisor or in conjunction with the craftsperson who performed the job.

The minimum score of "1" for a PM task means that the condition of the component is very close to failure. A maximum score of "9" indicates that the component is in excellent condition.

9.1.1.2 The overall general condition of the component is not evaluated. Only the condition with regard to the specific work performed by the PM is used in determining the "score." For example, the description on a maintenance job request is "Valve Packing Change-out." The score is determined by evaluating the condition of the packing and whether it is close to failure or in very good condition. The score is always related to a specific component and should only be assigned while performing work under a PM maintenance job request. For example, if a mechanic found that the valve packing was already leaking before performing the PM task, then no score should be assigned.

9.1.1.3 When performing a PM, a failure not related to the task and not previously discovered may be uncovered. In this case, the minimum score of "1" should be assigned and corrective maintenance initiated to repair the component.

9.1.1.4 This method facilitates initiation of an evaluation to determine if adjustments to PM task frequencies are warranted. The following are typical criteria that may be used to initiate a review of past PM performance to establish the basis to adjust the interval of the task:

- At least two consecutive high scores, as established by the plant, may indicate the need to increase the interval between PM task performances provided that no corrective maintenance was performed between the two periods.

- A low score, as established by the plant, may indicate the need to decrease the interval between PM tasks performances.

9.1.1.5 The "as-found" scoring should be performed each time the PM is performed, during power operations as well as outages.

9.1.1.6 Reports containing PM task scoring and proposed frequency changes should be periodically provided to management.

To implement this method, it should be emphasized to craftspersons that a good, detailed description of the "as-found" condition of the component and the work performed should be recorded on all PM maintenance job requests. This allows engineering personnel to evaluate and trend the data to optimize task intervals and determine effectiveness of the tasks.

9.1.2 Component Failure Trending

A PM program is designed to maintain the inherent reliability of equipment. This reliability may be determined by analyzing the failure or performance history of the component. Therefore, failures should be graphically trended to produce a record of component performance and provide indicators to facilitate changes in the component's design or existing PM tasks. The trending program should-include selected critical components so that the most effective adjustments to the PM program may be made.

Much of the data needed to establish a trending program is collected during the initial enhancement effort. Some of the data includes failure time/date, failure mode/cause, and statistically derived data such as failure rate. These parameters may be determined from plant-specific data or from industry sources.

Adverse trends in failure data is cause to initiate an evaluation or investigation to determine and correct the causes of the problems. The following method may be used to determine if the results of component failure trend analysis warrant changes to the PM program:

- If a PM task exists but the trend analysis shows an increase in failures, a review of the component analysis may be necessary to determine if an additional failure mode should be considered or if the adverse trend is-caused by programmatic deficiencies. Additionally, consideration should be given to decreasing the existing PM task interval.

- If a PM task exists and there are no failures over a significant period at time, then consideration should be given to increasing the task interval. In this case, it may be advantageous to use a condition-monitoring task to determine the optimum task frequency and to determine if the task is applicable and may effectively detect degradation before a failure occurs.

The timely collection and analysis of failure data is essential to improve component performance. Incomplete failure and repair descriptions on maintenance job requests often hinder timely analysis. One method that has proven to be effective in obtaining trending information on job requests is to initiate use of failure and repair codes. Codes established by the, plant should be easily sorted by computers to facilitate a trend analysis.

Other sources of data that should be used to make adjustments to the PM program are the plant's performance-monitoring and predictive-monitoring programs. Results of these programs may provide indications of adverse trends and may help identify components with performance or reliability problems.

To be effective in maintaining plant equipment design conditions with high levels of availability, the PM program shall contain appropriate tasks, be properly executed, and be routinely reviewed and updated. These activities should be integral responsibilities of the appropriate groups and receive commensurate priority and attention. These actions, effectively implemented, may make a significant contribution to safe and reliable plant operation.

