Wastewater Operator Certification Training

Module 11: Maintenance

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Unit 1 – Introduction to Maintenance

Learning Objectives

- Describe the purpose of maintenance and its importance to the overall operation of a wastewater facility.
- List three goals of a maintenance program and briefly describe each one.

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.

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The steps in maintenance will include, at a minimum:

- Periodic review of a schedule to determine what tasks should be conducted on a system.
- Regular review of expendable items to ensure sufficient supplies are on hand or ordered.
- Issuing work orders or scheduling tasks to accomplish maintenance.
- Review of the completed task.
- Modification of the preventive maintenance (PM) schedule, if necessary.
- Budget management.

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.

Maintenance, in the overall operation of a facility:

- Reduces the potential for unexpected equipment shutdown.
- Promotes a schedule of downtime that is most convenient.
- Assures the reliability of the system to maintain treatment standards.
- Reduces overall costs by correcting minor problems before they become major problems.
- Provides data on the usable service life of equipment and predicts a replacement schedule.

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”?)

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

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: **fixed asset management; maintenance of design intent; efficiency of operations; safety and environmental protection; and system reliability**.

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 loans. Accountants or engineers 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.

By using a maintenance program, facilities may:

- Postpone equipment replacement.
- Maximize the service life of the facility and its equipment.
- Utilize inventory control methods.
- Exercise proper storage protocol.

Maintenance of Design Intent

A facility and its equipment are designed for specific functions. This is part of the engineer's design intent. Do not remove or modify any equipment controls.

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

Efficiency of Operation

Proper service of the equipment helps to ensure that equipment continues to function at its most efficient level. Be sure to periodically check equipment's actual performance, in terms of cost and energy usage, against the manufacturer's rated performance.

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.

Safety and Environmental Protection

Wastewater treatment plants have a direct impact on public health. Plant operators constantly monitor process parameters to ensure quality control.

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 that the public is protected.

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 to prevent accidental usage of equipment.
- Being aware of isolation distances for motor control centers.
    - See Appendix A for an example of isolation guidelines.
- Always replacing guards over moving parts after service.
- Following confined space procedures.
- Monitoring slipping/falling hazards during maintenance activities that involve grease or oil.
- Performing good housekeeping procedures, such as cleaning floors, maintaining adequate lighting, removing clutter, and assessing fire hazards.
- Marking underground utilities (call 1-800-242-1776).
    - See Appendix A for an example of excavation guidelines.
- Maintaining a safety program at the worksite and participating in regular safety trainings.
- Following any special working requirements.
    - See Appendix A for an example of a “Hot Work Permit.”

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.

Figure 1.1 Safety Hazard

What safety hazards can you identify in the photograph of the pump above?

System Reliability

The wastewater 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.

- Identify critical components, which may fail, in a system; plan to protect these components.
- Duplicate or maintain standby equipment to ensure no loss of operations.
- Acquire replacements quickly and cost-effectively.
- Know the consequences of the failure of all components; plan ahead.

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

1. List the five goals of a wastewater treatment plant's maintenance program.

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

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

4. Give three examples of the ways in which plant maintenance directly impacts the quality of the treatment process.

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

Unit 2 – Structure of a Maintenance Program

Learning Objectives

- Define Standard Operating Procedures (SOP) and explain their primary purpose.
- State three reasons why record keeping is important.
- Name two criteria used to determine if work should be contracted to outside sources.
- List four preventive maintenance tasks.
- Identify and briefly describe major components of a maintenance program.

Organization

A maintenance program must be structured so that it serves the facility. The tasks that an operator or mechanic completes at a small plant are vastly different from those at a larger facility. In some complex organizations, a team of mechanics may serve several facilities. The specific methods employed by one facility may not work at another facility. No matter what size facility, however, organization is required to ensure that all systems are properly managed.

The complexity of a maintenance group depends upon factors such as 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.

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.

The organization is composed of staff. There are three types of staff that may be encountered in a typical wastewater facility: **field staff; supervisory or technical support staff; and contracted staff.**

Field Staff

Field staff is known as in-house staff because they work on site. They are usually employed by the township, borough, or city that the plant serves. Various levels of expertise can be found in the staff.

Sometimes, limited resources are translated into limited staff and outside help is sometimes used. Sometimes there exists a relationship with other departments in the political boundaries (township, borough, or city), who may work together with the plant to provide staff or resources. For example, the grounds maintenance personnel may be the same folks who take care of the town square's garden.

Supervisory or Technical Support Staff

These employees have a higher level of capability in one or more areas. They are responsible for overseeing people and/or resources. They should be made aware of all PM notices issued from the manufacturers of plant equipment.

Contracted Staff or Services

These people are not usually familiar with an individual plant's peculiarities, but they often have been exposed to a variety of experiences at similar plants. When the particular task for which they were hired is complete, they are no longer paid by the facility.

Modernization of equipment or systems, new installations, and overhauls are often contracted to outside firms.

Another section in this unit, "Contract Work," will examine the reasons for hiring contract workers.

Record Keeping

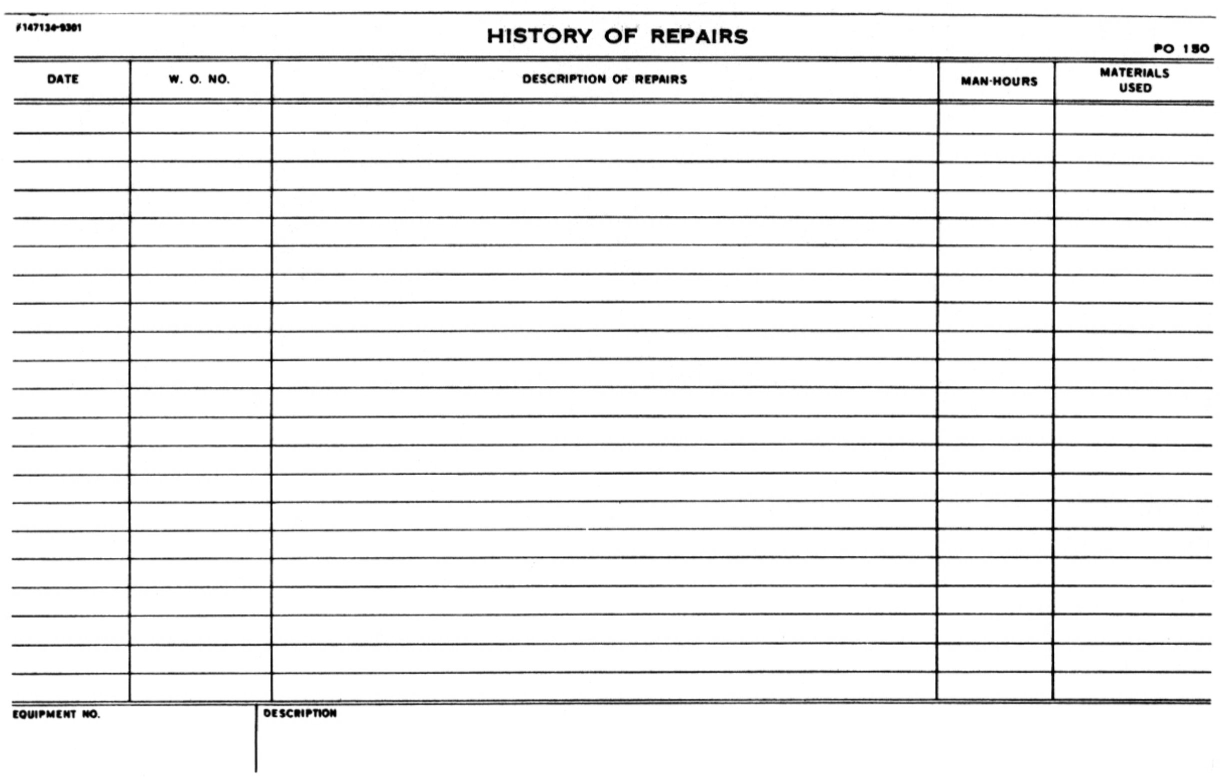
Record keeping is an important component of any treatment plant. Through collection and management of information, important trends may come to light.

Some important factors that may be tracked by collecting and managing records include:

- Trends in preventive maintenance, such as how planned maintenance impacts the number of unplanned breakdowns.
- Financial implications of the current or past maintenance plans.
- Risk assessment of critical equipment and component failure.

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.

Each individual task was logged by hand. You will find several examples of paper-based reporting forms in Appendix B. One example, a repair history logsheet, is shown below.


#147134-9301

HISTORY OF REPAIRS

PO 150

DATE	W. O. NO.	DESCRIPTION OF REPAIRS	MAN-HOURS	MATERIALS USED

EQUIPMENT NO.

DESCRIPTION

Figure 2.1 Paper-based Repair History

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.

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. Unit 3 of this training module will discuss specific steps for setting up a CMMS. 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. Before a system is in place, it is a good idea to ask the following questions in order to determine what kind of system might be right for a particular facility:

- How easily can the system be installed, used, and modified?
- Who will input the data? Is special training required?
- What is the initial cost of the program, the annual upgrade or maintenance fees for use, the cost of converting from our present system, programmer's fees, or costs of special equipment required?
- Can work orders be generated by the system? Can maintenance schedules be modified?
- Will the program allow compatibility with other departments in the plant?

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.

You will find other examples of CMMS screen shots in Appendix C.

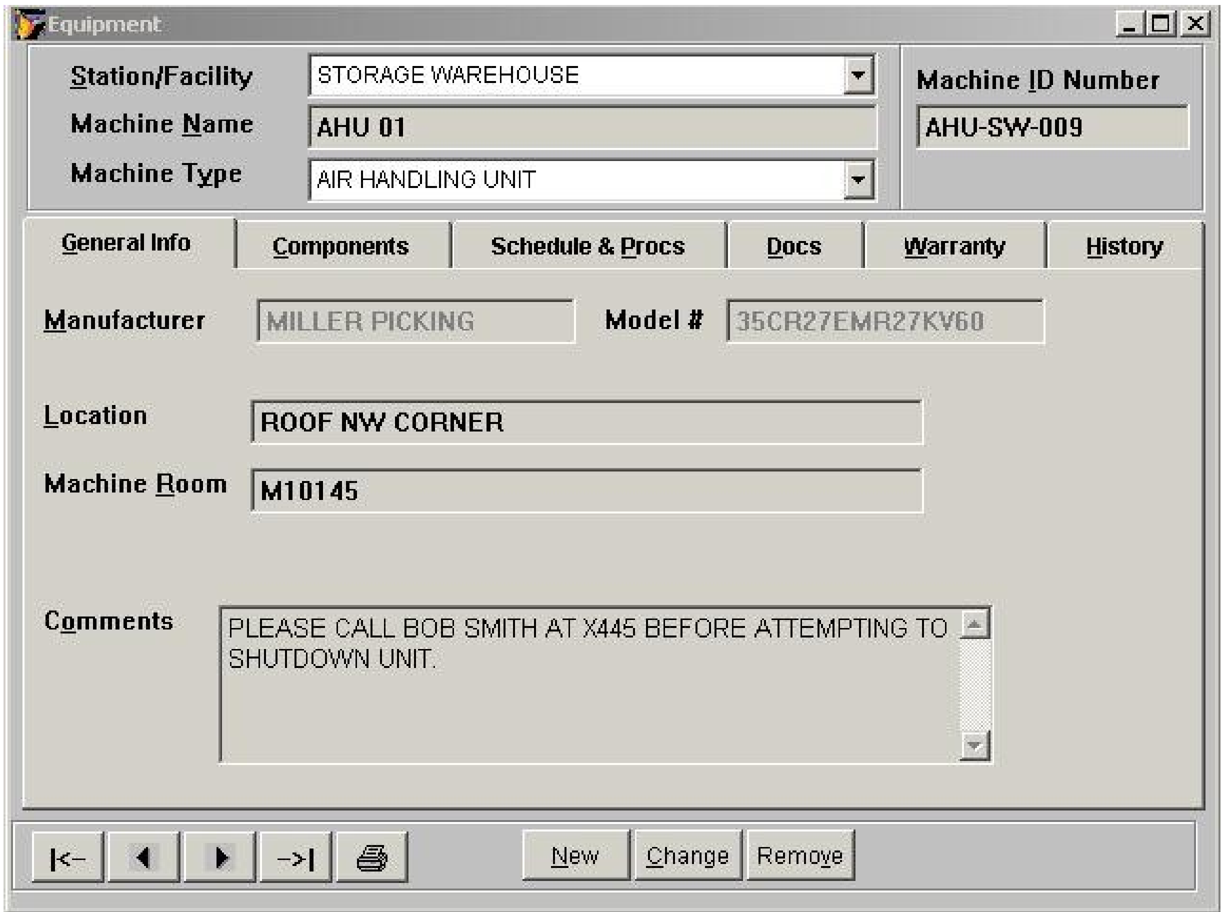


Figure 2.2 CMMS Data Sheet
(Courtesy of Ira J. Spier, President of Spier Consulting, Inc.
75 South Broadway, 4th floor, White Plains, NY 10601)

Contract Work

All plants rely, to some extent, on work carried out by outside personnel. There are three main factors 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 staff is 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

- Staff at smaller sites generally have broad experience in general maintenance.
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- 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.

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

Preventive Maintenance

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.

A maintenance program needs to be concerned with, and involved in, many different components. They work together with other plant departments. In a typical facility, the maintenance department:

- Assumes primary responsibility for the necessary maintenance activities.
- Determines the frequency of activities.
- Schedules repairs.
- Handles emergencies concerning equipment.
- Performs routine, preventive maintenance.
- Has input on necessary capital improvements at the plant.
- Keeps records.
- Manages inventory.
- Requests, makes, or authorizes purchases.

Activities

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.

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?

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?

