Drinking Water Operator Certification Training

Module 10: General Maintenance

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

Topical Outline

Unit 1 – Introduction to Maintenance

I. Overview
   A. Definition of Maintenance
   B. The Role of Maintenance in the Overall Operation

II. Goals of a Maintenance Program
   A. Safety and Environmental Protection
   B. Fixed Asset Preservation
   C. Maintenance of Design Intent
   D. Efficiency of Operation
   E. System Reliability

Unit 2 – Structure of a Maintenance Program

I. General Guidelines
   A. Organizational Structure
   B. Computerized Maintenance Management Systems (CMMS)
   C. Contract Work
   D. Preventive Maintenance as the Key Effort

II. Components of a Maintenance Program
   A. Scheduled Preventive Maintenance Tasks
   B. Unplanned Daily Activities
   C. Planned Project Work
   D. Record Keeping
   E. Inventory Management
   F. Purchasing

Unit 1 – Introduction to Maintenance

Learning Objectives

- Define the maintenance function.
- Describe the role of maintenance in the overall operation.
- List and describe the five goals of a maintenance program.

Definition of Maintenance

Maintenance is a support function providing a cohesive process that assists Operations and other departments in fulfilling the mission of the facility. This is achieved by ensuring that all equipment and systems are operated at an expected level of reliability within a specified budget and within the life cycle of the equipment.

.

The Role of Maintenance in the Overall Operation

As soon as a facility is built, its buildings and systems start a predictable decline in condition and efficacy. Some elements—such as a roof or building envelope—may have a life cycle of 25 to 30 years before major work is required. Other items—such as pumps and compressors—will need regular service almost immediately after start-up.

The role of maintenance is to identify and remedy potential problems before they impact plant operation. This requires establishment of a set of operating parameters. The design specifications for the equipment help to identify the maintenance parameters. By using a proactive approach (maintaining equipment so that it does not break down as often), we can ensure a level of service that ensures maximum operating efficiency.

What are some factors that impact the availability of equipment? (What causes “downtime”?)

How do your ideas fit into the four categories your instructor has shown?

What are some factors that help to ensure high availability of equipment (minimal “downtime”)?

How do your ideas fit into the three categories your instructor has shown?

As we mentioned in the previous section, a proactive approach to maintenance can prolong the usefulness of a facility. In this section, we will examine the five general goals of a maintenance program: safety and environmental protection; fixed asset management; maintenance of design intent; efficiency of operations; and system reliability.

Safety and Environmental Protection

IMPORTANT: ALL REQUIRED SAFETY PROCEDURES MUST BE FOLLOWED AT A WATER SYSTEM. MANY ACCIDENTS OCCUR AT TREATMENT PLANTS EACH YEAR THAT COULD BE AVOIDED BY FOLLOWING SIMPLE SAFETY PROCEDURES.

Water treatment plants have a direct impact on public health. Plant operators constantly monitor process parameters to ensure the quality of the water.

It is the responsibility of the maintenance group to ensure that sensors, meters, and recorders function so that they can provide accurate data to the operators. This information is used to adjust plant processes to ensure the public receives a quality product.

It is equally important that valves and metering equipment function properly in response to plant operator requests.

Good practice also extends to the actual service and maintenance of the equipment. Injuries to plant personnel result when people work without thinking through the tasks or they accept risks that are not necessary. Common ways to minimize hazards include:

- using lockout-tagout procedures when isolating valves and equipment.
- always replacing guards over moving parts after service.
- following confined space procedures.
- performing good housekeeping procedures.

Poorly maintained equipment can lead to:

- poor water quality that is dangerous to public health.
- hazardous discharges of chemicals to the environment.
- safety hazards to plant personnel.

Figure 1.1 Safety Hazard

Safety for plant personnel, consumers, and the environment is a result of (1) performing the proper level of maintenance, and (2) performing that maintenance correctly.

Fixed Asset Management

Designers estimate the useful life of the equipment and systems. This information is used for master planning and budgeting. Treatment plants are constructed with funds that have been secured through the sale of bonds or from bank loans. Accountants plan a predictable depreciation of plant value over time.

Government and banking institutions desire that their investment is properly maintained over the life of the facility.

Maintenance of Design Intent

A facility is designed for specific functions. For example, a certain facility may be required to deliver 60,000,000 gallons of water per day (60MGD), treated at specified quality standards, and leaving the plant within a defined pressure range. The equipment is chosen and arranged to effectively meet that requirement. This is part of the engineer's design intent.

Maintenance is performed, in part, to ensure that the design intent is maintained throughout the life of the facility.

Efficiency of Operation

The plant is designed to ensure that the water is processed with a reasonable power usage. Proper service of the equipment helps to ensure that equipment continues to function at its most efficient level.

For operating and environmental responsibility standards, minimum energy consumption is desired.

Efficiency standards can be applied to labor use, as well. Labor is a significant part of plant expenses. By correctly assigning and using labor for routine maintenance functions, adequate personnel are available for other applications throughout the plant.

Another goal of the maintenance function is to use the available labor force effectively.

System Reliability

The water treatment operator consistently delivers a product within the customer's specified parameters. Federal, state, and local regulatory agencies also establish and enforce performance levels for plant operation. There is no room for fluctuation in the quality and quantity of water from a municipal plant.

Good maintenance practices will greatly increase the reliability of the water treatment system.

Key points for Unit 1 – Introduction to Maintenance

- Maintenance is a support function providing a cohesive process that assists Operations and other departments in fulfilling the mission of the facility.
- Injuries to plant personnel may result when people work without thinking through the tasks or they accept risks that are not necessary.
- Safety for plant personnel, consumers, and the environment is a result of (1) performing the proper level of maintenance, and (2) performing that maintenance correctly.
- Government and banking institutions desire that their investment is properly maintained over the life of the facility.
- Maintenance is performed, in part, to ensure that the design intent is maintained throughout the life of the facility.
- For operating and environmental responsibility standards, minimum energy consumption is desired.
- Another goal of the maintenance function is to use the available labor force effectively.
- Good maintenance practices will greatly increase the reliability of the water treatment system.

UNIT 1 Exercise

1. List the five goals of a drinking water plant's maintenance program.

2. Explain why the banker or municipal residents are concerned about plant maintenance.

3. List three items that require daily maintenance. List two that require periodic screening and rare maintenance.

4. How does regular maintenance impact the availability of personnel?

5. Give three examples of the ways in which plant maintenance directly impacts the quality of drinking water produced at the plant.

6. What could happen if a pump were allowed to operate with excessively worn wear rings?

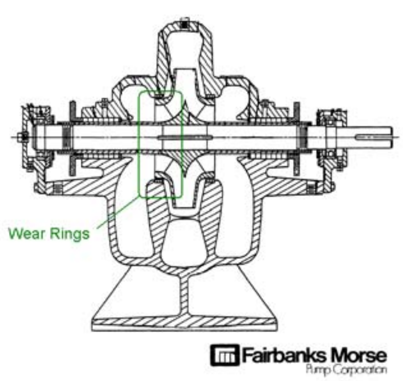


Figure 1.2 Wear Rings

(This page was intentionally left blank.)

Unit 2 – Structure of a Maintenance Program

Learning Objectives

- Define SOPs and explain their primary purpose.
- Name two criteria used to determine whether or not work should be contracted to outside vendors.
- Specify and briefly describe the six major components of a maintenance program.
- List four preventive maintenance tasks.
- State three reasons that record keeping is important.

Organizational Structure

The complexity of a maintenance group depends upon factors such as water system size, average age of the system, amount of work that is contracted to outside sources, and the degree of in-house engineering support. However, the basic premise of organizational structure is the same in any plant. Organizational charts, Standard Operating Procedures, and maintenance manuals all help the structure of the plant to run smoothly.

An Organizational Chart guides employees through the hierarchy of the organization. All workers need to know what they are supposed to do in order to fulfill job requirements, and they need to know who their supervisor is. Therefore, the organizational structure of any plant must have:

- Clearly defined roles and responsibilities.
- Clearly defined reporting structure.

You should be familiar with your facility's organizational chart and its structure.

A large organization will have a central engineering and maintenance group that supports both treatment and distribution functions. A smaller operation may rely on support from other plant departments or other municipal departments. Some maintenance functions can be assigned to the operators at any plant.

What maintenance tasks might a plant operator in a small facility complete?

What maintenance tasks might a plant operator in a large facility complete?

Why does it make sense to involve operators in the maintenance plan of any facility?

Standard Operating Procedures, or SOPs, are guidelines developed by management to ensure that the facility's practices conform to internal and external requirements. They establish uniformity and provide information on issues of safety and operation.

SOPs help a facility to comply with mandated standards. For example, the United States Department of Environmental Protection (US DEP), through its Safe Drinking Water Act (SDWA) sets limits for certain contaminants in drinking water. How might a facility's SOPs ensure compliance with these requirements?

Finally, the organizational structure is supported by ready access to operations and maintenance manuals. The service information that these documents supply allows repairs and adjustments to be made in a scheduled way that helps management to prudently allocate financial, equipment, and labor resources. A set of manuals for all equipment should be kept at the plant.

Computerized Maintenance Management Systems (CMMS)

What is CMMS?

Early tracking and reporting functions were accomplished with pen and paper. Most preventive maintenance was handled by referring to scheduling charts or index cards. This method was effective, of course, but was time-consuming and prone to being disorganized. Paperwork could get lost. Also, it was difficult to link the maintenance function to other activities, such as inventory or purchasing.

Large organizations switched to mainframe computers in the 1960s and 1970s. At once, the work orders and maintenance databases were computerized. The cost of those computer systems, in dollars and space and human resources, was prohibitive for most municipalities. Today, affordable and easy-to-use desktop computers have paved the way for a variety of user-friendly but powerful programs tailored to municipal operations. These are known as **CMMS, or Computerized Maintenance Management Systems.**

Assessing the Needs of the Organization with CMMS

The key to ensuring that a facility meets the goals of operation that we outlined in Unit 1 of this manual is to develop and execute an effective maintenance program. First, we must assess the needs of the organization and then we must put in place a cohesive, manageable program. Computers can help with this task. Below are some benefits one might expect from a CMMS:

- Allows creation of a database of facility information.
- Tracks regular and preventive maintenance work orders.
- Brings order to the execution of maintenance work.
    - Tracks work in progress.
    - Creates reports of backlogged work.
    - Automatically generates preventive maintenance work orders.
        - Generated by date (for example, every three months).
        - Generated by amount of activity.
        - Generated by manufacturer’s specifications or standards of the facility.

Many commercial software programs are available. The best one for a specific plant should be determined by a group of operators, maintenance personnel, and supervisors. Consider these ideas when choosing a program:

- Ease of installation.
- Ease of use.
- Installation and set-up costs.
- Package price.
- Labor needed for data collection.
- Cost of converting existing databases into the new program.
- Additional hardware requirements, such as handheld scanners.

Below is a “screen shot,” or image of a computer screen, that shows what information might be entered into a CMMS. You can see how much data might be collected and managed by using a program like this.

Notice the ease with which information can be added, revised, or deleted; just click a button.