ATTACHMENT A
DATA PACKAGE CHECKLIST

System:

Component:

Manufacturer:

Equipment ID:

Design Information

1. Design Basis Descriptions
2. Technical Safety Requirements
3. FSAR1
4. PRA Report
5. IPE
6. Design Drawings
   - P&ID
   - Schematic
   - Logics/Loops
7. Vendor Catalogs/Manual
8. Vendor Drawings
9. System Descriptions
10. EQ Requirements

Operation Information

1. Operating Procedures
2. Operating Logs
3. ISI/IST Requirements
4. Surveillance Requirements
5. Unit Availability Reports
6. Training Lesson Plans

Maintenance Information

1. Maintenance Procedures
2. Vendor Technical Manuals and Bulletins
3. Corrective Maintenance History
4. Preventive Maintenance History/Tasks

Operating Experience

Commitment Tracking Data Base
Lessons Learned
Occurrence Reporting and Processing System (ORPS)

ATTACHMENT B
COMPONENT FUNCTIONS

System: Instrument Air

Component: Instrument Air Dryer

Originator:___________________

Reviewed:_____________________

Approved by:__________________

Function #	**Function**	**Source Document**
1.	Provides water vapor temperature	Operating Procedures
2.	Cools compressed air	Training Manual
3.	Removes liquids from an air system	Training Manual
4.	Removes water and oil aerosols from the air system	Maintenance Procedure
5.	Removes heat from the air between stages of compressors	Maintenance Procedure

APPENDIX E
EXAMPLE VIBRATION MONITORING PROGRAM PROCEDURE

APPENDIX E
EXAMPLE VIBRATION MONITORING PROGRAM PROCEDURE

1.1 Identification of Monitored Equipment

1.1.1 The predictive maintenance coordinator should maintain a listing of plant equipment included in the predictive maintenance vibration monitoring program. This listing (Appendix E, Table 1 of this procedure) should contain the following information on each piece of equipment:

a. component tag number and description

b. priority

c. interval of monitoring

NOTE: For purposes of this good practice. Table 1 illustrates only a small portion of the equipment included in the vibration monitoring program.

1.1.2 Specific points to be monitored on each machine should be designated by the predictive maintenance coordinator. Each point should be marked on the machine in a conspicuous manner (e.g., by using a paint or ink-marking device) to help ensure that data is taken in a consistent manner. Permanently mounted pick-up pads also are an effective method for ensuring consistent data.

1.1.3 Upon request from members of plant management or in support of other maintenance activities, data may be taken on equipment other than that listed in Table 1.

1.2 Scheduling of Vibration Surveys

1.2.1 Equipment should be scheduled for vibration testing at the frequency indicated in Table 1. Readings may be taken more frequently at the discretion of the predictive maintenance coordinator or as requested by plant staff. Vibration baseline readings should be taken after any maintenance affecting the rotating components of the machinery, such as bearing replacements. In addition, vibration data on selected plant equipment may be useful prior to securing the equipment for a planned outage to allow for repairs.

1.2.2 Equipment not in operation at the time of a scheduled test should not be started for the sole purpose of obtaining vibration readings unless justified. Such vibration tests should be rescheduled to a time consistent with normal plant and equipment operations, but within vibration test interval.

1.2.3 Surveys should be scheduled to coincide with in-service testing for equipment that is normally not operated except for testing.

1.3 Data Collection

1.3.1 For each machine and measurement point, data should be taken in a format designated by the predictive maintenance coordinator (i.e., filtered, unfiltered, velocity, displacement, etc.).

1.3.2 Any instrument capable of reading the desired vibration parameters may be used to obtain data. If possible, the same type of test equipment should be used on any given component.

1.3.3 Each set of readings on a particular machine should be made with the machine running under the same operating conditions (load, flow, head, etc.) as previous readings. On major equipment, the operating conditions may be determined by observing local instruments and/or by contacting operations.

1.3.4 Vibration readings should be taken at all measurement points included in each vibration survey route. If readings cannot be taken because of operating or environmental conditions, the readings should be rescheduled. Corrective actions should be taken to enable readings to be taken such as increased radiation shielding, decontaminated areas, use of ice vests, etc.

1.4 Examination and Evaluation of Trend Data

1.4.1 After taking each set of vibration data, the data should be reviewed to identify any excessively high readings or undesirable trends indicating a degradation of equipment condition.

1.4.2 Vibration monitoring/analysis is not an exact science; greater emphasis should be placed on observed trends than on actual vibration levels at any time. The severity of an individual vibration reading should be determined by a subjective evaluation of all observed symptoms and should consider such factors as prior experience with the same or similar equipment, industry standards, regulatory requirements, and vendor recommendations.

1.4.3 As an aid to rapid identification of potential problems, nominal alarm limits for each monitored machine should be established by the predictive maintenance coordinator. Comparable limits should be used for machines that are similar in design or are known to have similar vibration characteristics. Limits should be established by examining historical data for machines of the same type that have a good operating history.

1.4.4 When degraded equipment condition is indicated, the predictive maintenance coordinator should take action to ascertain the validity of the data. The predictive maintenance coordinator should notify the responsible maintenance organization when the suspected deficient condition has been verified.