Frequency

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*

Scheduled Repairs

Scheduled repairs allow management to plan staffing, parts, and financial needs. There are three types of scheduled repairs in the facility.

- Time-Planned Repairs are scheduled on a calendar basis. They are done every day, every month, every year, and so forth.

- Running Repairs and Emergencies are activities that have not been scheduled, but must be completed in a specified period of time. These types of repairs upset normal organized operations at the plant.

- Process Adjustments are completed as needed. Some equipment allows adjustment only while in operation. Some equipment requires regular adjustment, as normal usage upsets its normal operating parameters or calibrations.

Emergencies

It is a better idea to plan to avoid emergencies as much as possible. Emergencies inhibit effective budgeting and, as discussed above, they upset the normal, scheduled workday. Additionally, a premium price is usually charged for last-minute ordering or special shipping services.

However, even the best maintenance program will not prevent the need to carry out unplanned activities from time to time. Since we expect some level of these types of occurrences, we can allocate an average level of resources to them.

- 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?

Preventive Maintenance

One of the objectives of this chapter was to identify four preventive maintenance tasks. The four tasks that are frequently identified as PM functions in wastewater treatment plants include: **lubrication; calibration; condition assessment and monitoring; and consumables replacement.**

Lubrication

- Lubrication of moving parts is a fundamental aspect of equipment maintenance.
- The goal of lubrication is to prevent contact between moving parts of the bearing surfaces.
- Lubrication generates a cooling effect on the parts.
- Choosing and using the proper lubricant is essential.

Calibration

- The process system may rely on monitoring equipment and automated controls.
- Inaccurate sensors and recorders can cause upset in an entire system.
- The manufacturer's recommendation for 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.

Consumable Replacement

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

- Aeration process filters.
- Oil filters.
- Belts and chains that are replaced due to normal wear.

Capital Improvements

A maintenance team may be asked to suggest improvements to the plant's structure or the processes. When an improvement is very large, in terms of required funding, time, or operational impact, it is considered to be a "capital improvement."

Some examples of capital improvement projects include:

- New treatment tank.
- Upgrade of an aeration blower.
- New chemical feed system.
- Flow pacing of chemical feed system.

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.

Retaining records is important for legal, historical, budgetary, and benchmarking purposes.

- Regulatory agencies may require documentation of equipment maintenance.
- Documentation of maintenance functions can serve as legal proof, as needed.
- Tracking information can indicate historical patterns. These patterns can point to areas that are less than cost-effective, faulty, or time- and labor-intensive.
- Management can refer to retained records to plan, improve, or manage budgets.
- Benchmarking is a process that compares the plant's performance to industry standards; records help find areas of excellence and weakness in an organization.

Inventory

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 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.

Purchases

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.

Planned Purchases for Inventory Management

Plans are made to purchase equipment in several ways.

- Annual purchases include chemicals, pump parts, lubrications, and filters. Good record keeping can indicate how many of these items should be purchased for the coming year.
- Moderate-range purchases are made every five to ten years and include upgrades to equipment, diagnostic services, and painting.
- Long-term purchases are planned years in advance and are costly. They include new aeration system blowers and new raw wastewater pumps.
- Specialized or critical equipment purchases must be planned carefully. As the specialization of equipment, and its technology, increases, the chances of quickly and locally finding a part decreases. Similarly, critical equipment must be purchased in whole or part in a timely manner.
- Special purchase categories apply to major contracts, and include the three-quote requirement, following standardized bidding procedures, and utilizing the state's "piggyback" program.

Unit 3 – Implementation of a Maintenance Plan

Learning Objectives

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

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

- Obtain design information in order to establish a Design Master Equipment List (DMEL).
- Verify information and collect specific maintenance information in order to establish a Maintenance
  - Master Equipment List (MMEL).
- 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 nameplate information, the design information, or the shop drawing list.

Maintenance Master Equipment List (MMEL)

The Master Equipment List is expanded into a comprehensive spreadsheet that more accurately reflects the actual facility. This Maintenance Master Equipment List (MMEL) requires nameplate information from the actual piece of equipment that is being cataloged.

Often, the equipment schedules from the drawings (one basis for the Master Equipment List) do not provide the final manufacturer's information.

Equipment Identification

Looking 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 3.2 Labels[2]

From the MMEL 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 last method 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.

☑ 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.

- Aeration Blower: model #5733; manufactured by Toric; acquired 2/20/03; located at the Main Street facility
- Sump Pump: model #24; manufactured by Spelling; acquired 3/13/01; located at the Lee Highway facility
- Bar Screen: model #35; manufactured by SteelGuide; acquired 10/15/99; located at the Brunning facility
- Bar Screen: model #35; manufactured by SteelGuide; acquired 10/15/99; located at the Main Street facility

Number Code:

Alpha-numeric Code:

Smart Number Code:

Several factors are involved in establishing preventive maintenance requirements.

- Expected completion time for each PM.
- Staff requirements.
- Elapsed operational time.
- Seasonal requirements.
- Elapsed calendar time.
- Diagnostic testing results.
- Adjustment to former PM schedule, if necessary.

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.

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. It should be created to be understood by people with different levels of comprehension.

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.

The written procedural content should identify, at a minimum, all of the following:

- Labor requirements.
- Techniques to be used.
- Tools needed.
- Special parts required.
- Shared consumable times (oil/grease filters).
- Safety considerations.

Updates/Revisions

Revise the maintenance plan as the following items are considered.

- Unexpected breakdowns may indicate the need to revise the PM schedule or procedures.
- Manufacturer's information or recommendations may be updated.
- Technical support facilities may provide more specific or timely guidance.

Calculating Task Frequencies

Two important considerations provide the necessary information for calculating task frequencies: how often is the task performed and how long does it take?

How Often is the Task 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.

How Long Does the Task Take?

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.
- Ease of obtaining control of equipment from Operations.
- Complexity of startup/shutdown and isolation procedures.
- Location of equipment.
- Coordination with contractors and other departments.

Establish Preventive Maintenance Hour Requirements

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.

- Establish what equipment is on site.
- Create the library of procedural tasks.
- Calculate task frequencies.
- Calculate the length of tasks.
- Establish requirements for PM staffing.

Unit 4 – Typical Maintenance Procedures

Learning Objectives

- Describe one method for testing pumps for proper operation.
- List three preventive maintenance steps that are typically applied to pumps.
- Provide an example of non-destructive electrical testing.

As the complexity of systems increases and new materials are developed to handle chemicals and products, it becomes increasingly important to maintain up-to-date contact information from the vendor of each system. The information in this unit is meant to provide an introduction into items that could be part of the maintenance procedures followed at a water pollution control facility. It is not all-inclusive, nor is meant to be a manual of practice or SOP for any particular piece of equipment, system, or overall facility.

Types of Pumps

Two types of pumps are common to wastewater treatment plants: centrifugal and positive displacement.

Centrifugal Pumps

- Centrifugal is the most common type of pump.
  - Cavitation will damage the pump or the impeller.
- Pump testing should compare the actual capacity against the rated performance or design intent.
- Vibration analysis helps to determine if the pump or motor is causing vibration.
- There are three types of impellers that can be used in the pumps.
  - Open type is used for fluids with solids, and is less prone to clogging.
  - Closed type is used for clear fluids since it is more prone to clogging; but this may be the more efficient design type for impellers and associated pumps.
  - Screw type is a hybrid that incorporates both open and closed types.

The **impeller** is the internal component, which rotates, in a pump. The rotation effect results in fluids being moved from the center of the impeller towards the outer side.

Open Impeller

Figure 4.1 Open Impeller[1]

Closed Impeller

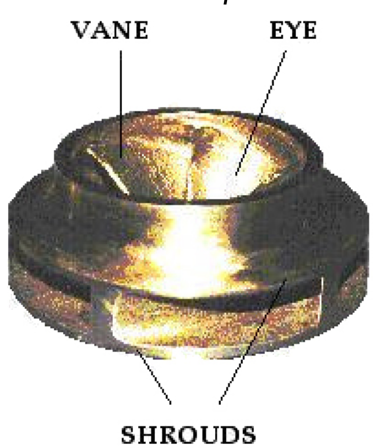


Figure 4.2 Closed Impeller[2]

Screw Impeller

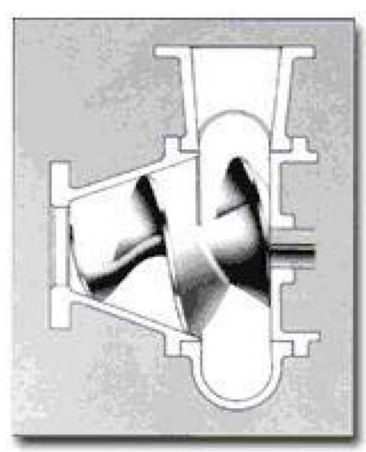


Figure 4.3 Screw Impeller[3]

Which impeller type in the centrifugal pump would you use for primary clarifier sludge? Why?

Which impeller type in the centrifugal pump would you use for a utility water pump? Why?

Positive Displacement Pumps

Progressive Cavity

Figure 4.4 Progressive Cavity Pump[4]

Piston

Figure 4.5 Piston Pump[5]

Diaphragm (rod driven)

Figure 4.6 Rod-driven Diaphragm Pump[6]

Diaphragm (air operated)

Figure 4.7 Air Operated Diaphragm Pump[7]

Rotary Lobe

Figure 4.8 Rotary Lobe Pump[8]

Peristaltic

Figure 4.9 Peristaltic Pump[9]

Chemical Compatibility

Always be aware of the fluids being pumped.

- Refer to manufacturer's specifications for information about fluid compatibility.
- See Appendix D for supplemental information.

☑ Look at Appendix D. What kind of pump would you use if alum were present? Why?

What kind of pump would you use if ferric chloride were present? Why?

What kind of pump should you never use if ferric chloride were present? Why?

What information can you find in Appendix D that fits into your treatment facility?

Overheating

Overheating is caused by closed valves on a centrifugal pump.

- Overheating damages the pump.
- Overheating can build up pressure and steam.
- Overheating is an indication of a problem.
- If casing is much warmer than normal fluid temperatures, there is a possible problem. If heat is excessive, shut down the pump and allow it to cool before working on it.

Packing Gland and Mechanical Seal

A **packing gland** is a section of rope-like material that surrounds a rotating shaft. The clearance between the shaft and gland is so small that only a very minor amount of fluid can pass between the shaft and gland.

- Packing glands can be lubricated two ways: by water or oil.
- Water lubrication of packing cools the packing and provides flushing action.
- Some seepage is normal, but it must be controlled and eventually pumped or drained to the sump.
- Oil lubrication is applied occasionally, as in the case of a piston pump. The oil lubrication points would include the connecting rod bearing and the trough where the piston slides.

Figure 4.10 Packing Gland[10]

Figure 4.11 Mechanical Seal[11]

- Mechanical seals have closer tolerances, but require a higher level of mechanical ability to install.
- Some mechanical seals may not need lubrication.
- In special cases where there may be no source of potable water, a non-lubricated mechanical seal may be used. However, use of some water—either potable or recycled wastewater—as a lubricating and cooling agent is desirable whenever possible.

Lubrication

Each piece of equipment has special lubrication needs.

- See the manufacturer's information in order to ensure a long service life for the equipment.
- All grease or oil is not the same; proper selection is critical.
- Oil changes and analyses are important.
- See Appendix E for more information on lubrication analyses.

MANAGERS SUMMARY REPORT

XYZ MANUFACTURING
CLEVELAND, OH
EXAMPLE REPORT
REPORT DATE: 1/26/96

CRITICAL - Equipment and/or lubricant requires immediate attention

Sample ID	Sample Description/Recommendations	Page
USE-DRYER #4-GB (10003)	**C1 AGITATOR** Consider scheduling an inspection of the bronze bearing retainers and bushings as well as the gear teeth for severe abnormal wear and pitting. Check also for spalling of the bearing rollers and shaft. **Lubricant Recommendations [CRITICAL Status]:** Iron and copper levels continue to increase and suggest severe corrosion and pitting of the gear teeth, bearings, and any bushings. The physical properties indicate that this lubricant is degraded and can no longer support this agitator. The anti-wear additive package is depleted and it appears that this unit has entered a CRITICAL lubricant condition. Also, the viscosity is higher than expected. This further indicates a degraded lubricant. Consider inspecting this unit for damage and pitting of the gear teeth and bearing components.	**1**

Figure 4.12 Lubrication Analysis Report[12]

Pump Curve

- Check and record pressure gauge readings.
- Operating the pump outside of the curve area will destroy the unit.
- Learning to read a pump curve is extremely desirable; refer to the Pump and Hydraulic training module in this series.

Types of Blowers and Compressors

Blowers tend to provide more air than compressors, but at lower pressure.

Centrifugal

Centrifugal blowers allow variable output and operate quietly. See below for an example of a blower, with the parts clearly marked.