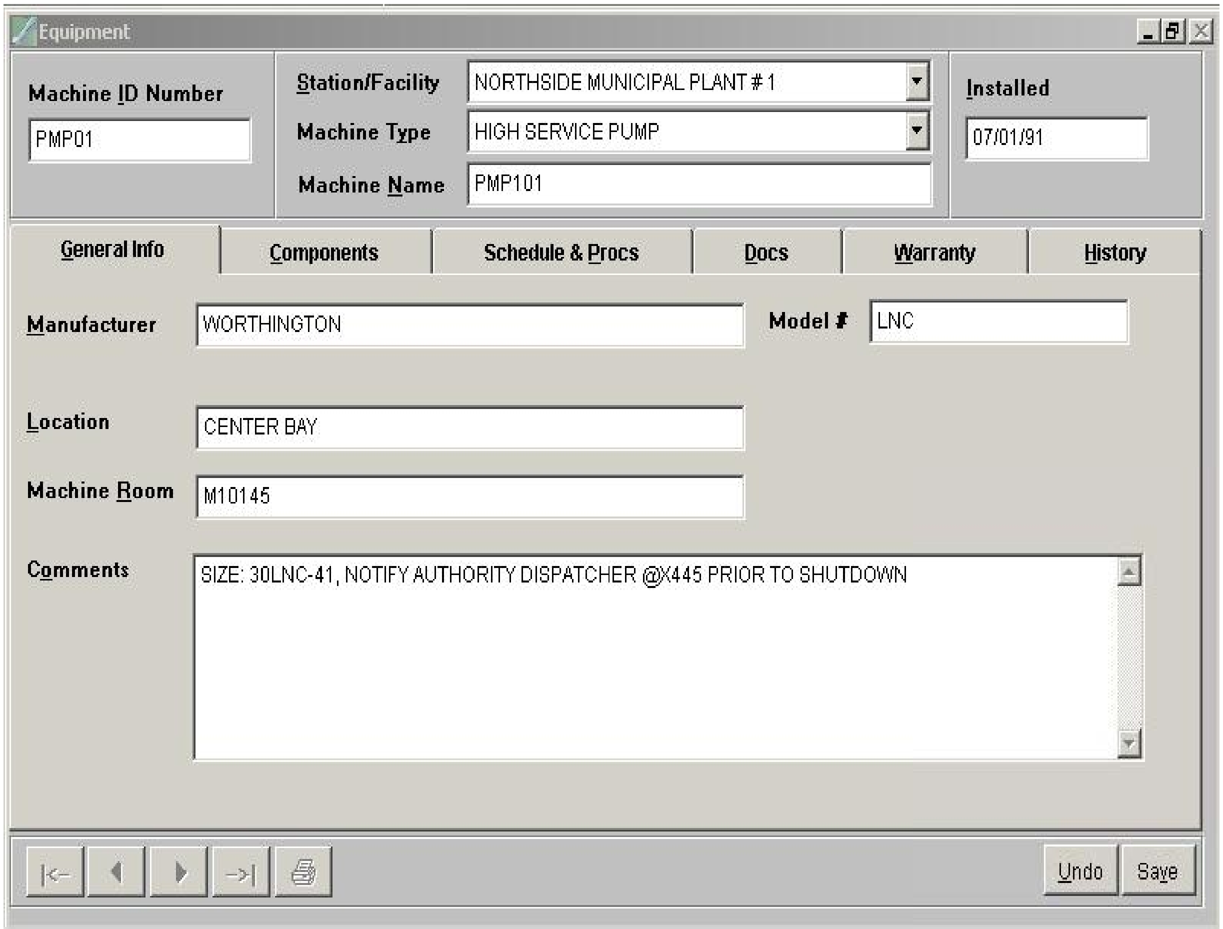


Figure 2.1 CMMS Data Sheet
(Courtesy of Ira J. Spier, President of Spier Consulting, Inc.
75 South Broadway, 4th floor, White Plains, NY 10601)

Implementation of a Maintenance Program with CMMS

- Data gathering is critical.
- Accurate fieldwork ensures a meaningful database.
- Data review must be completed when replacing an existing system.

Contract Work

All plants rely, to some extent, on work carried out by outside personnel. There are three main reasons for contracting work: maintaining a balanced work load at the plant; the size of the facility; and the specialization of the work.

Balanced Work Load

- Maintenance staffs are typically sized for the average work load.
- Unexpected work loads usually are resolved through overtime of regular staff and adding some contracted workers.
  - Emergencies can overwhelm normal staff.
  - Large overhaul jobs require additional staff.
  - Construction projects require additional resources.

Organization's Size

- Staffs at smaller sites generally have broad experience in general maintenance.
- As system size increases, more work is handled internally.

Specialized Work

- Special situations may not warrant extensive training of staff and the purchase of special tools and equipment.
  - Emergency generator service.
  - High voltage electrical work.
  - Instrumentation repair and calibration.
  - Specialized safety issues.

Preventive Maintenance as the Key Effort

The heart of any maintenance operation is the preventive maintenance (PM) effort. PM involves regularly checking and servicing equipment so that it is in peak operating condition. Preventive maintenance allows the maintenance department to catch any potential problems before they impact the functioning of the equipment.

Preventive maintenance (PM) is sometimes referred to as "predictive" maintenance. This terminology reinforces the idea that PM is planned and scheduled. We can "predict" when it will be done, what will be done, and how much it will cost in terms of dollars, time, equipment, and personnel. Advanced maintenance techniques, such as vibration analysis, lubrication analysis, and IR scans, may provide clues to help determine when maintenance is required.

What are some examples of PM that are performed at the facility in which you work? How often are the tasks performed?

What consequences could you imagine if the PM work was neglected for a long time?

Look at the graphic below and determine how EPM (electrical preventive maintenance) recommendations are related to costs. Does more maintenance automatically equal less cost? When does the cost of maintenance lower the cost of other problems?

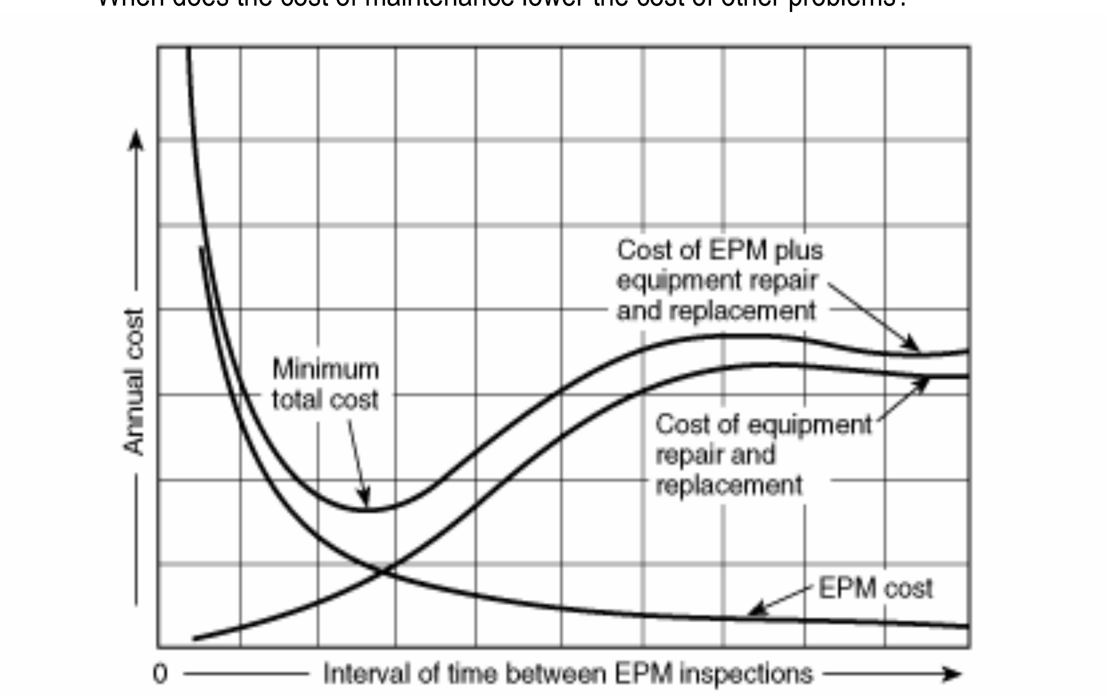


Figure 2.2 EPM Costs

A maintenance program is comprised of many activities. In essence, these activities can be grouped into types of maintenance: **preventive maintenance; corrective maintenance; and breakdown maintenance**. More information about each of these follows below.

Preventive Maintenance

The idea of preventive maintenance, or PM, is to avoid the need for costly repairs due to lack of attention to a system. It is performed on a regular basis and is scheduled in advance.

PM was named in the previous section as the heart of any maintenance plan.

Corrective Maintenance

Corrective maintenance (CM) has the goal of preventing further damage to equipment that has suffered some ill effect. The maintenance is a result of inspecting the equipment and it addresses a specific problem. Often, a short time period exists between identification of the problem and the need to correct it.

A quick corrective maintenance can prevent major system failure and prevents the equipment from being removed from service for extended periods without advanced warning.

What are some examples of corrective maintenance that are performed at the facility in which you work?

How do you identify the items in need of corrective maintenance?

Breakdown Maintenance

Breakdown maintenance is often a result of the failure of PM or CM functions. It is an unscheduled task and is often time-sensitive. The equipment usually must be removed from service for a prolonged period; spare parts may not be on hand; and the cost in labor is extensive.

What are some examples of breakdown maintenance that are performed at the facility in which you work?

Thinking about the examples you have heard in class, what other types of maintenance, if any, could have prevented the breakdown maintenance?

Maintenance tasks are performed with varying degrees of frequency. The frequency may depend upon manufacturers' recommendations, amount of wear and tear received, staff time constraints, or plant conditions.

List some maintenance activities that occur at your plant during these time frames:

- ***Daily***

- ***Weekly***

- ***Monthly***

- ***Quarterly***

- ***Annually*** (Remember that this does not mean January 1. Annual maintenance is performed one year from the last incident of maintenance. This staggers task for personnel requirements, and meets requirements for equipment. Use the date of installation to determine the annual maintenance date.)

- ***Seasonally***

There are six major components of a maintenance program.

- Scheduled Preventive Maintenance Tasks
- Unplanned Daily Activities
- Planned Project Work
- Record Keeping
- Inventory Management
- Purchasing

Scheduled Preventive Maintenance Tasks

Typical areas of service include lubrication, calibration, condition assessment and monitoring, and consumable replacement.

Lubrication

Lubrication of moving parts is a fundamental aspect of equipment maintenance. The goal of lubrication is to prevent contact between the moving parts of the bearing surfaces. Choosing and using the proper lubricant is essential. Modern lubricant properties allow a narrower range of products to cover more applications, but it is important to meet the equipment manufacturer's recommendations for lubricant type and usage.

Calibration

Process systems rely heavily on monitoring and automated control. Inaccurate sensors and recorders can cause upset in an entire system. The manufacturer's recommended frequency of calibration should be incorporated into the PM program.

Condition Assessment and Monitoring

Early maintenance programs typically relied on calendar-based scheduling of work tasks. Today, a broad choice of tools helps to pinpoint the optimal maintenance timing. Oil analysis, vibration analysis, and infrared testing are examples of available assessment methods.