1.5 Preparation and Distribution of Reports

1.5.1 The predictive maintenance coordinator or designee should notify responsible operations and maintenance personnel when any deficiency is noted that may jeopardize equipment operation.

1.5.2 Written reports should be prepared periodically to furnish necessary information to plant management.

1.5.3 Written reports should ordinarily be limited to "exception" reports describing problems that have been identified and information directly related.

1.6 Corrective Action and Follow-up

1.6.1 Equipment that has been found to have a known or suspected vibration problem should be scheduled for monitoring at more frequent intervals until the problem is resolved.

1.6.2 Following notification of completed corrective action, vibration readings should be taken to establish a new baseline.

1.7 Instrument Calibration

1.7.1 Test equipment used in support of the vibration monitoring program should be incorporated into the measuring and test equipment program in accordance with the plant procedure that governs the control of measuring and test equipment.

1.8 Program Upgrading

1.8.1 The predictive maintenance coordinator should continually seek to refine and improve the vibration monitoring program by the following:

a. being alert and responsive to actual and suspected equipment operating problems as reported by members of plant staff

b. coordinating the collection of vibration data on infrequently operated equipment to coincide with normal plant operation

c. evaluating readings taken to identify methods by which more appropriate or meaningful data may be taken

1.8.2 Upgrading of the program may entail increasing or reducing requirements in terms of machines to be monitored, type and number of measurements per machine, and time interval between readings. In addition, vibration monitoring equipment, including software, should be periodically evaluated and consideration made for upgrading based on changing technology.

1.8.3 Failures of equipment included in the vibration monitoring program should have detailed root cause investigations to determine why the program did not detect degradation before the failures occurred.

1.8.4 As a means of performing preliminary evaluation of equipment being considered for possible inclusion in the program and establishing measurement parameters for equipment to be added, vibration data may be taken on equipment other than that listed in Table 1.

Table 1
EXAMPLES OF EQUIPMENT INCLUDED IN THE VIBRATION MONITORING PROGRAM

Component Tag Number	Component Description	Priority (Ref: 6.4.1)	Nominal Frequency
3CENTSEP	Lube Oil Separator No 3	D	Semiannually
3F1A	Traveling Screen 3A1 Drive	D	Monthly
3K2	Turbine/Generator/Exciter	B	Monthly
3P1	Amertap BS Inducer Pump P1	D	Quarterly
3P1A	Generator Feed Pump 3A	B	Monthly
3P1B	Generator Feed Pump 3B	B	Monthly
3P3	Amertap BS Recirc Pump P3	D	Quarterly
3P3A	Heater Pump 3A	C	Monthly
3P38	Heater Pump 3B	C	Monthly
3P6A	Condensate Pump 3A	C	Monthly
3P6B	Condensate Pump 3B	C	Monthly
3P6C	Condensate Pump 3C	C	Monthly
3P7A	Circulating Water Pump 3A1	C	Monthly
3P7B	Circulating Water Pump 3A2	C	Monthly
3P9A	Intake Cooling Water Pump 3A	A	Monthly
3P9B	Intake Cooling Water Pump 3B	A	Monthly
3P200A	Coolant Pump 3A	A	Monthly
3P200B	Coolant Pump 3B	A	Monthly
3P201A	Charging Pump 3A	A	Monthly
3P201B	Charging Pump 38	A	Monthly
4V19A	Isophase Bus/Fan Motor 4A	D	Semiannually
4V19B	Isophase Bus/Fan Motor 4B	D	Semiannually
P10A	Diesel Fuel Transfer Pump A	A	Quarterly
P10B	Diesel Fuel Transfer Pump B	A	Quarterly
P39	Fire Pump - Motor Driven	A	Semiannually
4P15	Turbine Lube Oil Filter Pump	D	Quarterly
4P16A	Primary Water Makeup Pp 4A	D	Quarterly
4P16B	Primary Water Makeup Pp 4B	D	Quarterly
4P31	Turning Gear Oil Pump No 4	D	Annually
4P32	Auxiliary Oil Pump No 4	D	Annually
4P36	Air Side Seal Oil Pump	D	Quarterly
4P37	Hydrogen Side Seal Oil Pump	D	Quarterly
4P40	Bearing Oil Life Pump - Unit 4	D	Annually
4P49	Gland Steam Cond Drain Pump	D	Quarterly
4P86A	Demineralizer Hold Pump 4A	D	Quarterly
4P86B	Demineralizer Hold Pump 4B	D	Quarterly

APPENDIX F
EXAMPLE LUBRICATION OIL ANALYSIS PROCEDURE

APPENDIX F
EXAMPLE LUBRICATION OIL ANALYSIS PROCEDURE

1.1 Identification of Included Equipment

1.1.1 The predictive maintenance coordinator should maintain a listing of equipment included in the oil analysis program. Samples may be taken from equipment not included in Appendix F, Table 1, as requested by plant staff.