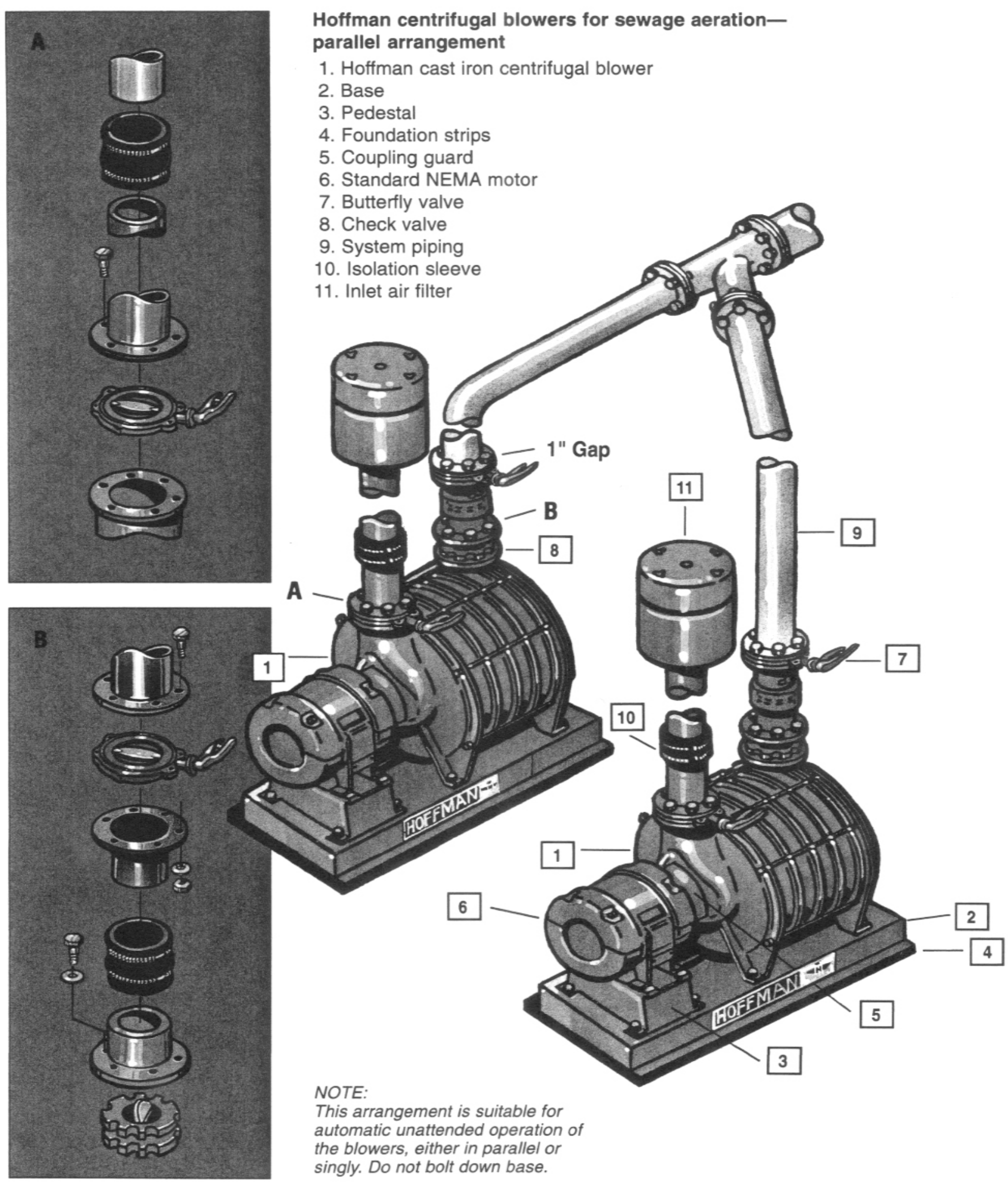


Figure 4.13 Centrifugal Blower[13]

Vibration analysis is important to extend the life of a centrifugal blower.

- This important part of maintenance can also be used to check the condition of alignment, pumps, and motors.
- See Appendix F for more information on vibration analyses.

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.

Figure 4.14 Vibration Analysis Report[14]

Positive Displacement

Positive Displacement blowers tend to operate with a higher noise level. The rotary lobe is the most common model.

- They are useful with tanks with varying water levels.
- The output is almost constant, regardless of backpressure.
- These blowers can be damaged by closed valves.

Figure 4.15 Positive Displacement Blower[15]

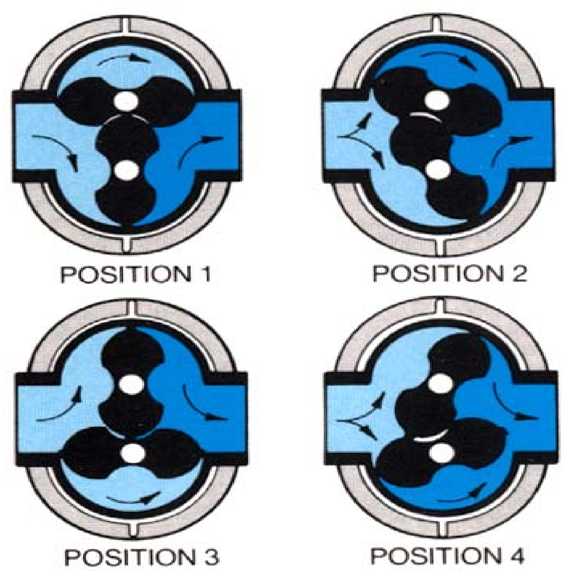


Figure 4.16 Positive Displacement Blower—Internal[16]

Periodic Exercise

Periodic exercise and the rotation of units placed in service is important to extend the life of the blower.

- Do not use one blower/compressor until major service is needed on it.
- Rotate operation of the units in service; weekly rotation may work in your plant.
- Replace the air filters regularly.
  - Air filters are used to protect the units from airborne particles.
  - Regular changing is based on several factors.
    - Hours of operation
    - Air filter restriction indicator
    - Local conditions

Chemical Compatibility

- Avoid locating blowers and compressors in rooms with chemical off-gases if there is danger of a reaction.
  - Chlorine should not be stored in the room with blowers and compressors.
  - Acid drums should not be stored in the room with blowers and compressors.
- Storing chemicals in the same room with the blower may be dangerous because of the warmer temperatures created by the blower, creating an increase in off-gassing.
- Avoid locating blowers and compressors in rooms with high dust levels.
  - Shut down units when possible in the event of nearby grinding operations, sandblasting, or excessively dry road conditions.

Types of Valves

Two types of valves typically will be encountered: restricted passage valves and open bore valves. The flow alignment or seating position may be critical for valves. Determine which is the pressure side; the manufacturer's or installer's instructions will provide this information.

Restricted Passage Valves

See Appendix G for examples of these valves:

- Butterfly.
- Checks.
- Flapper.
- Flapper-Swing Check.
- Globe.

Open Bore Valves

These valves are useful for fluids with small objects, and have less hydraulic headloss problems.

See Appendix H for examples of these valves:

- Ball.
- Knife Gate.
- Pinch.

Periodic Exercise

Valves must be exercised annually. If you are not using the CMMS, perform the following organizational activity to ensure periodic exercise.

- Create a list of all valves.
- Check the documentation, including manufacturer's recommendations, to determine exercise schedules.
- Note the critical locations; prioritize these.

Chemical Compatibility

- Always know what types of chemicals are in contact with the valve.
- The use of chemicals may not allow for one type of valve everywhere in the plant.
- A corrosion guide is included in Appendix D.

Backseat

Backseat occurs when the gate or globe valves are left fully open or in the “left hard against stop” position.

- This position is when the valve is opened hard against the stop position.
- Always leave the valve about one full turn from the fully open position; this will not impede hydraulic flow.
- If a valve is seized in the backseat position, it will appear to be closed because the valve cannot be turned.
- Flooding can result from this situation.
- Injury to staff can result from this situation.
- This information is not applicable to ball valves.

Limitations

“Working pressure” and “burst pressure” are two different values. Never install a valve with the intention of using it at the burst pressure because it will fail near that pressure. Always have a working pressure rating that exceeds the maximum pressure in the system.

- The flow direction can be critical for some valves; if improperly installed, it can fail to provide a proper seal and may even rupture.
- Lubrication is possible on some valves; check the manufacturer’s recommendation.
- Flushing can remove grit deposits.
- Adjustment of the packing gland may be required.

Types of Drives

There are two types of drives typically encountered in a treatment facility: close coupled and split shaft drives.

Close Coupled

- These drives are useful for limited space areas.
- They reduce the potential for belt slippage.
- They have a positive drive system, wherein the drive shaft from the motor is connected as part of the drive component. The shaft on a fan motor, for example, may also be part of the actual fan assembly.

Split Shaft

- These drives commonly are V-belt driven.
- They isolate the motor from the drive unit.
- The selection of sheaves can greatly increase the speed of the driven unit.

Drive Protection

- Shear Pins.
- Torque overload devices, such as a clutch drive system on a clarifier.
- The shear pin is the weakest component, but it serves to protect the more expensive components.
- Always use the correct size and type of shear pin.

Alignment

- Straight-edge alignment is crude, normally usable on low speed ,or used with non-critical systems.
- Dial indicator is a common technique, useable on most systems, and within most wastewater treatment plant capabilities.
- Laser alignment is becoming more popular, as it is precise and useful in critical applications.

Cleaning

- Ducts should be cleaned quarterly or semi-annually.

Unrestricted Intake and Exhaust Louvers

- Restricting the intake or exhaust function will adversely affect air flow and operation of the unit.

Preventive Maintenance

- Staff observations are important for maintaining the equipment; unusual noise indicates a mechanical problem with the air handler.
- Professional or contracted maintenance should be done annually.

Visual Inspection

Visual inspections can be the first line of defense against major problems. You may find indications of overheated circuits or cracked power cords. Be vigilant and perform these inspections on a daily, walk-around basis.

Diagnostic Testing
(Non-destructive Testing)

Amperage Pulled

Checking the amperage pulled is used to determine if there is a higher than normal load on a circuit.

Megger Test

This is used to test insulation properties of equipment, and is done by an electrician with specialized equipment. Most WWTPs may not have the resources to perform this test on their own.

GFI (Ground Fault Interrupter)

Test GFI outlets about once per month. Either an indicator light or a meter should be plugged into the GFI outlet. Pushing the button simulates a fault condition and the outlet should go dead. Pushing the reset button should restore the power.

Thermographic Scan (Infrared)

A thermographic scan works on the principle that, as electrical resistance through a circuit increases, heat is generated as energy is lost. This heat generation is visible as an infrared signature. The naked eye cannot see these changes in heat; nor can they usually be felt without getting too close and creating a possible electrocution hazard.

See Appendix I for illustrations of an area that may look acceptable to the naked eye, but when viewed through an infrared detection device, the electrical connection or unit shows a hot spot that may be an indication of pending failure.

Other Testing

The testing of some equipment, such as a transfer switch and an emergency generator should be developed by the manufacturer of the equipment. Know your vendors and your equipment manufacturer's recommendations.

Types of Gauges and Thermometers

Gauges

The Bourdon pressure tube in pressure gauge is the most common type.

- As the pressure increases, the tube straightens out; when connected to the linkage, this causes the needle to rotate through the range of the dial.
- Depending upon the fluid inside, a diaphragm may be inserted to protect the internal components of the gauge.
- See Appendix J for examples of the Bourdon pressure tube in a pressure gauge.

Thermometers

Three types of thermometers are common: bi-metal; vapor actuated/liquid contact; and electronic probe thermometers.

- Bi-metal thermometers work upon the different expansion rates of two metals to create movement of a needle.
- Vapor actuated, or liquid contact, thermometers allow the ability to isolate the gauge from the source for protection or increased readability of the gauge.
- Electronic probes are used in conjunction with a meter to electronically determine the pressure of a system. It depends upon a thermocouple to sense the temperature and affect resistance in a circuit.
- See Appendix K for examples of these thermometers.

Vibration Isolation

Below are some items to remember when planning for vibration isolation.

- Removable mount allows for quick disconnect and for installing the gauge only when a reading is being taken.
- Rubber mount allows permanent mounting on the pump.
- Glycerin- or oil-filled is used to dampen movement and lubricate the needle.
- Isolation from constant pressure or vacuum is necessary. Most gauges should be shut off or removed when not actually being used.

Calibration

- It is critical to check the accuracy of pressure gauges and thermometers.
- If the readings are incorrect, it will create false information which could add unnecessary maintenance or give false security that precludes necessary maintenance activities.

Periodic Reading and Recording

- If everything appears to be normal, read and record gauges and thermometers at least once every two weeks.
- Use a log sheet to record readings.
- Review the readings on a regular basis.
- Investigate any variations.

Dewatering involves removing a tank from service, draining, and cleaning it. This allows for inspection of components that are not normally visible.

Frequency

- The minimum frequency for dewatering tanks is once every two years.
- If postponed, you may not be able to correct problems before they upset processes due to major equipment failure.
- Too often, a dewatering is scheduled but is postponed for other priorities or for uncontrollable conditions.

Scheduling

- Schedule dewatering during low flow or light usage periods.

What are some factors that impact the schedule of dewatering tanks?

Level of Sensitivity

The first determination of the accuracy of the alarm system is the level of sensitivity that is required.

- Avoid over-sensitive set points.
- Avoid overly sophisticated equipment where it is not needed.
- Determine the maintenance requirements of the alarms.
- Operators should have input into what equipment may need to be alarmed.

Testing of Sensor or Probe

- Sensor (or probe) testing allows only limited testing of the system; it checks only one aspect.
- The alarm signal may not be transmitted off site during the testing; you do not want to alert emergency personnel to a non-crisis situation.
- Testing frequency should be weekly or monthly.

Full Test

- A full test involves testing all alarm functions.
- A signal is transmitted off site. Be sure that emergency personnel have been notified that you are conducting a test so that they do not respond as if it were an emergency.
- Conduct the full test semi-annually or annually.

[1] Joe Evans, Ph.D., “Sewage Pump Impeller Selection,” http://www.pacificliquid.com/IMPELLERS.pdf, (accessed 5/15/03).

[2] Joe Evans, Ph.D.

[3] Joe Evans, Ph.D.

[4] “Progressive Cavity Pumps,” York Fluid, http://www.process-controls.com/York_Fluid/Weathrford.html, (accessed 5/25/03).

[5] “Plunger Pump,” Wastecorp, http://www.wastecorp.com/plunger_pump_selection.html, (accessed 5/25/03).

[6] “Diaphragm Pumps,” Wastecorp, http://www.wastecorp.com/minimud_1002S.html, (accessed 5/25/03).