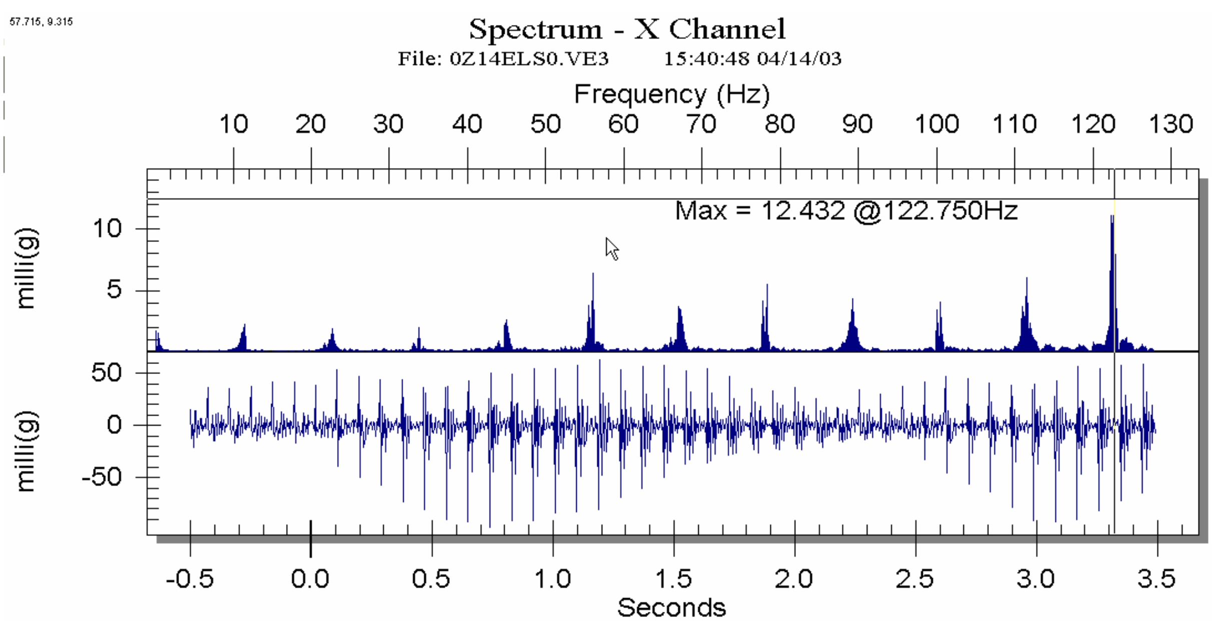


Figure 2.3 Vibration Analysis

Consumable Replacement

Some items must be replaced periodically; they cannot be repaired. Some examples include:

- Air filters that remove particulates such as dust and spores.
    - Indoor air quality is related to the level of maintenance that HVAC equipment (including filters) receives.

- Fluid filters that cull suspended solids from streams.

- Belts and chains that are replaced due to normal wear.

Unplanned Daily Activities

Even the best maintenance program will not prevent the need to carry out unplanned activities. However, since we expect some level of these types of occurrences, we can allocate an average level of resources to them. Corrective and breakdown maintenance are unplanned activities. Below are three examples:

- Running repairs, such as a broken drive chain.
- Adjustments, such as belt tensions.
- Emergencies, such as floods, power failures, mechanical equipment failures.

How does your facility plan for the unplanned? What resources are available to deal with emergencies?

Planned Project Work

All facilities need updating from time to time. Some examples are listed below.

- Modernization
  Plant modernization is usually contracted to outside sources. Control panels are upgraded, and more current types of equipment (such as chlorinators) are occasionally installed.

- New Installations
  In-house staff can be used to carry out some new work. Smaller projects, such as installing a new chemical injection pump and feed line, can be handled by the regular staff.

Why might outside contractors work on larger new installations?

- Overhaul/Life Extension
  Most equipment receives a periodic overhaul, based on performance monitoring and the manufacturer's recommendations.

What is the object of equipment overhaul?

What input should an operator have in assessing the need for overhauls?

Record Keeping

Recording and retaining treatment process information is an integral part of the operator's job. However, data gathering and retention is also important in the maintenance operation. It allows:

- Prediction of maintenance efforts.
- Better condition assessments for overhaul and replacement.
- Support for departmental staff and resource requests.

Tracking information can show historical patterns. These patterns can point to areas that are less than cost-effective, faulty, or time- and labor-intensive. As shown below, expenditures are more easily justified when the documentation supports them.

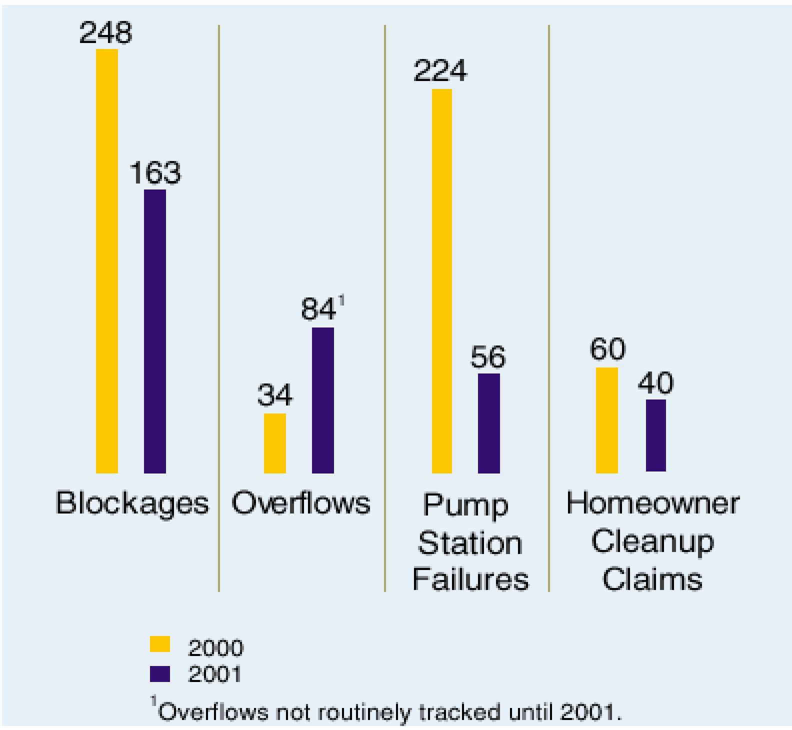


Figure 2.4 Routine Tracking[1]

Inventory Management

The key to an effective inventory control system is keeping the minimum number of parts in stock while, at the same time, protecting against emergencies and providing flexibility to carry on daily activities. This is a difficult balance to achieve, and its success depends upon several factors.

- Critical spare parts for key equipment should be on hand at all times.
- Work closely with service providers and contractors to ensure that they have parts which are readily available.
- Partner with providers and contractors to determine which parts will most likely be needed; keep these on hand at the plant.
- Plan a manageable inventory while considering the storage space available at the facility.
- Know, and develop a relationship with, vendors and suppliers for replacement parts BEFORE you need them in an emergency.
- Use CMMS inventory control features to track spare parts and supplies.
- Use CMMS to track and predict potential needs; have a contingency plan.

In all sized plants, inventory needs to encompass the requirements for these critical areas:

- Key equipment spare parts.
- Common small repairs.
- Emergencies, as possible.
- Preventive maintenance.

Purchasing

Purchasing supplies and spare parts is an integral part of the maintenance operation. In a large facility, there may be a separate purchasing agent or department; small facilities rely on the maintenance supervisor to fulfill this responsibility. Some CMMS programs have a purchasing component that will generate requisitions, purchase orders, and invoice payments.

Acquiring parts for a job consists of a series of related procedures, such as

- Accurately identifying the item(s) required.
- Requisitioning the item from stock or from the vendor.
- Acknowledging receipt when parts arrive.
- Paying the vendor after the invoice review process has been completed.

What procedures are followed at your plant to secure parts, notify personnel that parts are available, and pay the vendor? Listen to your fellow trainees to determine if any other plants have processes that could be helpful to your site.

Key points for Unit 2 – Structure of a Maintenance Program

- An Organization Chart will clearly define the reporting structure of a facility and allow each employee to understand who their supervisor is.

- Standard Operating Procedures (SOPs) are guidelines developed to ensure that the facility's practices conform to internal and external requirements.

- Tracking and reporting on the maintenance programs are very important activities. A computerized maintenance management system (CMMS) may be required at your facility.

- Work may be contracted with outside contractors depending on the need to maintain a balanced workload at the facility, the size of the facility, and specialized skills needed to do the work.

- Preventive maintenance (PM) is an essential activity in a facility. PM can catch potential problems before they have a significant effect on operations.

- In general, a maintenance program includes the following types of maintenance activities: preventative maintenance, corrective maintenance, and breakdown maintenance.

- The six major components of a maintenance program are:

    - Scheduled Preventive Maintenance Tasks
    - Unplanned Daily Activities
    - Planned Project Work
    - Record Keeping
    - Inventory Management
    - Purchasing

Unit 2 Exercise

1. A chart that clearly defines roles and responsibilities and the reporting structure where you work is called a ____________________ chart.
2. SOP means a ________________ ________________ ________________ or guideline that was established by management to ensure that the facility's practices conform to internal and external requirements.
3. A CMMS, which is short for ____________________ ____________________ ____________________ ____________________ allows the creation of a database of information about your facility, can track regular and preventative maintenance work orders and bring order to the execution of maintenance work.
4. List the three main reasons for contracting work to be done by outside personnel:
   a. ___________________________________
   b. ___________________________________
   c. ___________________________________
5. _________________________ maintenance often occurs when there is a failure of preventative and corrective maintenance.
6. _________________________ maintenance is the heart of any maintenance plan.
7. _________________________ maintenance has the goal of preventing further damage to equipment that has suffered some ill effect.
8. Repairing a broken drive chain and adjusting tension in a belt would be examples of ________________ ________________ activities.
9. Plant modernization and installation of new equipment are examples of ________________ ________________ work.
10. Data gathering and retention is an example of ________________ keeping.

[1] United States Environmental Protection Agency, Case Study, Clearwater, FL MOM Program.

(This page was intentionally left blank.)

Unit 3 – Implementation of a Preventive Maintenance Plan

Learning Objectives

- Name the three processes required for the establishment of an equipment database.
- Identify two types of equipment identification numbering systems.
- List the three major components of a Preventive Maintenance Plan.

When creating a new database, there are processes to follow. Each step will be discussed in more detail in this unit.

- Verify information and collect specific maintenance information in order to establish a master equipment list

- Enter the information into the plant's CMMS or a manual program.