NOTE: For purposes of this good practice, Table 1 illustrates only a small portion of the equipment included in the lubrication oil analysis program.

1.2 Scheduling of Sampling

1.2.1 Oil samples should be scheduled per the intervals indicated in Table 1.

1.2.2 Scheduled sampling dates and/or intervals may be adjusted according to recommendations from the analysis laboratory or plant management.

1.2.3 Samples may be taken more frequently at the discretion of the predictive maintenance coordinator or as requested by plant staff. For example, oil samples on selected plant equipment may be useful prior to securing the equipment for a planned outage to allow for repairs.

1.3 Sample Collection

1.3.1 Collection of oil samples may be initiated by maintenance job request or procedure.

1.3.2 Oil samples should be representative. Whenever possible, samples should be drawn when the oil is still hot and well mixed.

1.3.3 Samples should normally be collected by withdrawing oil directly from oil sumps/reservoirs with suction tubes into clean, new sample bottles.

1.3.4 After collection, oil samples that are not radioactively contaminated should be delivered to the predictive maintenance coordinator for processing.

1.4 Sample Processing

1.4.1 The predictive maintenance coordinator or designee should ensure that any information forms or other documents required by the laboratory are completed and the samples are packaged for shipment to the laboratory.

1.4.2 Personnel preparing information forms should use clear, consistent terminology so that the analysis laboratory may relate their reports to the correct reservoirs.

1.4.3 The means of shipment of samples to the oil analysis laboratory should be selected on the basis of urgency of need.

1.5 Handling of Sample Analysis Reports

1.5.1 Following analysis of samples by the laboratory, analysis reports for each sample should normally be forwarded from the laboratory to the predictive maintenance coordinator or designee.

1.5.2 Preliminary reports may be made by telephone from the laboratory when tests indicate a deficient condition exists or if "rush" handling is requested for specific samples.

1.5.3 The predictive maintenance coordinator or designee should review the data from each report, with any recommendations from the laboratory, comparing the current data to previous report data. If a need for corrective action is indicated by the information available, the predictive maintenance coordinator or designee should initiate or request that action be taken by appropriate plant groups.

1.5.4 An example lubrication analysis report form is provided in Appendix, F, Figure 1.

1.5.5 Typical sources of metallic elements in lubricating oils are provided in Appendix F, Table 2.

1.6 Preparation of Reports

1.6.1 The predictive maintenance coordinator or other persons cognizant of the lubricating oil sampling program should notify responsible plant management when a deficiency is noted that may jeopardize plant equipment and/or operations.

1.6.2 The predictive maintenance coordinator should prepare written periodic report(s) or furnish needed information to plant management to describe any identified problems, unsatisfactory trends, trends following corrective action, or to recommend oil change frequencies based on analysis results and trends.

1.7 Corrective Action Follow-up

1.7.1 Equipment that has been found to have a known or suspected lubricant problem may be sampled at more frequent intervals as recommended by the laboratory or as requested by the predictive maintenance coordinator until the suspected problem has been resolved or corrective action has been taken.

1.7.2 Following any corrective action, a follow-up sample should be taken promptly to reestablish the "baseline" for the equipment in question and to ensure that the action taken was adequate.

1.8 Program Upgrading

1.8.1 The predictive maintenance coordinator should continually seek to refine and improve the lubricating oil analysis program by the following:

a. maintaining an awareness of actual and suspected equipment operating problems

b. evaluating the potential for oil sampling and analysis methods to aid in detecting and identifying equipment problems

c. revising the program as appropriate to take advantage of improved sampling and analysis techniques as they become available

1.8.2 Upgrading of the program may entail increasing or reducing the requirements in terms of equipment included in the program and time interval between examples.

1.8.3 Failures of equipment included in the lubricating oil analysis program should have detailed root cause investigations to determine why the programs did not detect degradation before the failures occurred.