[7] “Metal Pumps,” Wilden Pump and Engineering Co., http://www.wildenpump.com/catalog/product-detail.cfm?pid=23, (accessed 5/25/03).

[8] “TopLobe—Trilobe Rotary Lobe Pump,” Johnson Pump Company, http://www.johnson-pump.com/OTHER/Rotary_lobe/Lobe_toplobe.htm, (accessed 5/15/03).

[9] “Peristaltic Pump,” Periflo Company, http://www.periflo.com, (accessed 5/29/03.

[10] “Chesterton Packing Gland,” http://www.cherstrton.com, (accessed 5/29/03).

[11] “Chesterton Mechanical Seal,” http://www.chesterton.com/mechanicalseals/, (accessed 5/29/03).

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

[13] “Hoffman Centrifugal Blowers for Sewage Aeration—Parallel Arrangement,” Hoffman Air and Filtration Systems, Catalog.

[14] Motor Technology, Inc.

[15] Dresser Industries, *Universal RAI Rotary Positive Blowers B-5002*, Dresser Industries, Inc., Roots Division, 1989, p. 3.

[16] Dresser Industries, p. 5.

APPENDIX A

SAFETY

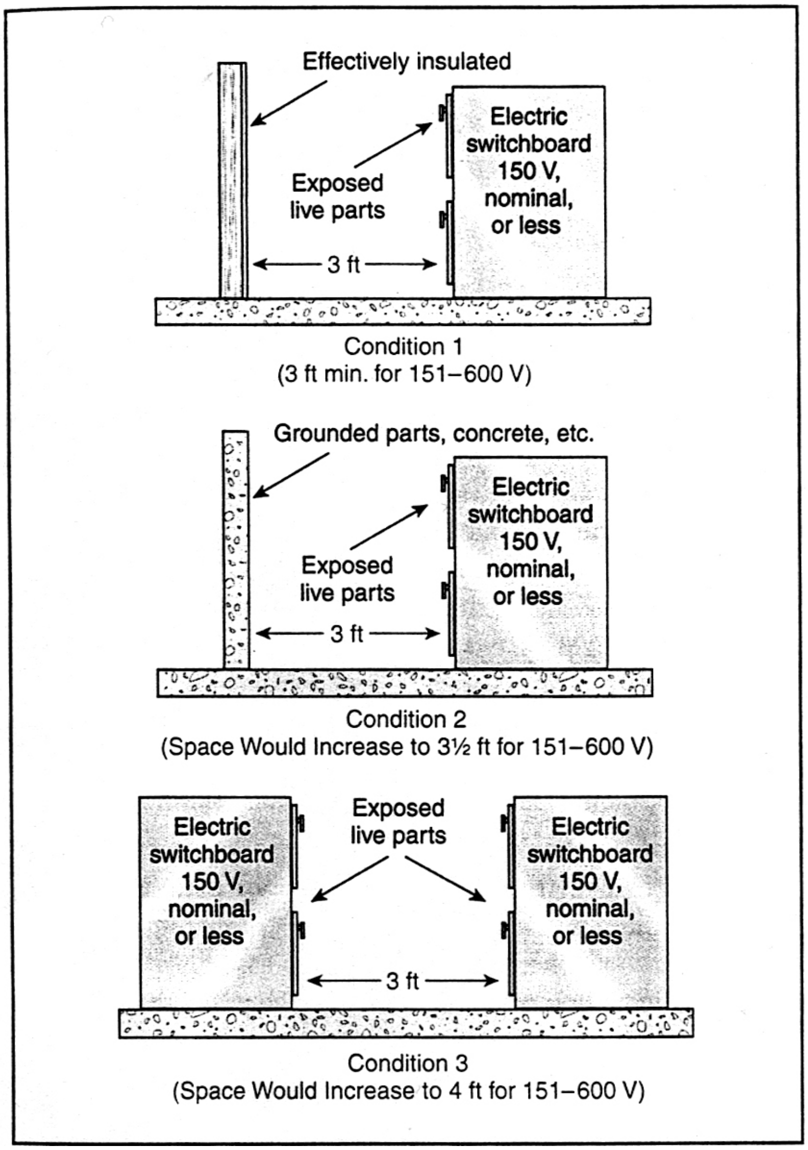


Figure A.1 Isolation Distances[1]

Distances measured from the live parts if the live parts are exposed or from the enclosure front if the live parts are enclosed. If any assemblies, such as switchboards or motor-control centers, are accessible from the back and expose live parts, the working clearance dimensions would be required at the rear of the equipment, as illustrated. Note that for Condition 3, where there is an enclosure on opposite sides of the working space, the clearance for only one working space is required.

NOTE: Appendix graphics are examples or illustrations only, and should not be viewed as guidelines or instructions.

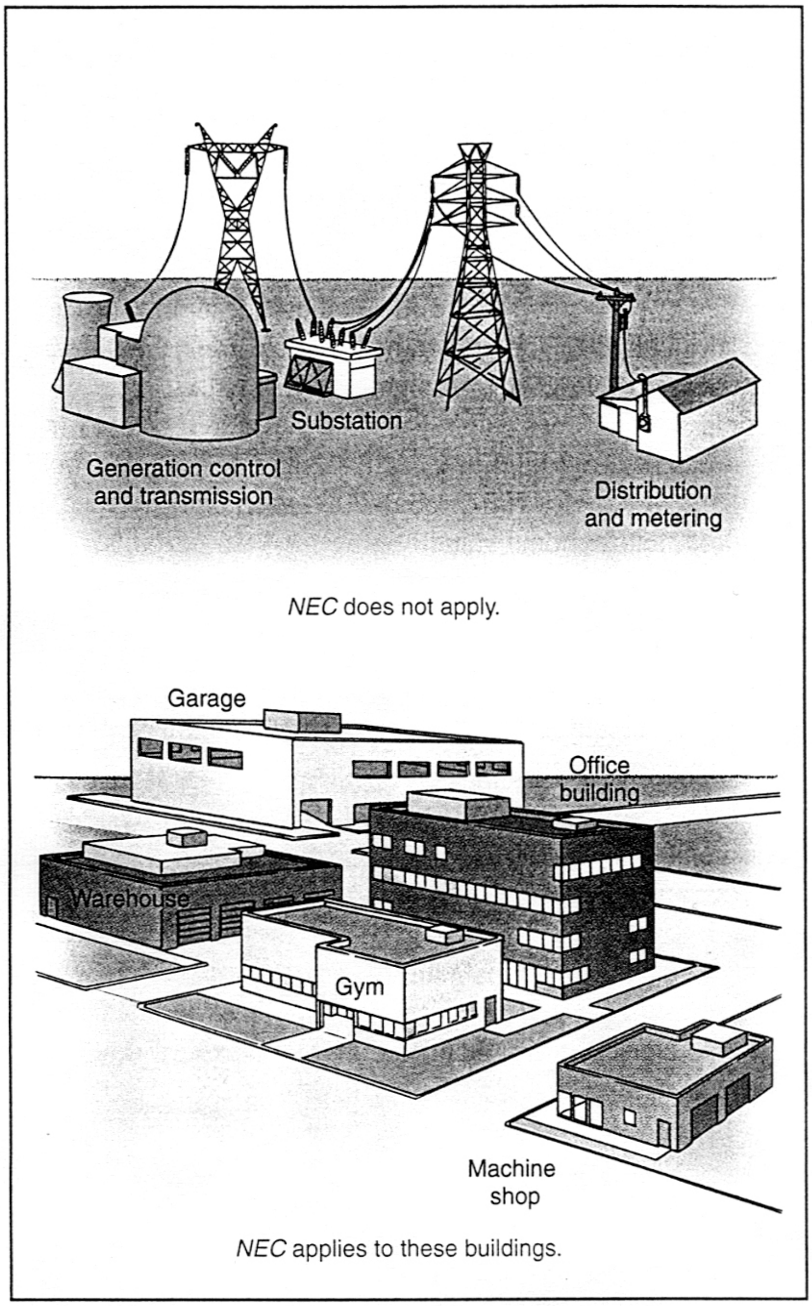


Figure A.2 NEC Provisions[2]

Typical electric utility complexes showing examples of facilities covered and not covered by the provisions of the NEC.

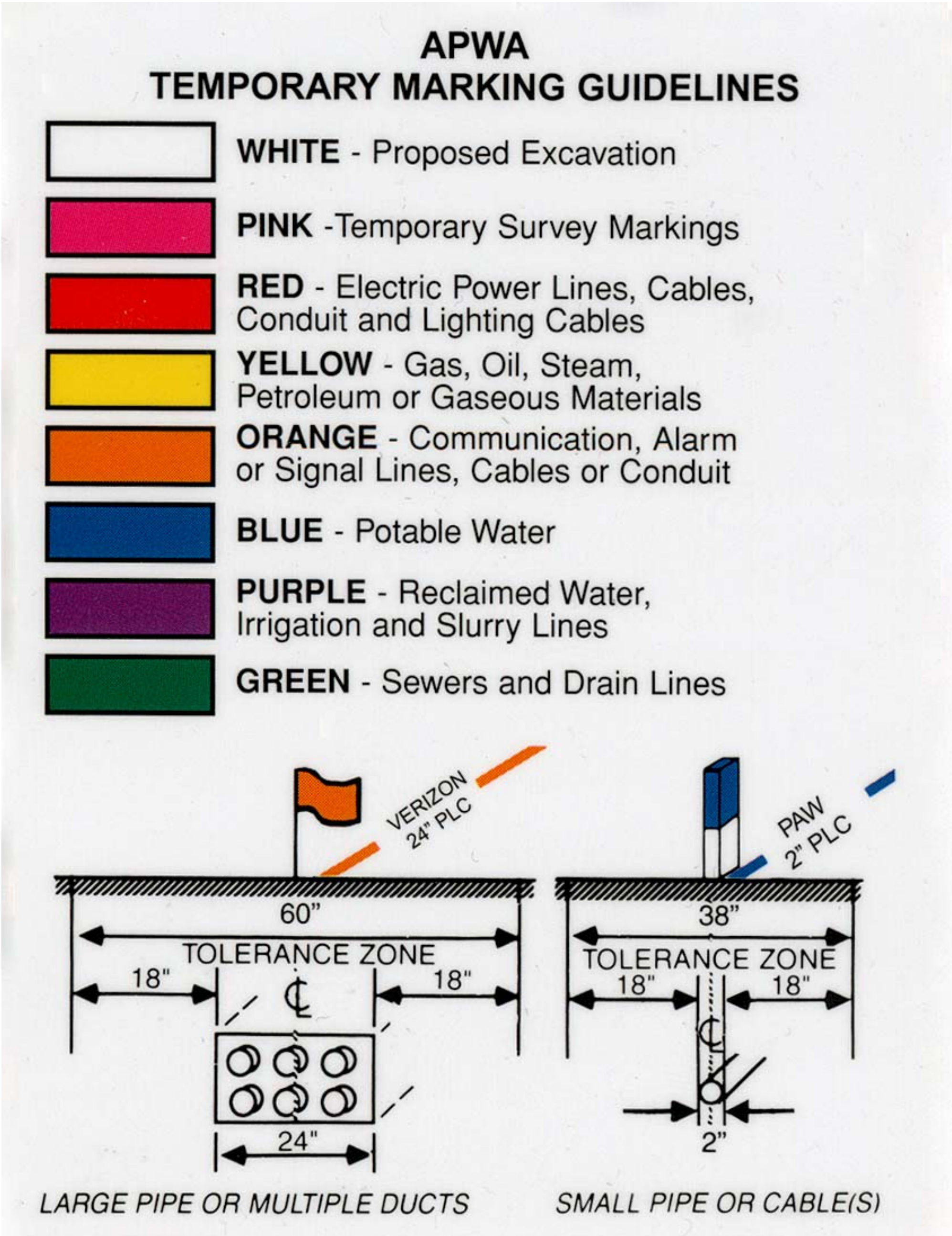


Figure A3 APWA Uniform Guidelines for Temporary Markings[3]

Moore® SpeediSet® - Patented 306

HOT WORK PERMIT

BEFORE INITIATING HOT WORK, CAN THIS JOB BE AVOIDED? IS THERE A SAFER WAY?

This Hot Work Permit is required for any temporary operation involving open flames or producing heat and/or sparks. This includes, but is not limited to: Brazing, Cutting, Grinding, Soldering, Thawing Pipe, Torch Applied Roofing and Welding.

PART 1

INSTRUCTIONS

1. Firesafety Supervisor:

A. Verify precautions listed at right (or do not proceed with the work).

B. Complete and retain PART 1

C. Issue PART 2 to person doing job.

HOT WORK BEING DONE BY:

☐ EMPLOYEE

☐ CONTRACTOR ____________________

DATE	JOB NO.

LOCATION/BUILDING & FLOOR

NATURE OF JOB

NAME OF PERSON DOING HOT WORK

I verify the above location has been examined, the precautions checked on the Required Precautions Checklist have been taken to prevent fire, and permission is authorized for this work.

SIGNED: (FIRESAFETY SUPERVISOR)

PERMIT EXPIRES:	DATE	TIME	AM PM

NOTE EMERGENCY NOTIFICATION ON BACK OF FORM. USE AS APPROPRIATE FOR YOUR FACILITY.

Factory Mutual System

2630 (5-92)PUBS PRINTED IN USA

REQUIRED PRECAUTIONS CHECKLIST

☐ Available sprinklers, hose streams and extinguishers are in service/operable.

☐ Hot Work equipment in good repair.

Requirements within 35 ft (11m) of work

☐ Flammable liquids, dust, lint and oily deposits removed.

☐ Explosive atmosphere in area eliminated.

☐ Floors swept clean.

☐ Combustible floors wet down, covered with damp sand or fire-resistive sheets.