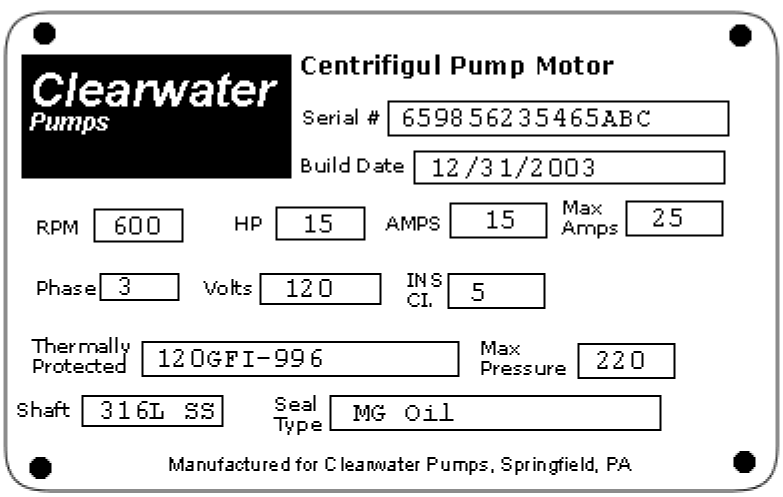
Master Equipment List

The first step in creating the database is to establish a master equipment list. This is a particularly helpful process for newly constructed facilities. Typically, the following equipment information is gathered:

- Type of equipment
- Quantity
- Model Number
- Capacity
- Electrical Characteristics
- Other Useful Information.

Some of this information can be found in the equipment schedules in the drawing package associated with a facility. However, these drawings do not always provide the final manufacturer's information.

The master list requires nameplate information from the actual piece of equipment that is being cataloged.



Equipment Identification

From the master equipment list we now have a list of all equipment under our care. Careful consideration must be given to identify each piece in a systematic way. All equipment must receive a unique identification code.

Some systems rely upon a *simple number code*, with each newly acquired piece of equipment receiving the next number in an increasing sequence. Item number 90012 may be a backwash pump, while item number 90013 is a trash rack. This type of tagging developed, in part, from fixed asset systems, which centered on tracking the presence of all items.

For simplification, some facilities use an *alpha-numeric code*, such as PMP-012 for a specific pump. In this example, all pumps at this facility would be tagged with an identifier that begins with PMP. PMP-012 would be pump # 12.

Many systems today use some form of "*smart numbering code.*" *Smart numbering* is really a system, or a technique, and not an actual term that personnel use to represent the tag's content. This smart number can be a numeric sequence. In our first example, the backwash pump was numbered 90012. If this were the case, then in a smart numbering system, all pumps tagged this way would start with a 9. The 00 following the 9 might stand for the facility at which it is located. The final numbers, 12, would indicate that this is pump #12.

This is probably the most common method used to identify equipment. One of the problems with the first two methods is that equipment ID may change based upon the date it was purchased. Additionally, similar equipment may have significantly different ID numbers under the other systems; with a smart system, identification becomes much easier.

Using smart numbering can allow location, equipment type, and unit number to be identified by looking at the tag number. In this case, the equipment would be tagged with numbers and/or letters that specified the type, location, and acquisition date of the equipment.

Look at the picture shown below.

- How many types of identification systems can you find?

- What are the possible consequences of this kind of labeling?

Figure 3.1 Labeling and Identification Problems

✓ In the following activity, you will create three types of tagging systems. Using the equipment listed below, create a Number Code, Alpha-numeric Code, and Smart Number Code for each of the products.

- Air Filter: model #5733; manufactured by Toric; acquired 2/20/03; located at the Main Street facility
- Backwash Pump: model #24; manufactured by Spelling; acquired 3/13/01; located at the Lee Highway facility
- Trash Rack: model #35; manufactured by SteelGuide; acquired 10/15/99; located at the Brunning facility
- Trash Rack: model #35; manufactured by SteelGuide; acquired 10/15/99; located at the Main Street facility

Number Code:

Alpha-numeric Code:

Smart Number Code:

Create a Library of Procedural Tasks

Purpose

We create written procedures to ensure consistent and appropriate service of the equipment. These written guidelines mean that all employees know what needs to be done, who needs to do it, and how to do it. The library also provides a tool for management and accountability.

When written, the facility's library of procedural tasks saves time by putting all the information together; employees do not have to look through owners' manuals, find SOPs, or seek the knowledge of other employees.

Pre-established written procedures allow an operator or maintenance technician to start working on a task as soon as the work order is received. He or she no longer needs to spend time researching manuals to find the correct type of lubricant or the bolt torque.

Specific Format

Procedures need to be presented uniformly to reduce confusion and to save time. The library of information we are creating is not meant to be a training or instructional tool. It is assumed that the person executing the tasks already has the required skill set to do so. Steps are presented in a logical, concise sequence that also notes equipment shut-down, disassembly, maintenance, reassembly, and restoration of service.

Content

The content, or information, for a library of procedural tasks includes specific maintenance tasks. Always start to collect the information by reviewing the manufacturers' literature. Obviously, an equipment maker is the most familiar with the capabilities and the needs of their own equipment. The degree of maintenance is determined, at a minimum, by the manufacturer's recommendations.

Actual site conditions and requirements may require modification of the manufacturers' recommendations. The applications, usage, and duty of equipment may mean that it needs more service than the typical recommendations imply.

Written Procedures

Once the plan is written, it can be used as Standard Operating Procedures (SOP) for equipment service. Although different mechanics may perform the work over a period of time, following the written steps will allow the correct work to be accomplished in a timely manner.

Maintenance Schedule

Two important considerations provide the necessary information for determining the maintenance schedule: how often the task is performed; and how long it takes to complete the task.

1. **Determine how often the task should be performed**

Keep the following items in mind:

- Severity of service.
- Type of service.
- Criticality of the equipment.

As noted in Unit 1, there is an optimum length of time between performing the tasks. A high frequency of maintenance can be:

- Disruptive due to constant activity.
- Costly in labor and materials.
- Likely to increase the chances of equipment problems..

A low frequency of maintenance, however, can be equally problematic. There could be:

- Higher equipment failure rates.
- Costly repairs or replacement of failed equipment.
- Higher downtime of equipment and systems.

Condition-based PM work orders are triggered by inputs from real-time events. These include testing such as vibration analysis and oil sampling.

2. Estimate how long each task takes

The time required to accomplish each procedure should be estimated. This is used in conjunction with the subsequent scheduling of the work. The total PM hours required by in-house forces can be calculated on a regular basis (monthly, quarterly, annually) if we maintain an accurate log of tasks required and hours needed.

The following points must be considered when estimating task times:

- Accessibility of equipment
- Complexity of startup/shutdown and isolation procedures
- Location of equipment
- Coordination with contractors and other departments.

Once you have determined the frequency of tasks and how long each task might take, you can create an overall maintenance schedule.

Staffing Needs

Maintenance departments may have difficulty in justifying staffing levels. The remedy to this problem is documentation. Since the cornerstone of a maintenance department is the PM function, the emphasis of staffing needs should be placed on that function.

Establishing the guidelines that we have discussed in this unit should assist the department in justifying appropriate staffing levels. Using the CMMS program to organize and project needs is recommended.

Perform each of the following steps. When you have completed steps 1-4, you will be able to adequately document PM Staffing Needs (step 5).

1: Establish what equipment is on site.

2: Create the library of procedural tasks.

3: Calculate task frequencies.

4: Calculate the length of tasks.

5: Establish requirements for PM staffing.

Key points for Unit 3 – Implementation of a Preventive Maintenance Plan

- The steps in the establishment of an equipment database are: create a master equipment list, collect maintenance information, and enter all information into a CMMS or a manual program.
- Each piece of equipment should have a unique identification code.
- Three basic types of identification code systems are: number code, alpha-numeric code, and smart numbering code.
- A “smart numbering code” system may make identification of equipment easier than using a sequential numbering system.
- Creating a library of procedural tasks for maintenance tasks will save time and help insure that different workers perform the required maintenance tasks in the same way.
- A maintenance schedule must take into account how often each maintenance task should be performed and how long each task is expected to take.
- Preventative Maintenance staffing requirements are relatively easy to calculate once the master equipment list, library of procedural tasks, and maintenance schedule with timeframes are available.

Unit 3 Exercise:

1. What equipment information is important to gather when making a master equipment list?
    a. Type of equipment
    b. Quantity
    c. Model Number
    d. Capacity
    e. Electrical Characteristics
    f. All of the above

2. All pieces of equipment should receive a unique _______________ code.

3. The acronym SOP stands for
    a. “Standard Osmosis Protocol”
    b. “Standard Operating Procedure”
    c. “Simulated Operation Procedure”
    d. “Standards of Practice”
    e. None of the above

4. In developing a ___________________ schedule, it is important to understand how often certain tasks should be performed and how long each task takes.

5. Maintenance departments can help to justify their ________________ needs by accurately listing what equipment is on site, create a library of procedural tasks, determine how often each tasks needs to be done and how long it takes to do.

Unit 4 – Typical Maintenance Procedures

Learning Objectives

- Describe one method for testing pump check valves for proper operation.
- List three preventive maintenance steps that are typically applied to pumps.
- Provide an example of non-destructive electrical testing.
- Describe two common maintenance jobs required by electric motors.

A review of typical Preventive Maintenance (PM) tasks contained in this unit will provide a guide to understanding what is expected in generating PM procedures. However, this unit will not give specific details on performing site-specific tasks. Only research into information about a site's unique equipment and how it functions within the content of the plant will allow specific tasks to be created. Depending on the facility, not all tasks discussed in this unit will be performed by in-house staff.

Pump Performance Issues

Before we review maintenance procedures, it is important to point out some pump performance issues.

To increase the life of a pump:

- It should be allowed to run for the longest period of time possible before being shut off. This helps to reduce the amount of starting torque on the thrust bearings and the pump. Starting also causes high power usage when compared to running the pump more consistently.

- Pump manufacturers always give a maximum amount of times a pump should be started per hour. This recommendation should be recorded in the O&M Manual and followed by the system.

Maintenance on a pump is important to keep the pump running at its optimum performance level. Worn impellers and bearings are just two issues that can cause poor performance.

It is important to note that when you see your pump performance affected, it is not always a problem with the pump itself. For example, suction head and suction lift on the pump can cause an apparent decrease in pump performance. These issues put a load on the pump, but they do not represent a pump maintenance problem.

Shaft Seal Adjustment

Shaft seals will be standard packing or mechanical.

Standard Packing Seals

Shaft seals are rings of gasket material that wrap around the shaft of the pump.
Shaft seals are contained within a "Stuffing box." This is a cylindrical box that surrounds the pump shaft designed to hold the packing rings. The box has packing nuts that can be tightened to maintain seals as the shaft seals wear.

- Proper packing adjustment consists of small, incremental taking up of the packing nuts to maintain proper sealing.
- When gland nuts are fully taken up, another ring of packing should be added.
- Periodically, the packing requires replacement.
- All rings need to be replaced, including the rings past the lantern ring (if utilized).
- Over-tightening leads to shaft/sleeve wear.
- Under-tightening leads to excess water leakage, which can cause corrosion of the gland bolts and allow water to infiltrate the bearings.

Note the leaking gland on a small circulating pump in Figure 4.1.

Figure 4.1 Leaking Gland

Mechanical Seals

In some situations, the packing material is not adequate for sealing the pump shaft. A mechanical seal can be used instead. A mechanical seal consists of:

1. A rotating element attach to the shaft

2. A stationary element attached to the pump casing.

- Always follow the manufacturer's recommendations carefully.
- Once installed, periodically check for leaks.
- Rapid failure is a concern; replace leaking seals immediately.
- Check flushing lines (if equipped) to make sure they remain clear.