TABLE- I
EXAMPLES OF EQUIPMENT INCLUDED IN THE LUBRICATING OIL SAMPLE ANALYSIS PROGRAM

Component Tag Number	Component/Reservoir Description	Priority (Ref: 6.4.1)	Nominal Frequency
K4A Diesel	Emergency Diesel Generator A - Engine Crankcase	A	Monthly
K4A/GOV	Emergency Diesel Generator A Governor	A	Quarterly
K4B Diesel	Emergency Diesel Generator B Engine Crankcase	A	Monthly
K4B/GOV	Emergency Diesel Generator B Governor	A	Quarterly
P2A	Aux Feed Pump/Turbine A	A	Quarterly
K3A	Aux Feed Pump/Turbine A Governor	A	Quarterly
P2B	Aux Feed Pump/Turbine B	A	Quarterly
K3B	Aux Feed Pump/Turbine B Governor	A	Quarterly
P82A	Standby Steam Gen Feed Pump A - Motor Inbd	D	Semiannually
P82A	Standby Steam Gen Feed Pump A - Motor Outbd	D	Semiannually
3P3B	Heater Drain Pump 3B - Motor Lower Bearing	C	Quarterly
3P3B	Heater Drain Pump 3B - Motor Upper Bearing	C	Quarterly
3P6A	Condensate Pump 3A - Motor Lower Bearing	C	Quarterly
3P6A	Condensate Pump 3A - Motor Upper Bearing	C	Quarterly
3P6B	Condensate Pump 3B - Motor Lower Bearing	C	Quarterly
3P6B	Condensate Pump 3B - Motor Upper Bearing	C	Quarterly
3P7A	Circulating Water Pump 3A1 - Motor Lower Bearing	C	Quarterly
3P7A	Circulating Water Pump 3A1 - Motor Upper Bearing	C	Quarterly
4P11B	Turbine Plant Cooling Water Pump 4B - Pump Inbd	C	Quarterly

TABLE- I (continued)
EXAMPLES OF EQUIPMENT INCLUDED IN THE LUBRICATING OIL SAMPLE ANALYSIS PROGRAM

Component Tag Number	Component/Reservoir Description	Priority (Ref: 6.4.1)	Nominal Frequency
4P200A	Reactor Coolant Pump A Motor Lower Bearing	A	18 Months
4P200A	Reactor Coolant Pump A Motor Upper Bearing	A	18 Months
4P200B	Reactor Coolant Pump B Motor Lower Bearing	A	18 Months
4P200B	Reactor Coolant Pump B Motor Upper Bearing	A	18 Months
4P201A	Charging Pump 4A - Crankcase or Gearcase Inboard End	A	Quarterly
4P201A	Charging Pump 4A - Fluid Drive	A	Quarterly
4P201B	Charging Pump 4B - Crankcase or Gearcase Inboard End	A	Quarterly
3P214A	Containment Spray Pump 3A	A	Semiannually
3P214B	Containment Spray Pump 3B	A	Semiannually

FIGURE 1
EXAMPLE LUBRICATION ANALYSIS DATA FORM

Component Tag Number: ___________________________________

Oil Type: ___________________________________

Reservoir: ___________________________________

Sample Number: ___________________________________

Sample Date/Time: ___________________________________

PHYSICAL DATA

Water Volume _____________

Solids Volume _____________

Fuel Dilution (% Volume) _____________

Fuel Soot (ABS) _____________

Glycol (Coolant) _____________

Total Acid Number _____________

Total Base Number _____________

Viscosity _____________

SPECTROCHEMICAL ANALYSIS IN PARTS PER MILLION BY WEIGHT

Silicon: ___________	Iron: ____________	Chromium: ____________
Aluminum: ____________	Copper: ____________	Lead: ____________
Tin ___________	Nickel: _____________	Silver: _____________
Molybdenum: ______________	Magnesium: ____________	Sodium: ____________
Boron: _____________	Barium: _____________	Calcium: ____________
Phosphorus: _____________	Zinc: _____________	

COMMENTS:

TABLE 2
TYPICAL SOURCES OF METALLIC IN LUBRICATING OILS

Element		Typical Source
Aluminum	(Al)	Pistons, bearings, dirt, additives
Barium	(Ba)	Additives, water, grease
Boron	(B)	Coolant, additives, sea water
Calcium	(Ca)	Additives, water, greases
Chromium	(Cr)	Cylinders, rings, crankshafts, gears, coolant
Copper	(Cu)	Bearings, coolers, bushings
Iron	(Fe)	Cylinders, crankshafts, water, rust
Lead	(Pb)	Bearings, greases, gasoline, paint
Magnesium	(Mg)	Bearings, additives, sea water
Manganese	(Mn)	Valves, fuel, steel shafts
Molybdenum	(Ro)	Additives, rings
Nickel	(Ni)	Shafts, gears, rings, turbine components
Phosphorus	(P)	Additives, coolants, gears
Silicon	(Si)	Defoamants, dirt
Silver	(Ag)	Bearings, solder
Sodium	(Na)	Coolant, additives, sea water
Tin	(Sn)	Bearings, solder, coolers
Zinc	(Zn)	Additives, bearings, platings