☐ Remove other combustibles where possible. Otherwise protect with fire-resistive tarpaulins or metal shields.

☐ All wall and floor openings covered.

☐ Fire-resistive tarpaulins suspended beneath work.

Work on walls or ceilings

☐ Construction is noncombustible and without combustible covering or insulation.

☐ Combustibles on other side of walls moved away.

Work on enclosed equipment

☐ Enclosed equipment cleaned of all combustibles.

☐ Containers purged of flammable liquids/vapors.

Fire watch/Hot Work area monitoring

☐ Fire watch will be provided during and for 60 minutes after work, including any coffee or lunch breaks.

☐ Fire watch is supplied with suitable extinguishers, charged small hose.

☐ Fire watch is trained in use of this equipment and in sounding alarm.

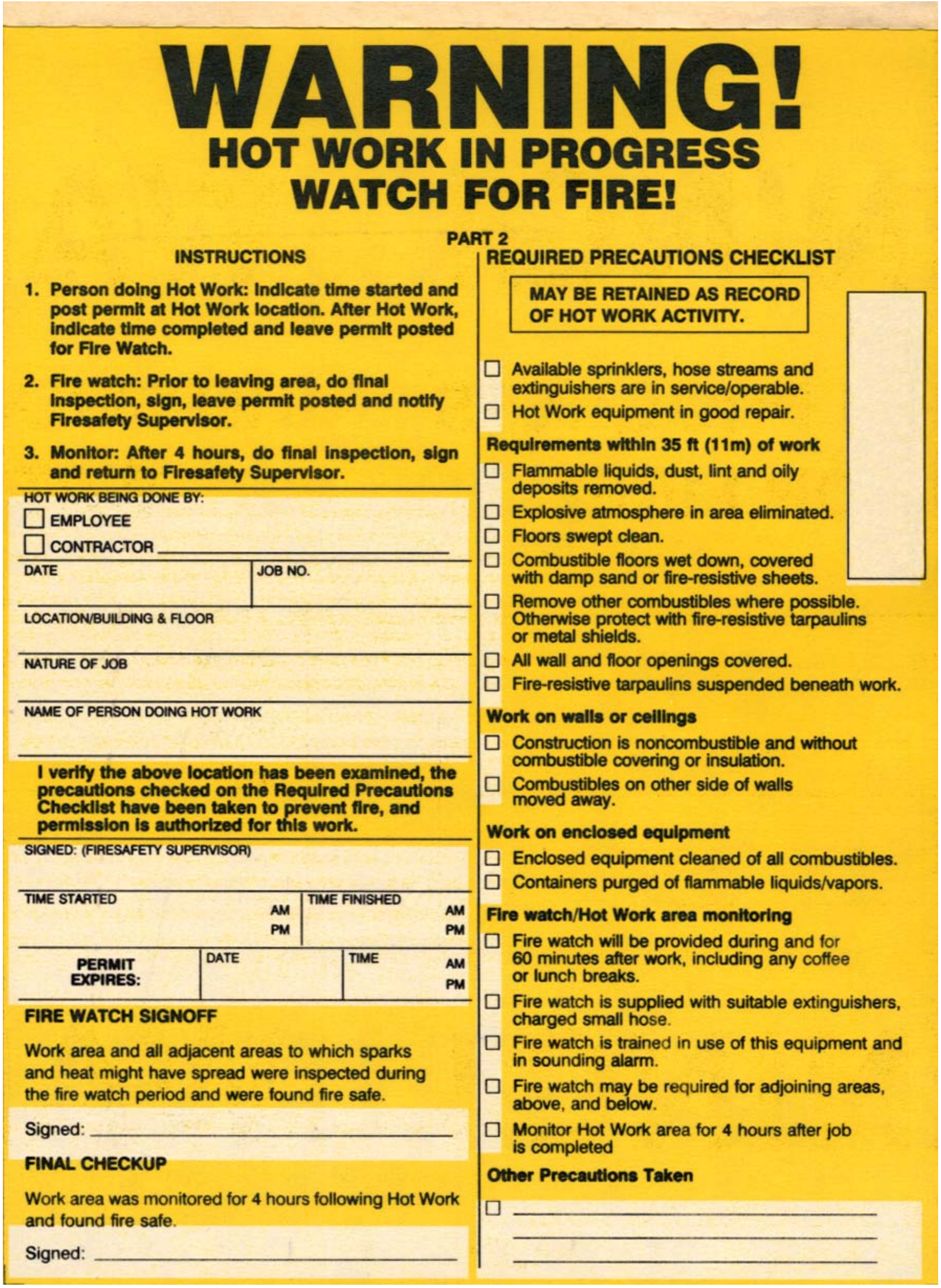
☐ Fire watch may be required for adjoining areas, above, and below.

☐ Monitor Hot Work area for 4 hours after job is completed

Other Precautions Taken

☐ ____________________

Figure A.3 Hot Work Permit (side one)[4]



WARNING!

HOT WORK IN PROGRESS
WATCH FOR FIRE!

PART 2

INSTRUCTIONS

1. **Person doing Hot Work: Indicate time started and post permit at Hot Work location. After Hot Work, indicate time completed and leave permit posted for Fire Watch.**
2. **Fire watch: Prior to leaving area, do final inspection, sign, leave permit posted and notify Firesafety Supervisor.**
3. **Monitor: After 4 hours, do final inspection, sign and return to Firesafety Supervisor.**

HOT WORK BEING DONE BY:

☐ EMPLOYEE

☐ CONTRACTOR ____________________

DATE | JOB NO.

LOCATION/BUILDING & FLOOR

NATURE OF JOB

NAME OF PERSON DOING HOT WORK

I verify the above location has been examined, the precautions checked on the Required Precautions Checklist have been taken to prevent fire, and permission is authorized for this work.

SIGNED: (FIRESAFETY SUPERVISOR)

TIME STARTED AM PM | TIME FINISHED AM PM

PERMIT EXPIRES: DATE | TIME AM PM

FIRE WATCH SIGNOFF

Work area and all adjacent areas to which sparks and heat might have spread were inspected during the fire watch period and were found fire safe.

Signed: ____________________

FINAL CHECKUP

Work area was monitored for 4 hours following Hot Work and found fire safe.

Signed: ____________________

REQUIRED PRECAUTIONS CHECKLIST

MAY BE RETAINED AS RECORD OF HOT WORK ACTIVITY.

- ☐ Available sprinklers, hose streams and extinguishers are in service/operable.
- ☐ Hot Work equipment in good repair.

Requirements within 35 ft (11m) of work

- ☐ Flammable liquids, dust, lint and oily deposits removed.
- ☐ Explosive atmosphere in area eliminated.
- ☐ Floors swept clean.
- ☐ Combustible floors wet down, covered with damp sand or fire-resistive sheets.
- ☐ Remove other combustibles where possible. Otherwise protect with fire-resistive tarpaulins or metal shields.
- ☐ All wall and floor openings covered.
- ☐ Fire-resistive tarpaulins suspended beneath work.

Work on walls or ceilings

- ☐ Construction is noncombustible and without combustible covering or insulation.
- ☐ Combustibles on other side of walls moved away.

Work on enclosed equipment

- ☐ Enclosed equipment cleaned of all combustibles.
- ☐ Containers purged of flammable liquids/vapors.

Fire watch/Hot Work area monitoring

- ☐ Fire watch will be provided during and for 60 minutes after work, including any coffee or lunch breaks.
- ☐ Fire watch is supplied with suitable extinguishers, charged small hose.
- ☐ Fire watch is trained in use of this equipment and in sounding alarm.
- ☐ Fire watch may be required for adjoining areas, above, and below.
- ☐ Monitor Hot Work area for 4 hours after job is completed

Other Precautions Taken

- ☐ ____________________

Figure A.4 Hot Work Permit (side two)[5]

Appendix B

Paper-based Logging System

EQUIPMENT OR STRUCTURE DATA

LOCATION			
MFR.		MODEL NO.	
ADDRESS		SER. NO.	
		MFR. ORDER NO.	
DATE INSTALLED	TYPE	CAPACITY	SIZE
COST	MANUAL NO.	SHOP DWG. NO.	
LUBE - TYPE	—CAPACITY	FITTINGS - TYPE	—QUANT.

DRIVE

EQUIPT. NO.		COUPLED TO:	MODEL NO.
MFR.		SERVICE FACTOR	SER. NO.
ADDRESS		SHOP DWG. NO.	MFR. ORDER NO.
		MANUAL NO.	TYPE
DATE INSTALLED:	OUT PUT COUPLING MFR.		FRAME
COST	RATIO	INPUT RPM	OUTPUT RPM
LUBE - TYPE	—CAPACITY	FITTINGS - TYPE	—QUANT.

MOTOR

MOTOR NO.	H P	RPM	SERV. FACTOR	MODEL NO.	
MFR.			BRUSH TYPE	SER. NO.	
ADDRESS			COUPLING TYPE	MFR. ORDER NO.	
			MOTOR TYPE	SHOP DWG. NO.	
DATE INSTALLED	PRI. VOLTS	PRI. AMPS	PHASE	DUTY	MANUAL NO.
COST	SEC. VOLTS	SEC. AMPS	HZ	FRAME	TEMP. RISE °C
LUBE - TYPE		FITTINGS		INSUL. CLASS	NEMA ENCL.

EQUIPMENT NO.	DESCRIPTION

Figure B1 Paper-based Equipment Log

#147131-9301

PREVENTIVE MAINTENANCE OPERATIONS

PO 149

EQUIPMENT NO. LOCATION

P M NO.	P M OPERATIONS	INTERVAL	P M NO.	P-M OPERATIONS	INTERVAL

Figure B2 Paper-based PM Log

#147132-9301

PREVENTIVE MAINTENANCE OPERATIONS SCHEDULE

PO 148

P M NO.

SPECIAL INSTRUCTIONS

DATE SCHEDULED	REMARKS	MAN HRS.	INIT. DATE

EQUIPMENT NO.	DESCRIPTION	WEEK. CONTROL	MONTHLY CONTROL
		1 | 2 | 3 | 4	JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC

Figure B3 Paper-based PM Operations Log

SPARE PARTS LISTING

EQUIPMENT NO.

PART NO.	DESCRIPTION	PART NO.	DESCRIPTION	PART NO.	DESCRIPTION

Figure B5 Paper-based Spare Parts Log

SPARE PARTS PURCHASE DATA

EQUIP NO.	DESCRIPTION		LOCATION	
MFR	MODEL NO.	TYPE	MFR. PART NO.	DATE INSTALLED
ORDER NO.	MANUAL NO.	FILE	SHOP DWG. NO.	FILE

	VENDOR	ADDRESS	TEL.	CONTACT
1.				
2.				
3.				
4.				
5.				
6.				

REMARKS:

PART NO.	DESCRIPTION

Figure B6 Paper-based Purchase Log

Appendix C

CMMS Screen Shots

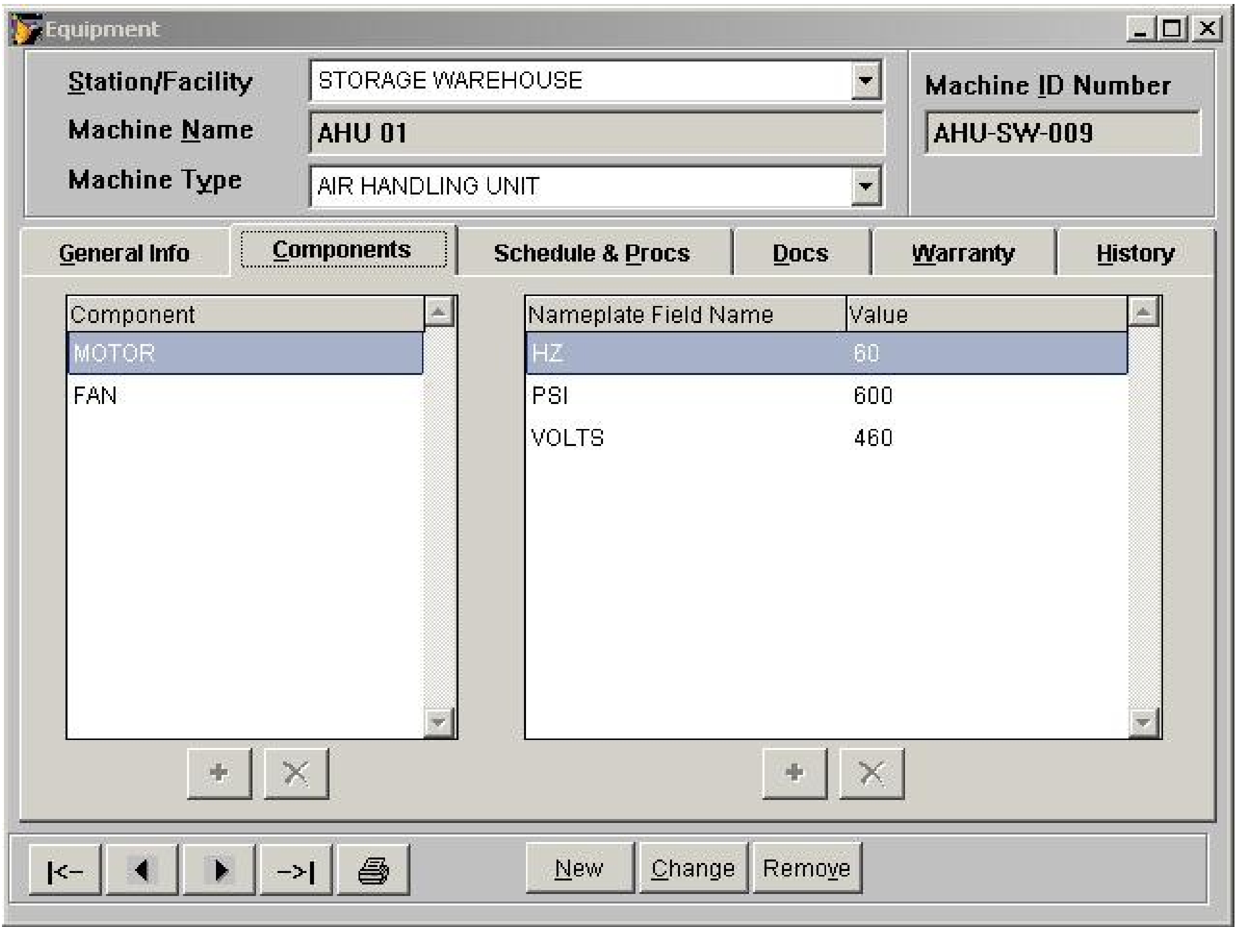


Figure C1 CMMS Equipment Log

NOTE: All Screen Shots in Appendix C were provided courtesy of Ira J. Spier, President of Spier Consulting, Inc. 75 South Broadway, 4th floor, White Plains, NY 10601