Lubrication

Lubrication protects equipment. To achieve the highest level of protection, we must ensure an adequate supply of lubricant to the surfaces and maintain the lubricant quality.

Ensure an Adequate Supply of Lubricant to the Surfaces

Smaller equipment may be equipped with sealed bearings, so you won't need to lubricate these pieces. However, when bearings require grease, regular attention and periodic applications of grease are necessary.

Relief Plugs

- When equipped with a relief plug, always remove it before applying grease.
- Removing the plug while greasing will also work the old grease out of the bearing.
- Apply the grease and run the unit to allow excess grease to work out of the relief plug.

Bearings

- Oil lubricated bearings typically utilize a sight glass or bowl. This indicates the fluid level and provides additional reservoir capacity.
- If the bearings are water cooled, check the inlet and outlet temperatures to ensure that flow is adequate.

Chain Drives

- Enclosed chain drives will have the lower casing act as an oil sump and may have an oil spray pump.
- It is important in oil lubricated systems to use a product with the correct viscosity for the application.

Maintain the Lubricant Quality

- Impurities reduce the effectiveness of the lubricant.
- Oil bearings can be contaminated with water from leaky glands. Water displaces the oil and allows metal-to-metal contact.
  - Periodically check the bearing sump for the presence of water.
- Always wipe the grease fitting or oil fill point prior to adding lubricant to avoid carrying foreign matter into the bearing.

Condition Assessment

The most common means of assessing the condition of a pump is for the operator or maintainer to look, touch, listen, and check the instrumentation (i.e., flow and amperage). While these are all good first steps in the maintenance procedure, they tend to be imprecise. Developing problems may be missed by the use of these tools. Various testing measures that are more precise can be applied; one such method is vibration analysis.

Vibration analysis is applied to pumps and other rotating equipment as a common means of determining condition. As with other predictive measures, a history should be built to pinpoint developing trends.

Such things as worn bearings, worn housings, loose bolts, and misalignment can cause excessive vibration in a pump. Misalignment can occur within a pump or between a motor and a pump which causes excessive vibration.

Figure 4.2 shows a close-up of an electric motor with an identification tag indicating the point to be tested. **Figures 4.3 through 4.7** show a representation of a vibration analysis report.

Figure 4.2 Vibration Analysis Point

January 17, 2000

Your Company Inc.
1500 Forest Glenn Road
Hagerstown, MD 20910
Attn. Mr. Customer

Dear Mr. Customer,
Enclosed is the report for the data collection that was performed at your facility on January 12, 2000.

The following is a list of suspected problems that require your attention:

HEAT PLANT

1.	#2 BOILER F.D. FAN	The overall vibration on the motor has increased this time. The vibration is at motor frequency. Check the motor sheave for wear. Check the motor base for loose bolts.

2ND FLOOR MACHINE SPACE

1.	#10 AH FAN	Replace the motor bearings. The technician has noted that the bearing is bad. The bearings were noted last time. The vibration on the fan continues to increase. Check the bearing housing at point "D" for looseness.
2.	NUCLEAR MED EXHAUST FAN AXIAL	The vibration has increased the last three data collections. Check for loose belts, dirt buildup on the fan etc.
3.	#8 AH SUPPLY FAN	The vibration on this unit has increased drastically this time. The vibration appears to be coming from the fan. At point "D" there is looseness. Check the bearing housing for wear. Check to see if the bearing is turning in the housing.
4.	#12 AH EXHAUST	The vibration on the motor has decreased this time. It is still higher than expected. The frequency is at motor speed.
5.	#24 EXHAUST FAN	The readings on the motor have been very erratic. The vibration is at motor speed. Check for a worn sheave or loose bolts.

UNITS BY CAFETERIA

1.	#6AH SUPPLY FAN	The vibration at point "C" has increased drastically this time. The vibration is at pump frequency.

Thank you for the opportunity to provide this valuable Predictive Maintenance service for your company. If you have any further questions, please feel free to call me at any time.

Sincerely,

Robert E. Seesholtz
Predictive Maintenance Mgr.

Figure 4.3 Vibration Analysis Manager's Report[1]

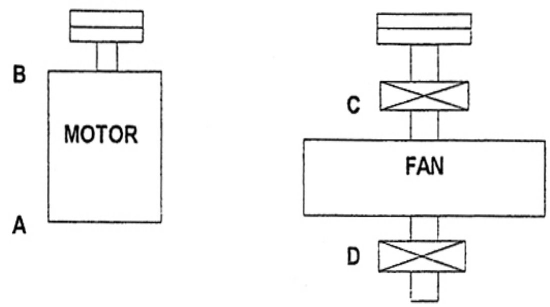
Customer

Job #

Date - **8/13/96**

Equipment Description: Fan AC-4
Penthouse #9 Building

ID #1010



Pick-Up		Velocity		Bearing Level		Equipment Used:
Point	Pos	In/sec	CPM		gSE	Remarks
	H					MARATHON 40 HP, 1745 RPM, 324T FR., 230/460V., 100/50 A., 3 PH., INS. CL.
	V					B, CODE E, HZ. 60, MAX. AMB. DEG. C. 40, MODEL #6C324TTDR7026CCW,
	A					S.F. 1.15, DE BRG. 77611, ODE BRG. 77509
	H					
	V					FAN: AMERICAN STANDARD, P/N 9-88869-04, S/N 542-175
	A					NO. OF VANES/BLADES 11, VANE/BLADE RPM 604
	H					
	V					COUPLING: MODEL BELTS HI POWER II C-195
	A					BELT TYPE: C-195, NO. OF BELTS: 4
	H					
	V					
	A					
	H					
	V					
	A					
	H					
	V					
	A					
	H					
	V					
	A					
	H					
	V					
	A					

Figure 4.4 Vibration Analysis Check Sheet[2]