APPENDIX G
EXAMPLE THERMOGRAPHY PROGRAM PROCEDURE

APPENDIX G
EXAMPLE THERMOGRAPHY PROGRAM PROCEDURE

1.1 Identification of Monitored Equipment

1.1.1 The predictive maintenance coordinator should maintain a listing of plant equipment included in the infrared thermography program. This listing (Appendix G, Table 1) should contain the following information on each piece of equipment:

a. component tag number and description

b. priority

c. interval of monitoring

NOTE: For purposes of this good practice, Table 1 illustrates only a small portion of the equipment included in the thermography program.

1.1.2 Specific points to be monitored on each piece of equipment should be clearly identified in route descriptions, etc. Route descriptions may include the use of simple diagrams or sketches as a field aid to help ensure that data is taken in a consistent manner. These diagrams or sketches also may be used for note-taking to aid in the development of written reports concerning specific surveys.

1.1.3 Upon request from members of plant management or in support of other maintenance activity, data may be taken on equipment other than that listed in Table 1.

1.2 Scheduling of Thermal Surveys

1.2.1 Equipment should be scheduled for thermographic monitoring at the interval indicated on Table 1. Data may be taken more frequently at the discretion of the predictive maintenance coordinator or as requested by plant staff. For example, thermal surveys on selected plant equipment may be useful prior to securing the equipment for a planned outage to allow for repairs and postmaintenance activity.

1.2.2 Equipment not in operation at the time of scheduled monitoring should not be started for the sole purpose of obtaining thermographic data unless justified. Such monitoring should be rescheduled to a time consistent with normal plant operations and within the nominal thermographic monitoring frequency, if possible.

1.2.3 Thermographic monitoring should be scheduled to coincide with in-service testing or other plant tests for equipment that is normally not operated except for testing, if applicable.

1.3 Data Collection

1.3.1 For each piece of equipment and measurement point, data should be taken in a format (i.e., temperature scale, range, emissivity setting, etc.) designated by the predictive maintenance coordinator or designee.

1.3.2 Any instrument capable of reading the desired data may be used to obtain the data needed. All such instruments should be incorporated into the measuring and test equipment program to establish and maintain calibration certification. If possible, the same type of test equipment should be used on any given component.

1.3.3 Each set of data taken for trending purposes on a particular piece of equipment should be made with the equipment operating under the same conditions (load, flow, head, etc.) as previous readings. On major equipment, the operating conditions may be determined by observing local instruments and/or by contacting operations.

1.3.4 Thermographic data should be taken at all measurement points included in each thermal survey route. If readings cannot be taken because of operating or environmental conditions, the readings should be rescheduled.

1.4 Examination and Evaluation of Trend Data

1.4.1 Thermographic data should be reviewed to identify any excessive, high readings or undesirable trends indicating a degradation of equipment condition.

1.4.2 Infrared thermal monitoring/analysis is not an exact science. Emphasis should be placed on observed trends as well as actual temperature differentials indicated at any time. The severity of an individual temperature indication should be determined by a subjective evaluation of all observed symptoms and prior experience should be considered with the same or similar equipment.

1.4.3 When a degraded equipment condition is indicated, the predictive maintenance coordinator or designee should take action to ascertain the validity of the data and should notify the responsible maintenance organization when the suspected deficient condition has been verified.

1.5 Preparation and Distribution of Reports

1.5.1 The predictive maintenance coordinator or designee should notify responsible operations and maintenance personnel when any deficiency is noted that may jeopardize plant operation.

1.5.2 Written. reports should be prepared periodically to furnish necessary information to plant management.

1.5.3 Written reports should ordinarily be limited to "exception" reports describing problems that have been identified and information directly related.

1.6 Corrective Action and Follow-up

1.6.1 Equipment that has been found to have a known or suspected temperature anomaly should be scheduled for monitoring at more frequent intervals until the problem is resolved.

1.6.2 Following notification of corrective action, additional thermographic data should be taken to establish a new baseline.