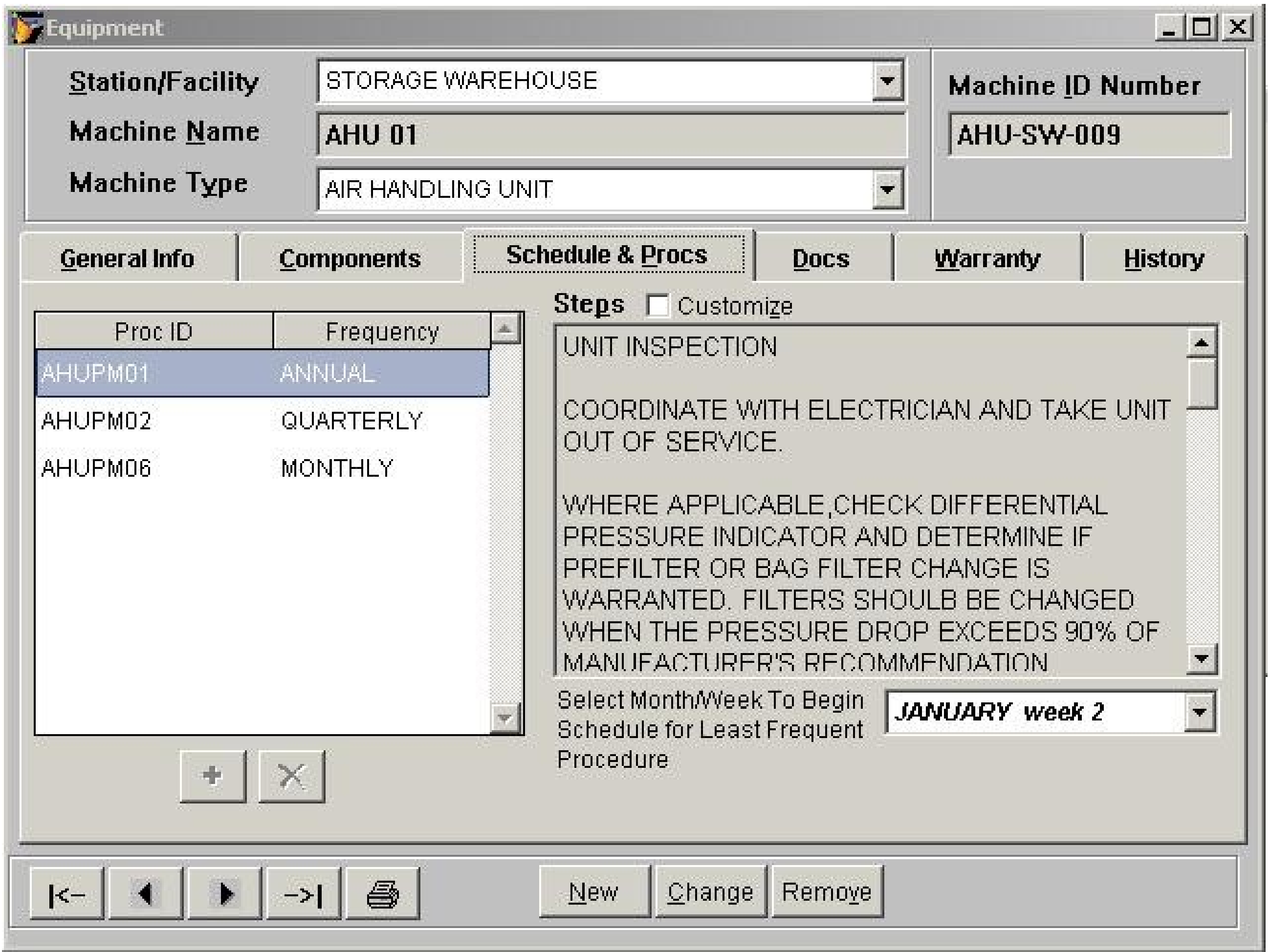


Figure C2 CMMS Inspection Log Screen

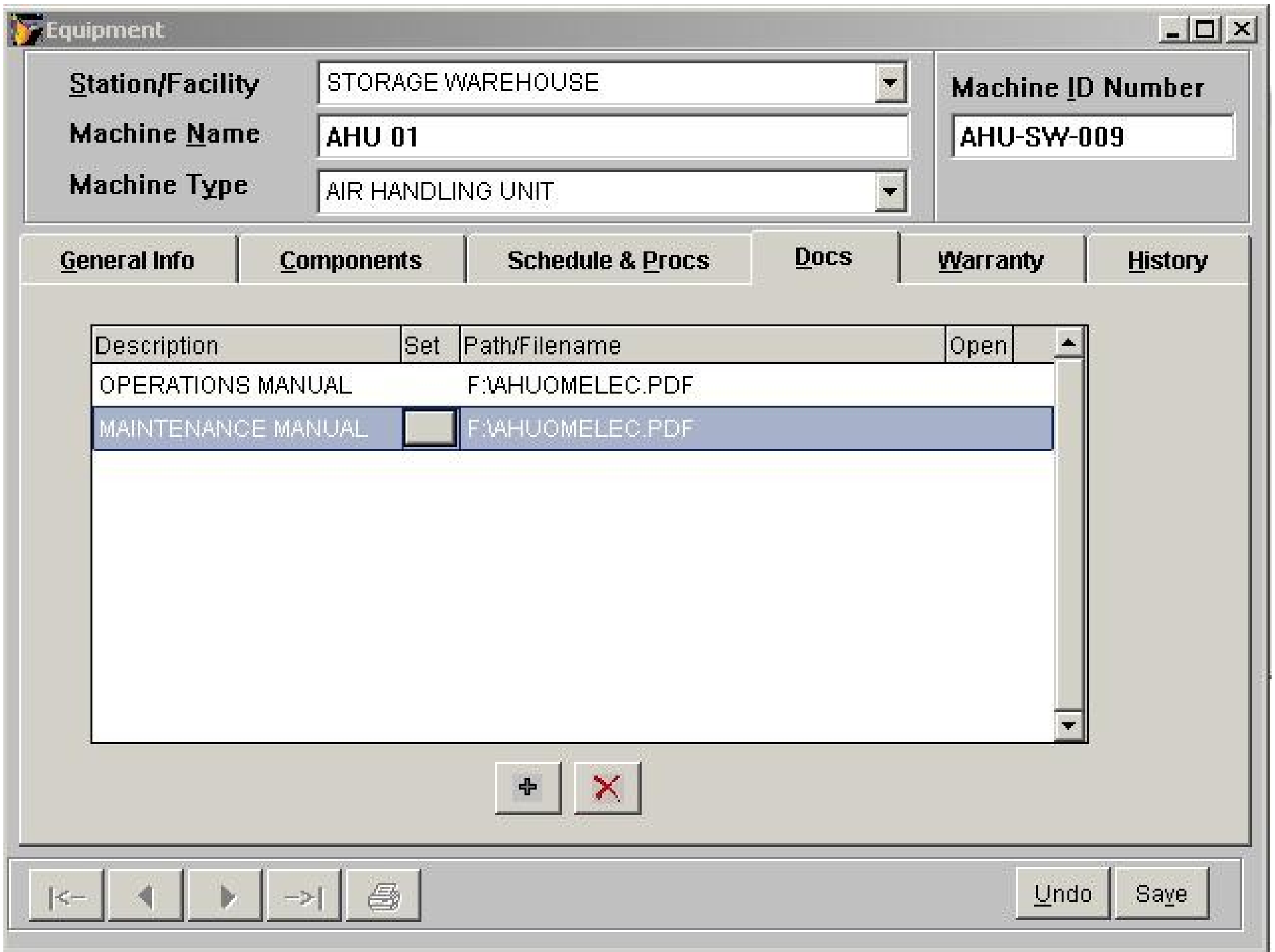


Figure C3 CMMS Manuals Screen

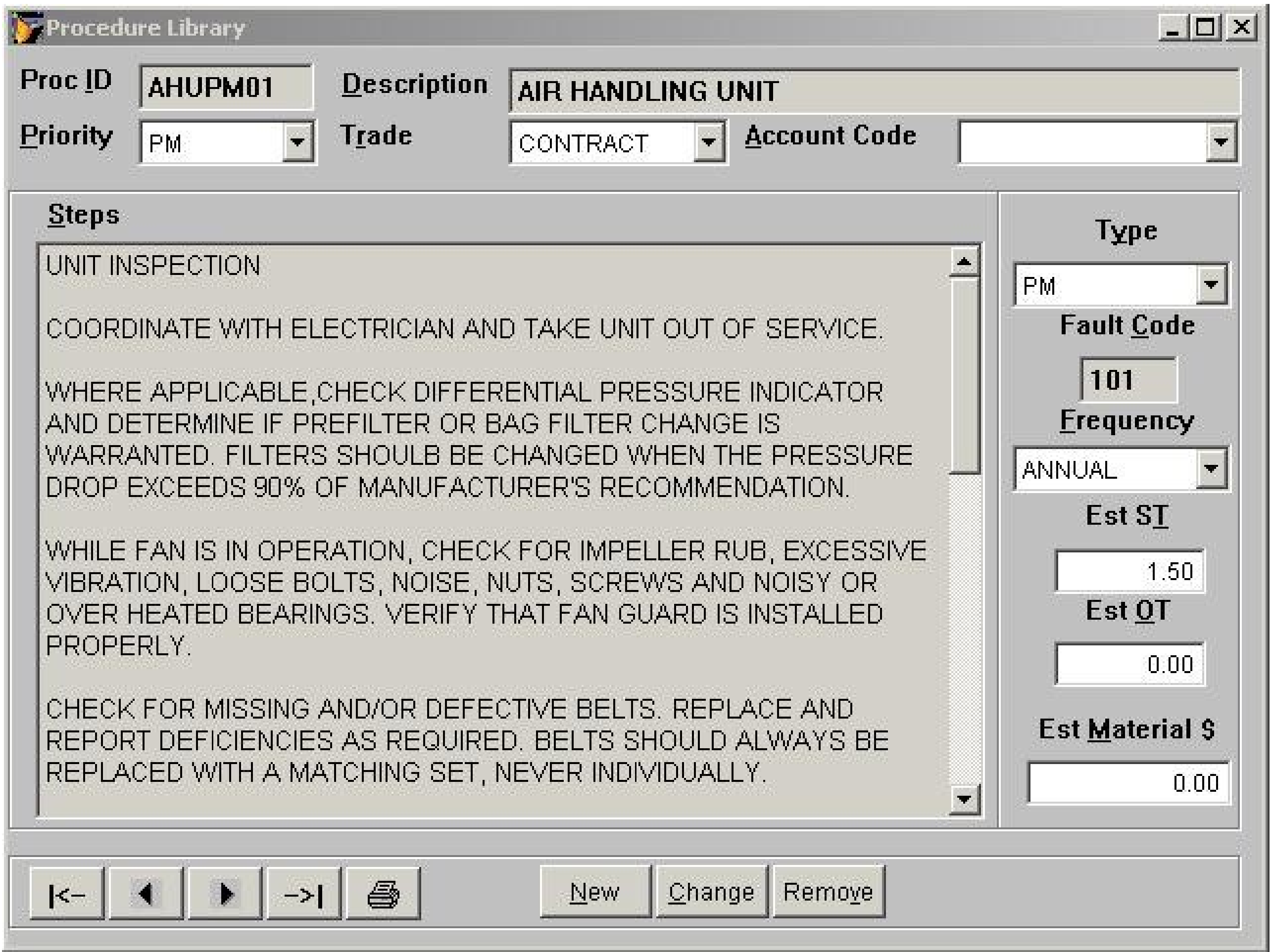


Figure C4 CMMS Procedures Detail Screen

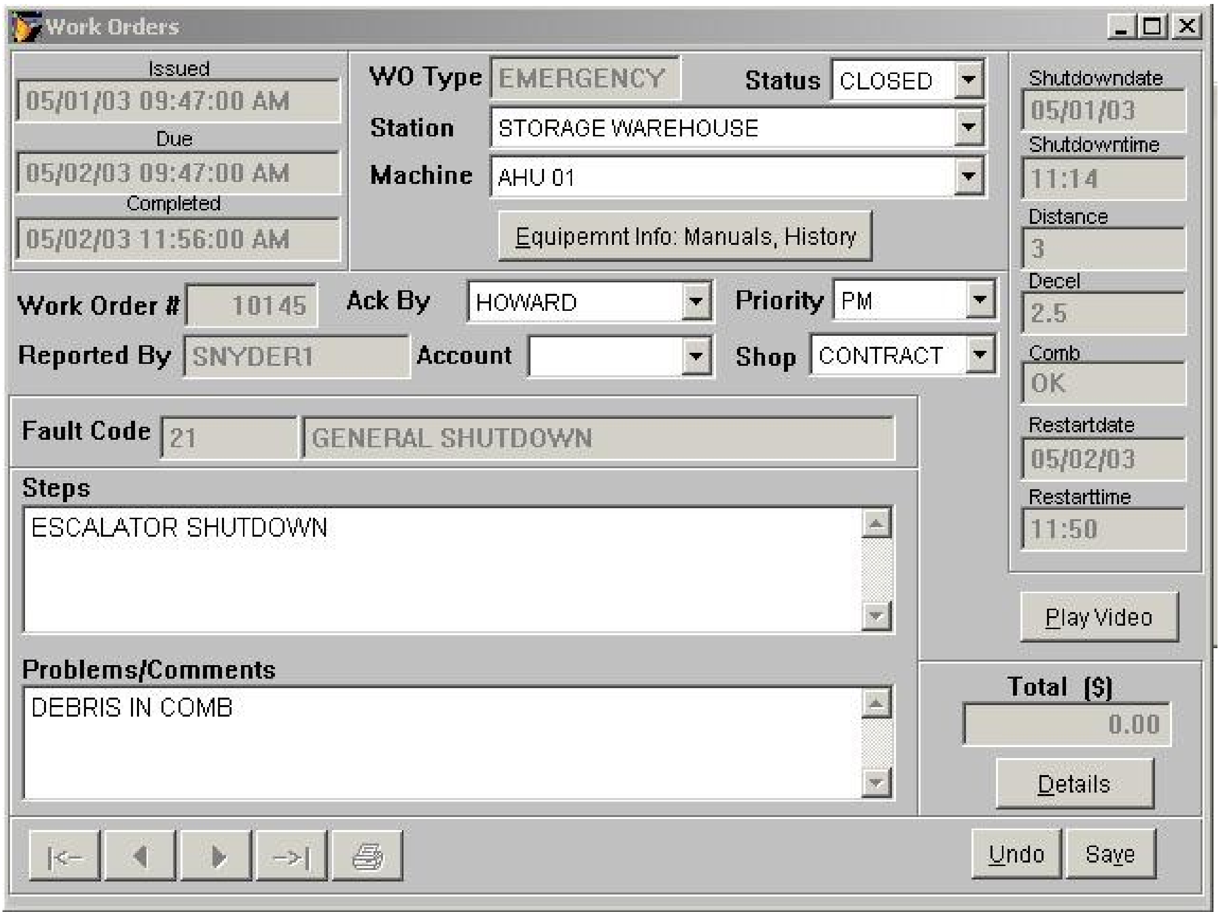


Figure C5 CMMS Work Order Screen

Appendix D

Chemical Compatibility for Pumps and Valves

	Carbon Steel	Stainless 304	Stainless 316	Stainless 20	Monel	Hastelloy C	Alumina Ceramic	TFE or KEL-F*	FPP(Glass-Filled Polypropylene)	PVC	Polyethylene	Kynar	Viton	Hypalon	Nordel	Neoprene
Acetaldehyde	B	A	A	A	B	A	A	A	A	C	C		C	C	C	B
Acetate Solvents	B	A	A	A		A	A	A	A	C	B		C	C		C
Acetic Acid, 20%	B	A	A	A	B	A	A	A,B*	A	A	A	A	C	C	C	A
Acetic Acid Concentrated to 150°F (66°C)		B	A	A	B	A	A	A		C		A	C	C	C	
Acetic Acid Concentrated to 212°F (100°C)	C	B	A	A		A	B	A	C	C		B	C	C	C	
Acetic Anhydride	C	B	A	A	B	A	A	A	B	C	A	C	C	C	C	A
Acetone	B	A	A	A	A	A	A	A	A	C	C	C	C	C	A	B
Alum	C	C	B	A	C	A	A	A	A	A	B	A	A	A	A	A
Aluminum Chloride	C	C	C	B	C	A	A	A	A	A	A	A	A	A	A	A
Aluminum Nitrate	B	A	A	A	B	A	A	A	A	A		A	A	A	A	
Aluminum Sulfate	C	C	B	A	C	A	A	A	A	A	B	A	A	A	A	A
Ammonia Anhydrous	A	A	A	A	B	A	A	A	A		B	A	C	C	A	A
Ammonium Bicarbonate	A	A	A	A	B	A	A	A	A	A		A	A	A	A	
Ammonium Bisulfite	B	A	A	A	B	A	A	A	A	A		A	A	A	A	
Ammonium Bifluoride	C	B	B	A	B	A	C	A	C			A	A	A	A	
Ammonium Hydroxide	C	A	A	A		A	A	A	A	A	B	A	B	A	A	A
Ammonium Nitrate	B	A	A	A	B	B	A	A	A	A	B	A		A	A	B
Ammonium Phosphate	C	B	A	A	B	A	A	A	A	A	B	A	A	A	A	A
Ammonium Sulfate	C	B	B	B	B	B	A	A	A	A	A	A	A	A		A
Ammonium Sulfite	C	A	A	A	B	A	A	A	A	A		A	A	A		
Amyl Acetate, Dry	A	A	A	A	A	A	A	A	C	C	C	B	C	C	C	C
Amyl Alcohol	A	A	A	A	A	A	A	A		B	A	A	A	A	A	A
Amyl Chloride	C	B	A	A	B	A	A	A	C	C	C	A	C	C	C	C
Aniline Chloride	C	B	A	A	B	A	A	A					B			
Aniline Dyes	C	A	A	A	A	A	A	A		C	C		B	B		C
Animal Fats and Oils		A	A	A		A	A	A		A		A	A	B		C
Aqua Regia	C	C	C	C	C	C	A	A	C		C	A	B	C		C
Ascorbic Acid	C	A	A	A		A	A	A	A							
Barium Chloride	C	C	C	B	C	A	A	A	A	A	A	A	A	A		A
Barium Sulfite	B	A	A	A	B	A	A	A	A	A		A	A	A	A	A
Benzaldehyde	B	A	A	A	A	A	A	A	A	C	C	B	C	C	B	C
Benzene	A	A	A	A	A	A	A	A	C	C	C	B	B	C	C	C
Benzene Sulfonic Acid 10%	C	B	B	A	B	A	A	A		A		B	A	A	C	
Benzoic Acid	C	B	B	A	A	A	A	A	A	A	A	A		C	C	C
Benzoyl Chloride	C	C	C	C	C	A	A	A	C				B	C	C	
Boric Acid	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Bromine Anhydrous	C	C	C	B	C	B	A	A	C	C	C	A	A	C	C	C
Bromine Dilute	C	C	C	C	C	A	A	A	C	B	C	A	A	A	A	C
Bromine Trifluoride	C	C	B	B	A	A	C	A	C				C	C	C	
Butadiene	C	A	A	A	A	A	A	A				A	A	B	A	
Butane	B	A	A	A	A	A	A	A		A	C	A	A	A	B	A
Butyric Acid 20%	C	A	A	A	A	A	A	A				A	C	C	C	
Butyric Acid, Concentrated	C	B	B	B	A	A	A	A				A	C	C	C	
Calcium Bisulfite	B	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A
Calcium Carbonate	A	A	A	A	A	A	B	A	B	A	A	A	A	A	A	A
Calcium Chlorate	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Calcium Chloride	C	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A
Calcium Hydroxide	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A
Calcium Hypochlorite	C	C	C	C	C	A	B	A		A	A	A	A	A	A	C
Calcium Nitrate	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Calcium Sulfite	C	A	A	A	A	A	A	A		A		A	A	A		
Calcium Sulfate		A	A	A				A	A	A	A		A	A		C
Camphor Alcohol Sol.	B	A	A	A	A	A	A	A							A	