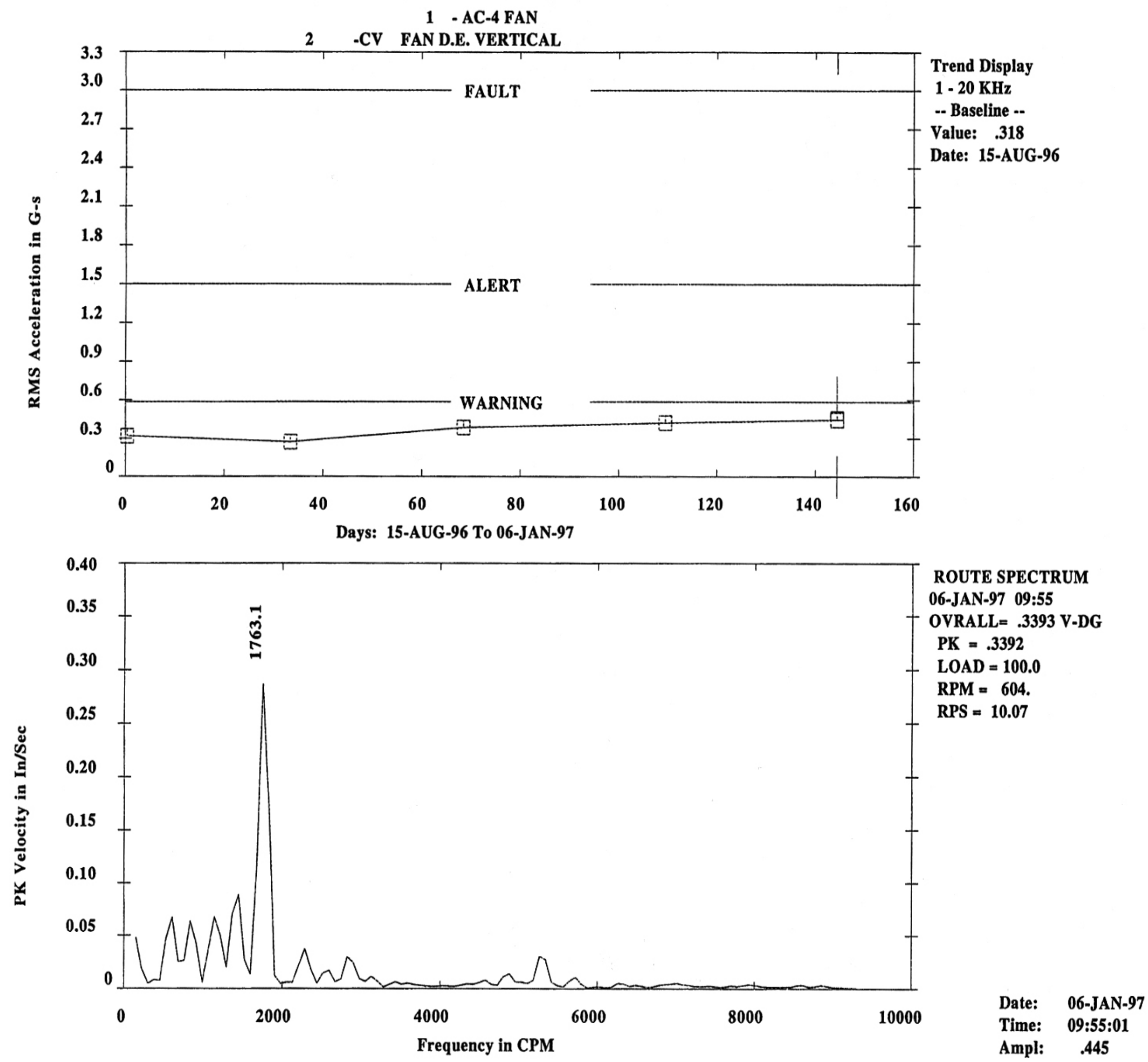


Figure 4.5 Vibration Analysis Graphical Representation[3]

```
                    Abbreviated Last Measurement Summary
                    ************************************

                Database:  D:\DATA\
                Station:   PENTHOUSE BUILDING #9
                Route No.  1:  PENTHOUSE BUIL
                Report Date:  22-JAN-97   15:50

MEASUREMENT POINT     OVERALL LEVEL       HFD / VHFD       MACHINE RPM
-----------------    ----------------   ----------------  ----------------

1         - AC-4A FAN                          (06-JAN-97)
       AH               .499 In/Sec        .0012 G-s       1755.0 RPM
       AV               .981 In/Sec         .214 G-s
       BH               .260 In/Sec        .0010 G-s
       BV               .854 In/Sec         .206 G-s
       BA               .412 In/Sec         .279 G-s
       CH               .213 In/Sec         .172 G-s        965.0 RPM
       CV               .738 In/Sec        .0087 G-s
       DH               .338 In/Sec        .0025 G-s
       DV               .631 In/Sec        .0014 G-s
       DA               .256 In/Sec        .0012 G-s

2         - AC-4 FAN                           (06-JAN-97)
       AH               .496 In/Sec         .260 G-s       1745.0 RPM
       AV               .924 In/Sec         .422 G-s
       AA               .481 In/Sec        .0011 G-s
       BH               .605 In/Sec        .0030 G-s
       BV               .526 In/Sec         .730 G-s
       CH               .207 In/Sec         .490 G-s        604.0 RPM
       CV               .339 In/Sec         .445 G-s
       DH               .247 In/Sec        .0012 G-s
       DV               .364 In/Sec         .111 G-s
       DA               .196 In/Sec        .0050 G-s

3         - AC-5 FAN                           (06-JAN-97)
       AH               .146 In/Sec         .089 G-s       1765.0 RPM
       AV               .279 In/Sec         .072 G-s
       AA               .460 In/Sec         .110 G-s
       BH               .171 In/Sec         .074 G-s
       BV               .319 In/Sec         .141 G-s
       CH               .141 In/Sec        .0011 G-s        500.0 RPM
       CV               .074 In/Sec        .0010 G-s
       DH               .134 In/Sec        .0012 G-s
       DV               .070 In/Sec         .065 G-s
       DA               .101 In/Sec        .0010 G-s

4         - #1 AIR COMP. SCREW                 (06-JAN-97)
       AH               .039 In/Sec        .0011 G-s       1785.0 RPM
       AV               .062 In/Sec        1.133 G-s
       AA               .086 In/Sec         .412 G-s
       BH               .054 In/Sec         .303 G-s
       BV               .099 In/Sec         .547 G-s
       CH               .152 In/Sec        1.711 G-s
       CV               .177 In/Sec        1.180 G-s
       DH               .508 In/Sec        5.156 G-s
       DV               .193 In/Sec        2.969 G-s
       DA               .268 In/Sec        2.531 G-s       1785.0 RPM

5         - #2 AIR COMP. SCREW                 (06-JAN-97)
       AH               .066 In/Sec         .482 G-s       1785.0 RPM
       AV               .056 In/Sec        .0021 G-s
       AA               .068 In/Sec        .0014 G-s
       BH               .053 In/Sec        .0019 G-s
       BV               .084 In/Sec         .484 G-s
       CH               .218 In/Sec        2.141 G-s
       CV               .220 In/Sec         .281 G-s
       DH               .487 In/Sec        4.656 G-s
       DV               .203 In/Sec        5.844 G-s
       DA               .313 In/Sec        .0020 G-s       1785.0 RPM
```

Figure 4.6 Vibration Analysis Detailed Report[4]

A variety of low volume pumps are utilized for dispensing chemicals. All pumps should receive some PM; however, a decision must be made pertaining to which pumps are worth repairing. For example, a .25 GPH solenoid-actuated diaphragm pump costs about $290.00, and it may not warrant extensive and costly repairs.

General considerations for metering pump repairs include the following guidelines.

- Be sure that replacement parts are appropriate for the system.
  - Know what materials for packing, fasteners, and pipe and valve fittings are compatible with the chemicals being handled.
- All leaks must be identified and repaired promptly.
- Make repairs to piping with the fewest joints and simplest runs.
- Keep gearboxes at proper oil levels.
- Ensure that mountings are tight in order to prevent vibration that can be transmitted to the piping.
- Keep intake strainers clean.
- Ensure that check valves operate.
  - Foot valves prevent the loss of prime.
  - Discharge valves on common header lines prevent back pressure on off-line pumps.
- Observe strokes per minute, and compare the results to the pump capacity chart.
- Be proactive in service.

Include Valves in PM Program

Valves that are important to plant operation due to criticality or replacement cost should be included in the PM program. Their inspection can be done in one of two ways: either being covered when other equipment is serviced, or as a unique maintenance item that is assigned its own identification number.

Valve Exercise

A periodic operation of the valve is recommended. This exercise should include:

- Lubricating stems, floor stand bearing points, and gearboxes.
- Checking hydro-motor fluids and lubricators on air supply lines.
- Observing of travel for smooth operation and any unusual binding or noise.
- Functioning of remote control points and manual operations.
- Adjusting packing, as required.

It is important to remember appliances associated with valves and gates, such as removable crank handles and portable actuators. They must be kept in good repair and stowed in their proper storage spaces.

Special Considerations

Plug Valves

Some valves, such as the lubricated plug type, have special requirements. After a certain number of cycles, they should receive the manufacturer's recommended sealing lubricant for the particular application. This will inhibit corrosion of the internal surfaces, assist in sealing, and provide lubrication. This type of valve can also freeze in place if it is not subject to routine care. The result is that the lubricant gun would need to be used to free it; this is time consuming in an emergency situation.

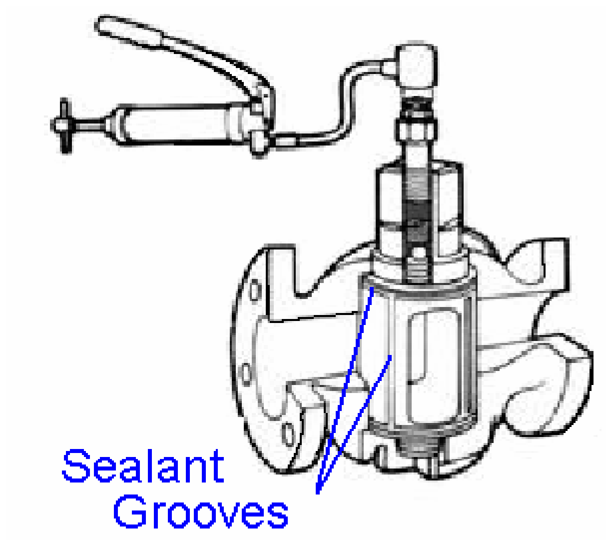


Figure 4.7 Plug Valve[5]

Low Head Valves

Large low head valves, such as sluice, canal, and slide gates, should be attended as follows:

- Adjust wedges as needed for proper sealing.
- Inspect screw nuts for wear.
- Check fixed seals and sliding faces for damage.
- Ensure that the stem covers and locking devices are in place.
- Inspect anchor bolts and frames for corrosion.

Performance Assessment

Valves will test for either a “go/no go” (open/closed) or variable position. Isolating valves and check valves in pumping systems can be checked in several ways, including the following:

- Valves passing large flows, such as a check valve with a stuck flapper, will often reverse-spin a pump if it is idle with another pump online.
- Shutting the suction valve on a pump, with the pump off, and opening the pump casing drains will indicate a leaking check valve or suction valve (if the pump is under positive suction head).
- Using ultrasonic testing is another check function. A number of companies specialize in measuring the acoustic signals that are generated by valves. This is an accurate and measurable technique.

Testing valves, like other plant equipment, usually requires coordination with Operations.

Some determinations should be made in scheduling the frequency of valve PM.

- The reality is that some valves in use can be very old. It may be prudent not to disturb them regularly.
- Some valves are hard to access.
- Valves may be located on lines that virtually never shut down.

If one or more of the above real-world facts apply to valves, a different course of action may be required in lieu of regular PM.

- From an operational standpoint, consider these valves non-functional.
- Service the valve with consideration of contingency plans; have necessary pieces on hand.
- Schedule planned replacement.

Finally, consider the role of the valve in the overall process. Valves in various services, such as flow regulation, backpressure control, surge protection, and level control should be checked to ensure that the valve performs correctly. This often means that auxiliary systems—such as hydraulic power units, logic controllers, and control air systems—are involved.

Electric Motors

Motor care typically involves the following three categories: cleaning; lubricating; and testing/inspecting.

Cleaning

- Ensure good ventilation.
  - Electric losses in motors create heat, which must be dissipated to avoid exceeding the design limits of the unit.
  - Heat is rejected by passing air internally or externally through or around the unit.
  - In some cases, motors are enclosed and cooled by a heat exchanger.
- Open type motors can draw dirt into the unit.
  - Inspect the motor openings for accumulations of dust and dirt.
  - Motors located outside often use screens to keep out leaves and rodents. Monitor them.
- Totally Enclosed Fan Cooled (TEFC) units rely on an extended exterior surface area to act as a heat sink, since the cooling air cannot flow freely closer to the point where the heat is generated.
  - It is particularly important to keep these clean for maximum heat transfer.
- Some wound rotor and many synchronous units are in service.
  - These older synchronous motors have brushes. Carbon dust from the brushes will be deposited on the brush holders and commutator area.
  - This can leak to carbon paths, causing grounds.
- Clean, dry compression is usually used to blow out dirt.
  - Utilize the lowest possible pressure to prevent damage to insulation.
- In some cases, solvents can be used to remove accumulations of dirt and grease.
  - Make sure the solvent will not damage the insulation.
  - Make sure the solvent does not flow into the bearings.

Lubrication

The same considerations follow in motor lubrication as mentioned under pumps. However, it is important not to over-lubricate motors. This situation would allow grease or oil to work past the seals and into the motor windings, which might affect the insulation and promote retention of dirt.

Testing (Nondestructive)

Vibration Analysis

Vibration analysis commonly is performed on motors. When conducted by experienced personnel, it can help pinpoint problems such as:

- Damaged bearing assemblies.
- Broken rotor bars.
- Shorted windings.

Amperage and Resistance Testing

The measured amps of a motor should not exceed the maximum amps shown on the motor's nameplate. High or low amps are an effective indication that there may be a problem with the motor, such as worn brushes or bearings.

Resistance Testing helps to determine if there are insulation problems that may be caused by deterioration due to overheating, exposure to chemical fumes, lubricants, or mechanical damage.

- Resistance is measured in Ohms.

Operating Temperature

Operating temperature is a valuable clue for detecting problems. Large motors often have resistance thermal detectors (RTDs) installed near the core of the windings and bearings. These can be used as a predictive tool. High bearing temperatures might be the result of:

- Insufficient lubrication.
- Increased load.
- Mechanical damage.
- Shaft currents.

Electric Controllers and Switchgear

Equipment at 600 volts, or below, can often be serviced by in-house staff **if qualified electricians are available**. **Electrical equipment should not be serviced by anyone unqualified.** Higher voltages must be serviced by outside vendors or in-house certified electricians.

While starters, panel boards, switchgear, bus ducts, and cabling all have different purposes, there are a number of recurring tasks that are common to most electrical maintenance.

Cleaning

Cleaning is a simple but effective way to ensure that equipment remains dependably in service. Before performing any PM tasks, conduct a visual inspection of the interior of the switchgear cubicle. Look for soot or discoloration of surfaces. Check for carbon paths on insulators. Scan for overheating of wires and terminals, or for chafing of wires.

The cubicle should then be vacuumed or blown out with compressed air to remove dust and debris. In outdoor switchgear, look for indications of water infiltration and see that ventilation screens and grills are in good repair.

Mechanical Checks

Periodically, all electrical terminations and bulbar connections must be retorqued. Equipment manufacturers provide the required torque specifications. Also, be sure to disassemble and clean discolored surfaces of terminals.

Whether it is a simple 5 horsepower full voltage starter or a 69 KV incoming feeder lineup, the integrity of the electrical enclosure is important.

- Keep out contaminants such as dirt, dust, and vapors.
- Prevent water incursion.
- Ensure that rodents and other pests are kept out.
- Make sure the structure can safely withstand and contain short circuit faults.
- Maintain physical safety barrier to personnel.
- Keep the area secure.

Adjustable Torque Wrench

Panels and covers must be secured tightly in place. Be sure that doors and door interlocks function. Keep screens, gaskets, and rain guards in place. Ensure that identification placards and safety warnings are applied and that indicator lamps are good.