1.7 Instrument Calibration

1.7.1 Equipment used to gather actual thermal data for the infrared thermography program should be incorporated into the measuring and test equipment program in accordance with plant procedures that govern the control of measuring and test equipment.

1.8 Program Upgrading

1.8.1 The predictive maintenance coordinator should continually seek to refine and improve the infrared thermography program by the following:

a. being alert and responsive to actual and suspected equipment operating problems as reported by members of plant staff

b. coordinating the taking of thermographic data on infrequently operated equipment to coincide with normal plant operation, as far as possible.

c. evaluating readings taken to identify methods by which mere appropriate or meaningful data may be taken

1.8.2 Upgrading of the program may entail increasing or reducing the requirements in terms of machines to be monitored, type and number of measurements per machine, and time interval between readings. In addition, thermography equipment should be periodically evaluated and consideration made for upgrading based on changing technology.

1.8.3 Failures of equipment included in the infrared thermography program should have detailed root cause investigations to determine why the programs did not detect degradation before the failures occurred.

1.8.4 As a means of performing preliminary evaluation of equipment being considered for possible inclusion in the program and establishing measurement parameters for equipment to be added, thermographic data may be taken on equipment other than that listed in Table 1.

TABLE 1
EXAMPLES OF EQUIPMENT INCLUDED IN THE INFRARED THERMOGRAPHY PROGRAM

Component Tag Number	Component Description	Priority (Ref. 6.4.1)	Nominal Frequency
3F1A	Traveling Screen 3A1 Drive	D	Quarterly
3F1C	Traveling Screen 3B1 Drive	D	Quarterly
3K2	Turbine/Generator/Exciter	B	Quarterly
3P6A	Condensate Pump 3A	C	Quarterly
3P6B	Condensate Pump 3B	C	Quarterly
3P6C	Condensate Pump 3C	C	Quarterly
3P7A	Circulating Water Pump 3A1	C	Quarterly
3P7C	Circulating Water Pump 3B1	C	Quarterly
3P37	Hydrogen Side Seal Oil Pump	D	Semiannually
3P40	Bearing Oil Life Pump - Unit 3	D	Annually
3P201A	Charging Pump 3A	A	Quarterly
3P201B	Charging Pump 3B	A	Quarterly
3P203A	Boric Acid Transfer Pump 3A	A	Quarterly
3P203B	Boric Acid Transfer Pump 3B	A	Quarterly
3P211A	Component Cooling Pump 3A	A	Quarterly
3P211B	Component Cooling Pump 3B	A	Quarterly
3V31A	Main Steam Penetration Cooling Fan/Motor 3A	D	Semiannually
3V31B	Main Steam Penetration Cooling Fan/Motor 3B	D	Semiannually
3X01	Main Transformer	B	Quarterly
3X02	Station Auxiliary Transformer	B	Quarterly
3X03	Start-up Transformer	A	Quarterly
3D02	Battery Charger 3A	A	Semiannually
3025	Battery Charger 3B	A	Semiannually
3Y01	Static Inverter 3A	A	Semiannually
3Y02	Static Inverter 3B	A	Semiannually

APPENDIX H
EXAMPLE USES OF PREDICTIVE MAINTENANCE TECHNIQUES

APPENDIX H
EXAMPLE USES OF PREDICTIVE MAINTENANCE TECHNIQUES

Equipment		Predictive Maintenance
1.	Generators	Radio-frequency monitoring Infrared thermography
2.	Turbines	Vibration monitoring Lubricating oil analysis and ferrography Bearing temperatures In-leakage detection
3.	Pumps	Vibration monitoring Acoustic emission Lubricating oil analysis and ferrography Bearing temperatures In-leakage detection Infrared thermography
4.	Electric motors	Vibration monitoring Infrared thermography Lubricating oil analysis and ferrography Bearing temperatures Insulation resistance
5.	Diesel generators	Vibration monitoring Lubricating oil analysis and ferrography Bearing temperatures Insulation resistance
6.	Condensers	In-leakage detection Acoustic monitoring Infrared thermography
7.	Circuit breakers	Infrared thermography
8.	Valves	Infrared thermography Acoustic emission In-leakage detection

APPENDIX H (Cont.)
EXAMPLE USES OF PREDICTIVE MAINTENANCE TECHNIQUES

Equipment	Predictive Maintenance
9. Heat exchangers	Acoustic emission Eddy current In-leakage detection Infrared thermography
10. Electrical equipment	Infrared thermography Insulation resistance Polarization index Electric circuit monitoring

APPENDIX I
EVALUATION OF PROPOSED METHODS/TECHNIQUES FOR INCORPORATION INTO PREDICTIVE MAINTENANCE PROGRAM

Appendix I
EVALUATION OF PROPOSED METHODS/TECHNIQUES FOR INCORPORATION INTO-PREDICTIVE MAINTENANCE PROGRAM

1. Provide a brief general description of the proposed technique. Include acceptance criteria, alarm points, frequency, and any other appropriate information.