Carbon Disulfide	C	A	A	A	A	A	A	A	C		C	A	A	C		C

Rating Key: A, Substantial Resistance; B, Moderate Resistance; C, Severe Effect; blank, No Data

Figure D1 Corrosion Guide [6]

	Carbon Steel	Stainless 304	Stainless 316	Stainless 20	Monel	Hastelloy C	Alumina Ceramic	TFE or KEL-F*	FPP(Glass-Filled Polypropylene)	PVC	Polyethylene	Kynar	Viton	Hypalon	Nordel	Neoprene
Carbon Tetrachloride, Dry	B	A	A	A	A	A	A	A	C	C	C	A		C	C	C
Carbon Tetrachloride, Wet	C	B	B	B	B	A	A	A	C	C	C	A		C	C	C
Carbon Water Slurries	C	B	A	A	A	A	A	A	A	A		A	A	A	A	A
Cesium, 260°F (127°C)	C	A	A	A	C	A	C	A		C			C	C	C	
Chlorine, Anhydrous	A	A	A	A	A	A	A	A,C*	C		C	A	C	C	C	C
Chlorine Water	C	C	C	A	C	A	A	A	A	A	A	A	A	A	A	C
Chloroacetic Acid	C	C	C	C	C	A	A	A	C			A	C	C	B	
Chlorobenzene	C	A	A	A	A	A	A	A	C	C	C	A	A	C	C	
Chloroform	B	A	A	A	A	A	A	A,B*	C	C		A	A	C	C	
Chlorosulfonic Acid	C	B	B	B	B	A	A	A,C*	C	C	C	C	C	C	C	C
Choline Chloride	C	A	A	A	A	A	A	A								
Chromic Acid to 150°F (66°C)	C	B	B	B	B	B	A	A			C	B		A	C	C
Citric Acid	C	B	B	A	B	A	A	A	A	A	A	A	A	A	A	A
Copper Chloride	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A
Copper Fluoride	C	B	B	B	A	A	C	A	C	A		A				
Copper Nitrate	C	B	A	A	C	B	A	A	A	A	A	A	A	A	A	A
Copper Sulfate	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A
Cottonseed Oil	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	
Creosols	A	A	A	A	A	A	A	A		C	C	A	C	C	C	C
Cyclohexane	B	A	A	A	A	A	A	A	C	C		A	A	C	C	C
Cyclohexanone	B	A	A	A	A	A	A	A	A	C		B	C	C	C	
Dichlorethane, Dry	A	A	A	A	A	A	A	A		C	C					C
Diethanolamine	A	A	A	A	A	A	A	A	A	C		C	C	C	C	
Diethyl Benzene	A	A	A	A	A	A	A	A	C	C						
Diethyl Ether	A	A	A	A	A	A	A	A				B	C	C	C	
Diethyl Sulfate	C	B	B	A	B	A	A	A								
Diethylene Glycol	B	A	A	A	A	A	A	A	A		A		A	A	A	A
Dimethyl Amine	A	A	A	A	A	A	A	A	C	C		C				
Dimethyl Phthalate	A	A	A	A	A	A	A	A		C		B	C	C	C	
Ether	A	A	A	A	A	A	A	A,B*	C	C		B	C	C	C	
Ethyl Acetate	A	A	A	A	A	A	A	A,B*	B	C	C	B	C	C	B	C
Ethyl Alcohol	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	
Ethyl Benzene	A	A	A	A	A	A	A	A	C		C	A	A	C	C	
Ethyl Bromide	C	C	C	C	C	C	A	A		C		A				
Ethyl Chloride	C	A	A	A	A	A	A	A	C	C	C	A	A	C	A	C
Ethyl Mercaptan	B	A	A	A	A	A	A	A	A	C						
Ethylene (Liquefied)	A	A	A	A	A	A	A	A								
Ethlene Dichloride	C	A	A	A	A	A	A	A	C		C	A	B	C	C	C
Ethylene Glycol	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Ethylene Oxide	C	A	A	A	A	A	A	A	C	C		A	C	C	C	C
Fatty Acids	C	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A
Ferric Chloride	C	C	C	C	C	B	A	A	A	A	A	A	A	A	A	A
Ferric Nitrate	C	B	B	A	C	A	A	A	A	A	A	A	A	A	A	A
Ferric Sulfate	C	C	B	C	C	A	A	A	A	A		A	A	A	A	A
Ferrous Chloride	C	C	C	C	A	C	A	A	A	A	A	A	A	A	A	A
Ferrous Sulfate	C	C	C	C	C	B	A	A	A	A	A	A	A	A	A	A
Filter Aid Slurries	B	A	A	A	A	A	A	A		A		A	A	A	A	
Fluosilicic Acid	C	C	C	B	B	A	C	A	C	A		A	A	A	A	A
Formaldehyde, 80°F (27°C), Rm. Temp	B	B	A	A	A	A	A	A	A	B		A	A	A	B	A
Formic Acid, 80°F (27°C)	C	B	A	A	B	A	A	A	A	B		A	B	A	A	C
Freons™, 80°F (27°C)	B	A	A	A	A	A	A	A,B*	A		C	A			C	C
Fuel Oil	A	A	A	A	A	A	A	A	A	A	C	A	A	B	C	C
Furfural	B	A	A	A		B	A	A	C	C	C	B	C	C	B	C
Furfural Alcohol	B	B	B	A	B	B	A	A	C	C	C		C	C	C	C
Gallic Acid, 5%	C	B	B	B	B	B	A	A	A	A		B	A	B	B	B

Rating Key: A, Substantial Resistance; B, Moderate Resistance; C, Severe Effect; blank, No Data

Figure D2 Corrosion Guide (continued)[7]