Functionality

- Contactor surfaces must mate evenly.
    - The coil must pull in rapidly to minimize arching and to apply the required pressure to hold the contacts together.
    - Springs and/or gravity action must draw away the contacts upon de-energizing the coil.
    - Shields and arc chutes must be in place securely to safely contain and extinguish the arc.

- Inspect fuses.
    - Do not assume that the fuse that is installed is the correct one for the job.
        - Both amperage and type must be appropriate.
    - Ensure that the clamping force of the fuse holder is sufficient to ensure low resistance.
        - Changing fuses and repeated heating reduce clamping force.

- Inspect overload relays.
    - Check the motor contactor overload heater elements.
    - They must match the size required for the motor.
    - Check tightness; cycles of heating and cooling can loosen screw terminals.
    - Many motor controllers are electronic; ensure the trip settings are correct.

- Check control circuits.
    - Ensure that the wire connectors and screw terminations are tight.
    - Check that proper fuses on control transformers were utilized.
    - Check the function of the following interlocks when checking the starters:
        - Valve position end switches.
        - Temperature lockouts.
        - Pressure lockouts.

Insulation Integrity

A simple field test that is available to plant electricians involves using a battery powered ohmmeter, or using a hand cranked insulation resistance meter commonly called a megger. Ohmmeter and megger testing are good for "spot" testing and afford the in-house staff a general idea of the equipment's condition. For more extensive testing, an electrical contractor is usually contacted.

- Ohmmeters will apply up to 24 volts and can indicate direct shorts and low resistances in the kilohm range.

- The megger applies approximately 500 or 1000 volt DC current to the conductor. This is held for about one minute and a reading is taken in the megohm range. This will not indicate how high a voltage the insulation can withstand, but will show the current leakage.

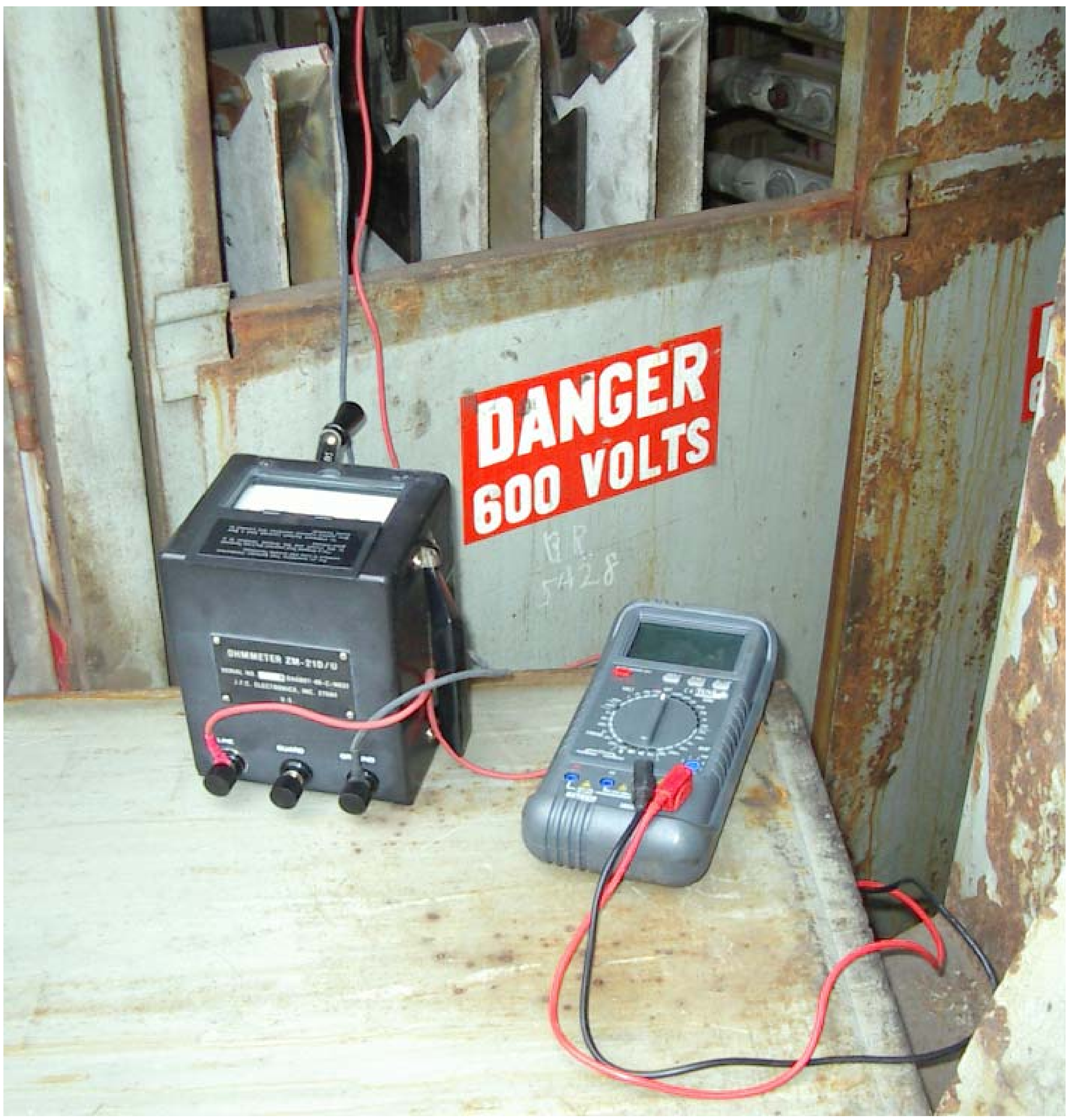
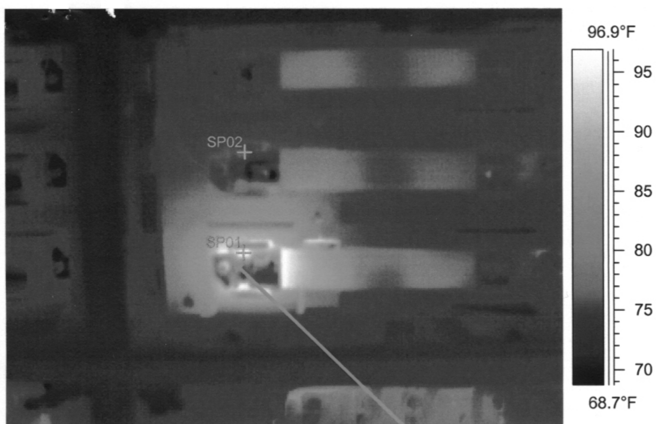


Figure 4.8 Ohm/Megger Testing

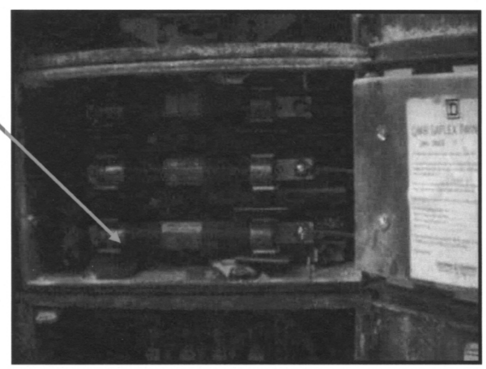
Thermographic Testing

Thermographic testing is another good predictive measure for determining the condition of electrical equipment. Many lower-priced scanners are available that are affordable to the average maintenance operation. These handheld devises can give a general indication of hot spots.

More sophisticated systems are used to very accurately record temperatures. Color still and video images can be taken with this equipment; it allows the maintenance staff to track problems and plan repairs.



FRAME NUMBER	C1210-03.img
AMBIENT TEMP	70.0°F
SPOT 1	99.2°F
SPOT 2	76.0°F
DELTA SPOT1 & SPOT 2	-23.1°F
DATE	12/10/2002
TIME	7:54:23 AM



CUSTOMER	Your Company
JOB NUMBER	S-0000
TECHNICIAN:	Chad Noll

EQUIPMENT: 440 volt distribution panel secondary mixer fuse block

AREA: Starch room

PROBLEM:

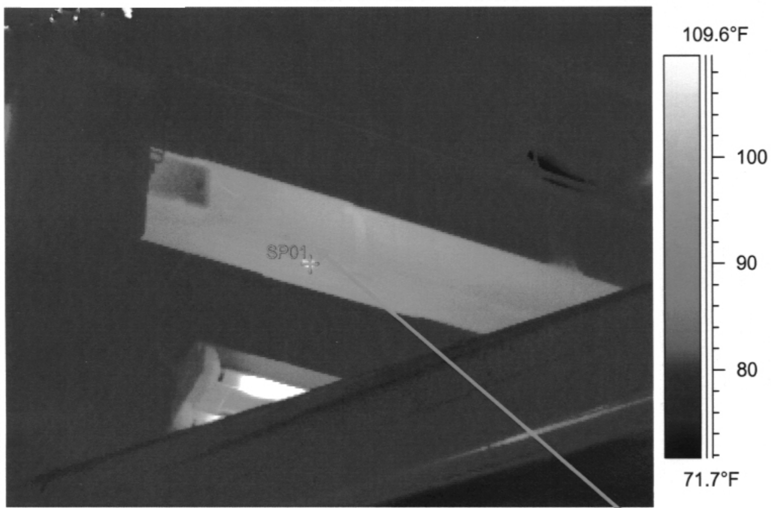
C Phase line side of breaker is overheated

PHASE TO PHASE CURRENT:

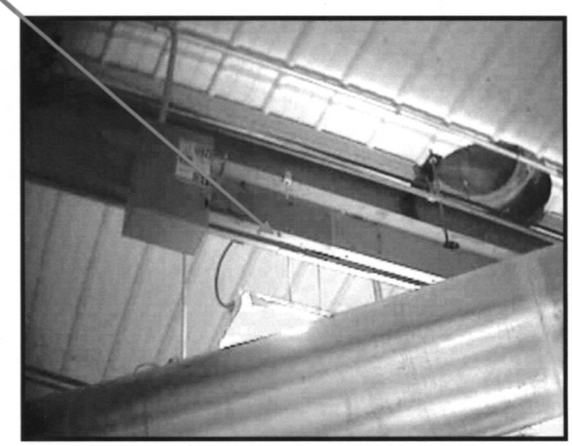
RECOMMENDATIONS:

Clean and tighten bad fuse clip or replace fuse block

Figure 4.9 Thermographic Testing[6]



FRAME NUMBER	C0226-01.img
AMBIENT TEMP	74.2°F
SPOT 1	110.5°F
SPOT 2	-
DELTA SPOT1 & SPOT 2	*
DATE	02/26/2002
TIME	9:12:09 AM



CUSTOMER	Your Company
JOB NUMBER	S-0000
TECHNICIAN:	Chad Noll

EQUIPMENT: Main buss duct

AREA: Richland plant

PROBLEM:

Bolted connection in buss bar is loose and overheated

PHASE TO PHASE CURRENT:

RECOMMENDATIONS:

Disassemble clean and tighten bad connection

Figure 4.10 Thermographic Testing[7]

Figure 4.11 Diesel Application

The service and care of diesel engines increasingly has become the domain of vendors who are certified by the manufacturer of the engine. The degree to which in-house staff service engines is influenced by the size of the organization, the number of units in service, and the size and complexity of those units.