2. What systems or equipment types would be monitored by the proposed method?

3. Has the proposed method been used at the plant before? If so, describe the application where used.

4. List any additional special test equipment required (not already available). Include estimate of cost if possible.

5. What special skills or training, if any, is required to implement the proposed method?

6. What other plants are known to be using or have used the proposed. method?

7. What other test or inspection methods, if any, may be used to monitor the same parameters?

8. What information would be provided by this technique that is not provided by test or inspection methods already in effect?

9. What past equipment failures may have been prevented if the proposed technique had been in effect (be as specific as possible)?

10. Provide any additional information that may be helpful in evaluating the benefits to be derived from implementing the proposed method or possible consequences of not implementing it:

Prepared by: ____________________ _________ Approved

_________ Disapproved for Implementation

Recommended: __________ Yes

__________ No

______________________________ ____________________

Predictive Maintenance Coordinator Maintenance Manager

APPENDIX J
TYPES OF MAINTENANCE
SAMPLE LESSON PLAN

TYPES OF MAINTENANCE
SAMPLE LESSON PLAN

LESSON PLAN

1. The instructor should be familiar with the following background information:

   a. A maintenance program includes two basic types of maintenance: corrective and preventive maintenance.

   b. A proper balance of both types of maintenances may provide a high degree of confidence that specific facility and process equipment degradation is identified and corrected, that equipment life is optimized, and that the maintenance program is cost effective.

   c. This balance may include, on one extreme, no preventive maintenance for some equipment that is allowed to run until it fails, since its failure would not adversely impact operations. On the other extreme, extensive preventive maintenance may be required for some equipment where failure may limit safe or reliable system operations.

   d. Each preventive maintenance action should be scheduled at appropriate intervals and combined with corrective maintenance activities on the same equipment. This would reduce the number of times equipment has to be removed from and returned to service.

2. To teach this lesson, the following training housekeeping items are required:

   a. Location for the training,

   b. Approximately 30 minute time period for the training,

   c. Notification of selected employees, and

   d. A copy of the site's corrective and preventive maintenance job request form(s).

3. This lesson has the following trainee enabling objective:

   Explain the uses of and differentiate between corrective and preventive maintenance.

4. Define and explain the following differences between corrective and preventive maintenance.

   a. <u>CORRECTIVE MAINTENANCE</u>

   - The repair or restoration of equipment that has a failure or is malfunctioning and not performing its intended function.

   - Corrective maintenance should normally be performed only on equipment previously selected to run until failure.

   - As a result of an effective maintenance program, only a small fraction of corrective maintenance should be needed on equipment that is important to safe and reliable system operations.

   - Some examples of corrective maintenance include:

     - replacement of a failed electrical breaker

     - weld repair of a cracked process line, and

     - repair of a failed instrument transmitter.

   b. <u>PREVENTIVE MAINTENANCE</u>

   - Periodic preventive maintenance is defined as actions taken on a fixed time interval.

     - Examples of periodic maintenance include: daily filter changes, weekly lubrications, or monthly calibrations.

   - Predictive maintenance results from trending and monitoring equipment performance parameters (i.e., vibration, oil, and infrared analysis on operating equipment) and initiating specific planned maintenance prior to equipment failure.

     - An example of predictive maintenance would be a pump bearing replacement, after wear-out was indicated as a result of an oil analysis.

5. Discuss with the trainees the corrective and preventive maintenance forms. Emphasize a clear understanding of each.

CONCLUDING MATERIAL

Review Activities:		**Preparing Activity:**
DOE	Field Offices	DOE-NE-73
AD	AL	
DP	CH	**Project Number:**
EH	ID	
EM	NV	MNTY-0003
ER	OR	
NP	RL	
NS	SR	
RW	SF	

Area Offices
Amarillo
Brookhaven
Kansas City
Kirtland
Princeton

Facilities
ANL
BNL
LBL
PNL
PPPL
SNL
NV REECo.
NV EG&G
OR OSTI
WHC
EG&G
RF
SLAC
WSRC