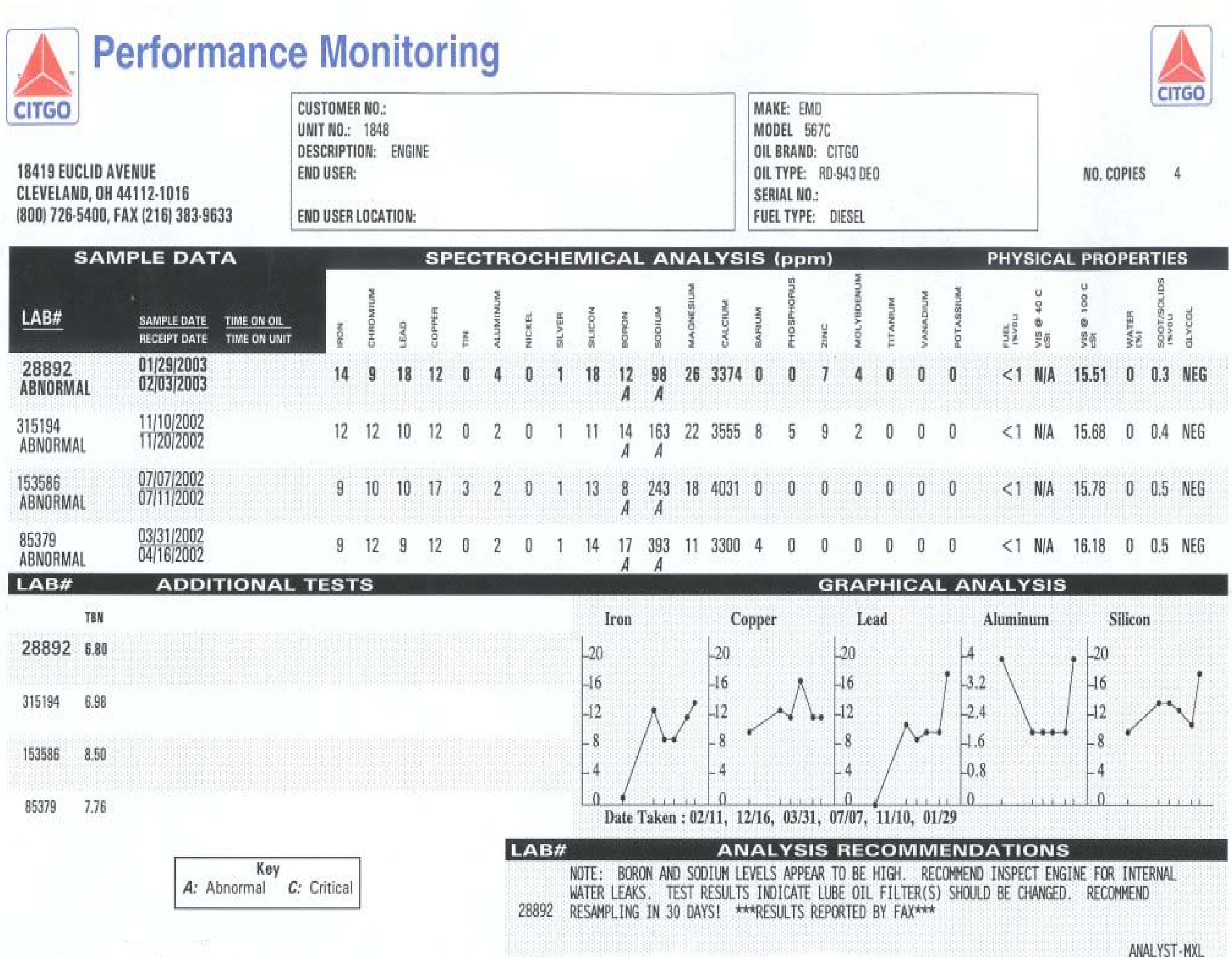
At a minimum, in-house staff must perform a pre-startup inspection of the units and monitor the engines during operation. Many diesel-driven pumps are installed for standby service or in emergency generator sets. Automatic operation is common; the PM plan must take this into account by ensuring that planned service is accomplished as quickly as possible. In some cases, arrangements are made to use a temporary unit.

A widely used and economical PM technique involves testing the coolant and lubricating oil. The lubricating testing is equally applicable to gearboxes and hydraulic systems.

To test the coolant, two items are commonly checked:

- Most efficient ratio of antifreeze to water.
    - If the concentration is high, the heat transfer effectiveness is reduced.
    - If the concentration is low, the fluid may freeze and damage the engine.
    - A common field test uses a hydrometer (or, more accurately, a refractometer).
    - Remember that sample temperature is critical for accurate readings.
- Level of inhibitor.
    - Additives come as part of the coolant or can be added as a supplemental package to protect against corrosion, scale formation, and wet sleeve liner cavitation.
    - Test strips are used in the field to check for pH levels, molybdate/nitrite level, and sulfate.

Field test kits are available for lubricating oil. They test for viscosity, presence of water, total acid number, and other factors. However, it is usually more appropriate to send a sample to a testing lab, which will provide more comprehensive testing. Most lubricating oil suppliers directly or indirectly provide this service, including providing sample bottles and shipping packaging. Report results include interpretation and trending based on previous samples.



Performance Monitoring

CITGO

18419 EUCLID AVENUE
CLEVELAND, OH 44112-1016
(800) 726-5400, FAX (216) 383-9633

CUSTOMER NO.:
UNIT NO.: 1848
DESCRIPTION: ENGINE
END USER:
END USER LOCATION:

MAKE: EMD
MODEL 567C
OIL BRAND: CITGO
OIL TYPE: RD-943 DEO
SERIAL NO.:
FUEL TYPE: DIESEL

NO. COPIES 4

SAMPLE DATA			SPECTROCHEMICAL ANALYSIS (ppm)																				PHYSICAL PROPERTIES					
LAB#	SAMPLE DATE / RECEIPT DATE	TIME ON OIL / TIME ON UNIT	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	SILICON	BORON	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	TITANIUM	VANADIUM	POTASSIUM	FUEL (%VOL)	VIS @ 40 C cSt	VIS @ 100 C cSt	WATER (%)	SOOT/SOLIDS (%VOL)	GLYCOL
28892 ABNORMAL	01/29/2003 02/03/2003		14	9	18	12	0	4	0	1	18	12 A	98 A	26	3374	0	0	7	4	0	0	0	<1	N/A	15.51	0	0.3	NEG
315194 ABNORMAL	11/10/2002 11/20/2002		12	12	10	12	0	2	0	1	11	14 A	163 A	22	3555	8	5	9	2	0	0	0	<1	N/A	15.68	0	0.4	NEG
153586 ABNORMAL	07/07/2002 07/11/2002		9	10	10	17	3	2	0	1	13	8 A	243 A	18	4031	0	0	0	0	0	0	0	<1	N/A	15.78	0	0.5	NEG
85379 ABNORMAL	03/31/2002 04/16/2002		9	12	9	12	0	2	0	1	14	17 A	393 A	11	3300	4	0	0	0	0	0	0	<1	N/A	16.18	0	0.5	NEG

ADDITIONAL TESTS

LAB#	TBN
28892	6.80
315194	6.98
153586	8.50
85379	7.76

GRAPHICAL ANALYSIS

Key
A: Abnormal C: Critical

ANALYSIS RECOMMENDATIONS

LAB#	
28892	NOTE: BORON AND SODIUM LEVELS APPEAR TO BE HIGH. RECOMMEND INSPECT ENGINE FOR INTERNAL WATER LEAKS. TEST RESULTS INDICATE LUBE OIL FILTER(S) SHOULD BE CHANGED. RECOMMEND RESAMPLING IN 30 DAYS! ***RESULTS REPORTED BY FAX***

ANALYST-MXL

Figure 4.12 Lubrication Analysis

Lubrication and hydraulic fluid testing has wide application in treatment plant equipment. Some benefits are listed below.

- Tests can trigger oil changes based on lubricant properties. Typically, this can mean an increase in duration between oil changes.
- Environmental impact of oil usage and disposal is reduced.
- An indication of the internal condition of the equipment is provided.

Key points for Unit 4 – Typical Maintenance Procedures

- In general, pumps should run as long as possible to avoid the mechanical stresses involved in restarting the pump.
- Standard packing seals around pump shafts need to be periodically tightened to eliminate water leakage and replaced when worn.
- Mechanical seals can provide long service if they are properly installed and checked periodically for leaks.
- For equipment using lubrication it is very important to ensure an adequate supply of lubricant and maintain the lubricant quality.
- Some equipment problems may be discovered by smelling hot wires, seeing leaking valves, or hearing excessive vibration noises, but vibration analysis can detect subtle changes in equipment operation that may indicate severe problems are beginning.
- It is important to remember appliances associated with valves and gates, such as removable crank handles and portable actuators. They must be kept in good repair and stowed in their proper storage spaces.
- Testing valves, like other plant equipment, usually requires coordination with Operations.
- Equipment at 600 volts, or below, can often be serviced by in-house staff if qualified electricians are available. Higher voltages are often serviced by outside vendors.
- Panels and covers must be secured tightly in place. Be sure that doors and door interlocks function. Keep screens, gaskets, and rain guards in place. Ensure that identification placards and safety warnings are applied and that indicator lamps are good.

Unit 4 Exercise

1. Which of following are known to increase the life of a centrifugal pump (Select all that apply)
   a. Only allow the pump to run for short periods of time
   b. Allow the pump to run for longest time possible before shutdown
   c. Follow manufacturer's recommendation for how many times per hour a pump should be started
   d. A pump should be started a minimum of 5 times per hour

2. Which of the following should be part of regular maintenance on a centrifugal pump? (Select all that apply)
   a. Oil the bearings
   b. Repack the shaft seal
   c. Loosen the chain drive
   d. Spray WD-40, or equivalent, into the relief plug

3. Of the following, which one is the most precise way to assess the condition of a centrifugal pump?
   a. Amperage
   b. Listening to the sound of the pump
   c. Measuring flow
   d. Vibration analysis

4. **True or False**: Valves should be exercised on a daily basis.

5. The following can be used to test an electric motor: (Select all that apply)
   a. Resistance testing
   b. Negative earth test
   c. Vibration analysis
   d. Ground fault test

6. (Fill in the blank) Periodically electrical terminals and bus bar connections must be ____________________.
   a. Unscrewed
   b. Re-torqued
   c. Greased
   d. Painted

7. ______________________ is a good way to determine the condition of electrical equipment using a hand-held scanner.
   a. Computer testing
   b. Cold testing
   c. Thermographic testing
   d. Chromatography testing

8. What two items are commonly checked on a diesel engine by water system staff? (Select all that apply):
   a. The coolant
   b. Engine management computer
   c. The lubricating oil
   d. Hydraulic lifters

[1] Motor Technology, Inc., York, PA 17402 (1-800-632-9060).

[2] Motor Technology, Inc.

[3] Motor Technology, Inc.

[4] Motor Technology, Inc.

[6] Milliken Valve Company, *Parallel Lubricated Plug Valve O&M Manual*, Series 170M/2-1M.

[6] Motor Technology, Inc.

[7] Motor Technology, Inc.