	Carbon Steel	Stainless 304	Stainless 316	Stainless 20	Monel	Hastelloy C	Alumina Ceramic	TFE or KEL-F*	FPP(Glass-Filled Polypropylene)	PVC	Polyethylene	Kynar	Viton	Hypalon	Nordel	Neoprene
Gasoline	A	A	A	A	A	A	A	A	C		C	A	A	C	C	C
Glucose	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycerine	B	A	A	A	A	A	A	A	A	A		A	A	A	A	A
Heptane	B	A	A	A	A	A	A	A	A	C	C	A	A		C	B
n-Hexane	B	A	A	A	A	A	A	A	A	C		A	A	B	C	B
Hydrazine, 35% and above	C	A	B	B	B	B	B	A	C	C			C	C	C	B
Hydrobromic Acid	C	C	C	C	C	B	A	A	A	B	A	A	A	A	A	C
Hydrochloric Acid, 37%	C	C	C	C	C		A	A	A	A	A	A	A	C	B	C
Hydrocyanic Acid	C	A	A	A	A	A	A	A	A	A		A	A	A	A	C
Hydrofluoric Acid to 48%	C	C	C	C	B	A	C	A	A	A	C	A	A	A	A	C
Hydrogen Chloride, Dry	A	A	A	A	A	A	A	A	A			A		C	C	
Hydrogen Cyanide	B	A	A	A	C	A	A	A		A		A		C	C	
Hydrogen Fluoride-Anhydrous	C	C	C	C	A	A	C	A	C		C	A				C
Hydrogen Peroxide 50%	C	A	A		C		A	A	A			A	C	C	C	C
Hydrogen Peroxide, 90%	C	A	A		C		A	A	B	C		A	C	C	C	C
Hydrogen Sulfide	C	B	B	B	B	A	A	A	A	A		A		B	A	A
Hydroquinone	A	A	A	A	A	A	A	A	A	A			C	C	C	
Hypo (Sodium Thiosulfate)	C	B	A	A	B	A	A	A	A	A		A	A	A	A	
Iodine Solution, 5%	C	C	C	C	C	A	A	A	C	C	C	A	A	C	C	C
Isopropyl Alcohol	A	A	A	A	A	A	A	A	A			B	A	A	A	
Isopropyl Chloride, Dry	B	A	A	A	A	A	A	A				A				
Kerosene	A	A	A	A	A	A	A	A	A	A	C	A	A	B	C	C
Lactic Acid, 50% 80°F (27°C)	B	B	A	A	C	A	A	A	A	A	A	B	A	A	A	A
Lard Oil	A	A	A	A	A	A	A	A	C			A	A	A	A	C
Lead Acetate	B	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A
Lead-Tetraethyl	B	A	A	A	A	A	A	A				A				
Magnesium Carbonate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Magnesium Chloride	C	B	B	A	C	A	A	A	A	A	A	A	A	A	A	A
Magnesium Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Magnesium Sulfate	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A
Maleic Acid-Dilute	C	B	A	A	B	A	A	A	B	A		A	A	C	C	C
Melamine Resins	C	B	B	B	A	A	A	A								C
Mercaptans	A	A	A	A	A	A	A	A				A				
Mercuric Chloride, Sol.	C	C	C	B	C	B	A	A	A	A		A	A	A	A	
Mercury	B	A	A	B	C	B	A	A	A	A	B	A	A	A	A	A
Methyl Alcohol	A	A	A	A	A	A	A	A	A	A		A	C	A	A	A
Methyl Cellosolve	A	A	A	A	A	A	A	A				A	C	C	B	B
Methyl Formate	A	A	A	A	A	A	A	A					C			
Methylene Chloride	B	A	A	A	A	A	A	A	C	C	C	B	C	C	C	C
Methyl Ethyl Ketone	A	A	A	A	A	A	A	A	B	C	C	C	C	C	A	C
Monochloroacetic Acid 70°F (21°C)	C	B	B	B	B	A	A	A	A	A		A				
Morpholine	A	A	A	A	A	A	A	A				C	C	C	C	
Muriatic Acid	C	C	C	C	C	A	A	A	A	A	A	A	A	A	B	C
Mustard	C	B	A	A	B	A	A	A	A	A						A
Naphtha	B	A	A	A	A	A	A	A	B	A	C	A	A	C	C	C
Naphthalene, Molten	A	A	A	A	A	A		C	C	C	C	A	A	C	C	C
Nickel Carbonyl, Solution		B	A	A		A	A	A								
Nickel Chloride, Solution		B	B	B	B	A	A	A	A	A	A	A	A	A	A	A
Nickel Nitrate, Solution		A	A	A	B	B	A	A	A	A	A	A	A	A	A	A
Nickel Sulfate, Solution		B	A	B	A	A	A	A	A	A	A	A	A	A	A	A
Nitric Acid to conc.-Rm.		A	A	B′	C	B	A	A	C	C	C	A	A	C	C	C
Nitric Acid, Red Fuming, Rm.		A	A	B	C	B	A	A	C	C	C	B	C	C	C	C
Nitro Benzene to 212°F (100°C)		B	A	A		A	A	A	C	C	C	B	B	C	C	C
Nitrous Acid, 5%		A	A	A		A	A	A				A				
Nitrogen Tetroxide		A	A	A		A	A	A				A	C	C	C	

Rating Key: A, Substantial Resistance; B, Moderate Resistance; C, Severe Effect; blank, No Data

Figure D3 Corrosion Guide (continued)[8]

	Carbon Steel	Stainless 304	Stainless 316	Stainless 20	Monel	Hastelloy C	Alumina Ceramic	TFE or KEL-F*	FPP(Glass-Filled Polypropylene)	PVC	Polyethylene	Kynar	Viton	Hypalon	Nordel	Neoprene
Nitrochlorobenzene				A		B	A	A		C			A			
Oleic Acid		A	A	A		A	A		A	A	A	A	B	C	C	B
Oleum-25%		B	A	A		A	A	A	C	C	C	C	B	C	C	C
Olive Oil	A	A	A	A	A	A	A	A	A	A	C		A	B	B	C
Oxalic Acid		B	B	A	A	A	A	A,B*	A	A	A	A	A	B	A	B
Paraffin-Molten	A	A	A	A	A	A	A	A	A							
Paraldehyde	A	A	A	A	A	A	A	A								
Pentane	A	A	A	A	A	A	A	A				A	A	B	C	
Perfumes	A	A	A	A	A	A	A	A						A		
Phenol-Molten	B	B	B	B	A	A	A	A	C	C	C	A	A	C	C	C
Phosgene		A	A	A		A	A	A		C						
Phosphoric Acid, 60% Free of HF	C	B	B	A		A	A	A	A	A	A	A	A	B	C	C
Phosphoric Acid, 75% Free of HF	C	B	B	A		A	A	A	A	A	A	A	A	B	C	C
Phosphorous-Molten		B	A	A	A	A		A	C		C					C
Phosphorous Oxychloride	C					A	A	A								
Phosphorous Trichloride	C	A	A	A		A	A	A	C			A	A	C	A	C
Pine Oil	A	A	A	A	A	A	A	A					B	C	C	
Phthalic Anhydride		B	B	A	B	A		A								
Potassium Chromate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Potassium Bromide	C	B	B	A		A	A	A	A	A	A	A	A	A	A	A
Potassium Carbonate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Potassium Chlorate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Potassium Chloride	C	B	B	A	B	A	A	A	A	A	A	A	A	A	A	A
Potassium Dichromate	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	
Potassium Ferrocyanide	B	A	B	A	A	A	A	A	A	A	A	A	A	A		
Potassium Hydroxide	B	B	A	A		A	C	A	C	A	A	A	B	A	A	B
Potassium Iodide	C	B	B		A	A	A	A		A		A	A	A	A	
Potassium Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Potassium Permanganate	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Potassium Sulfate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Propane	A	A	A	A	A	A	A	A	C	A	C	A	A	B	C	B
Propylene Dichloride, Dry	B	A	A	A	A	A	A	A	C	C	C					C
Propylene Glycol	A	A	A	A	A	A	A	A	A		A		A	A	A	C
Propylene Oxide	A	A	A	A	A	A	A	A,B*			B	C	C	C	A	C
Pyrogallic Acid	B	A	A	A	A	A	A	A								
Quinoline		A	A	A	A	A	A	A								
Silver Nitrate		A	A	A		A	A	A	A	A	A	A	A	A	B	A
Sodium-Molten		A	A	A		A		C	C		C					C
Sodium-Potassium, NaK Alloy		A	A					C								
Sodium Acetate		B	A	A	A	A	A	A,B*	A	A	A	A	C	C	A	B
Sodium Aluminate	B	A	A	A	A	A	A	A		A		A	B	A	A	A
Sodium Bicarbonate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Bichromate	B	A	A	A	A	A	A	A		A		A	A	A	A	
Sodium Bifluoride Slurry		A	A	A	C							A	C	A		
Sodium Bisulfate		B	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Bisulfite	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Borate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Bromide	C	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Carbonate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Chlorate	C	B	B	A	A	A	A	A	A	A	B	A	A	A	A	A
Sodium Chloride	C	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Chlorite	C	C	C	C	C	A	A	A	A	A		A	A	A	A	C
Sodium Citrate	B	A	A	A	A	A	A	A		A						

Rating Key: A, Substantial Resistance; B, Moderate Resistance; C, Severe Effect; blank, No Data

Figure D4 Corrosion Guide (continued)[9]

	Carbon Steel	Stainless 304	Stainless 316	Stainless 20	Monel	Hastelloy C	Alumina Ceramic	TFE or KEL-F*	FPP(Glass-Filled Polypropylene)	PVC	Polyethylene	Kynar	Viton	Hypalon	Nordel	Neoprene
Sodium Cyanide	B	A	A	A	B	A	A	A	A	A	B	A	A	A	A	A
Sodium Dichromate	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	B
Sodium Ferricyanide, 5%	B	A	A	A	A	A	A	A	A	A		A	A	A	A	B
Sodium Fluoride	C	C	B	B	B	B	C	A	C	A	C	A	A	A		C
Sodium Hydroxide, 50%	A	A	A	A	A	A	C	A	C	A	B	A	B	A	A	B
Sodium Hydroxide, 73%	B	B	B	B	B	A	C	A	C		B	A	C	A	A	B
Sodium Hypochlorite, 5%	C	C	C	C	C	A	A	A	A	A	B	A	A	A	A	C
Sodium Hypochlorite, 20%	C	C	C	C	C	A	B	A	B	A	B	A	B	A	C	C
Sodium Metaphosphate	B	A	A	A	A	A	A	A	A	A		A	A	A	A	B
Sodium Nitrate	B	A	A	A	B	A	A	A	A	A	A	A	A	A		A
Sodium Nitrite		B	A	A	A	A	A	A	A	A	A	A	A			A
Sodium Peroxide	C	A	A	A	B	A	A	A	A			A	A	B	A	A
Sodium Silicate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Sulfite		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Thiosulfate (Hypo)	C	B	B	A	B	A	A	A	A	A	A	A	A	A	A	A
Stannic Chloride	C	C	C	B		A	A	A	A	A	A	A	A	C	A	C
Stannous Chloride		B	A	A	B	A	A	A	A	A	A	A	A	A	A	A
Stearic Acid		A	A	A	B	A	A	A	B	A	B	A	A	B	B	B
Styrene		A	A	A	A	A	A	A					C	C	C	C
Sulfamic Acid				B		A	A	A	A							B
Sulfur-Molten		A	A	A	A	A	A	A				A	C	C	C	
Sulfur Chloride		C	C	A		A		A	C		B		C	C	C	C
Sulfur Dioxide, Dry	A	A	A	A	A	A	A	A			C	A			A	C
Sulfan™	C	B	A	A		A	A	A				C	C	C	C	
Sulfur Trioxide	C	B	A	A		A	A	A				C	C	C	C	
Sulfuric Acid below 93%	C	C	C	A	C	A	A	A	C	B	C	A	A	A	C	C
Sulfuric Acid-Commercial Concentrated	C	C	A	A	C	A	A	A	B	C	C	A	A	B	C	C
Sulfuric Acid, Fuming, 20%		B	A	A		A	A	A	C	C	C	C	B	C	B	C
Sulfurous Acid		B	B	A		A	A	A	A	A		A	A	A	C	
Tannic Acid, 10%		A	A	A	B	A	A	A	A	A		A	A	A	A	A
Tartaric Acid		B	A	A	A	A	A	A	A	A	A	A	A	A	B	A
Thionyl Chloride	C	C	B			A	A	A		C						
Titanium Dioxide Slurry	B	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Titanium Tetrachloride, Dry	A	A	A	A	A	A	A	A			C		A	A	B	B
Toluene	A	A	A	A	A	A	A	A	C	C	C	B	B	C	C	C
Tributyl Phosphate	B	A	A	A	A	A	A	A,B*	A	C	C	B	C	C	C	C
Trichloroethylene, Dry	A	A	A	A	A	A	A	A,C*	C	C	C	A	A	C	C	C
Tricresyl Phosphate	B	A	A	A	A	A	A	A	C	C	C		B	C	A	C
Triethanolamine		A	A	A	A	A	A	A	A	B	C	C	C	C	B	A
Trisodium Phosphate, Sol.	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Tung Oil	A	A	A	A	A	A	A	A	A				A	C	C	
Turpentine	A	A	A	A	A	A	A	A	C	A	B	A	A	C	C	C
Urea Formaldehyde	A	A	A	A	A	A	A	A				A				
Vegetable Oils	A	A	A	A	A	A	A	A		A		A	A	A	A	C
Uranium Nitrate		A	A	A	B	A		A								
Vinyl Acetate		A	A	A		A	A	A				A	C	C	C	C
Vinylidene Chloride		A	A	A	A	A		A								
Vinylidene Fluoride	B	A	A	A		A	C	A	C							
Xylene		A	A	A	A	A	A	A	C	C	B	A	C	C	C	C
Zinc Oxide Slurry	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zinc Sulfate	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Vitamin A		A	A	A		A	A	A					A	B		
Vitamin E		A	A	A		A	A	A					A	B		
Zinc Chromate		A	A	A		A		A		A			A	A	A	

Rating Key: A, Substantial Resistance; B, Moderate Resistance; C, Severe Effect; blank, No Data

Figure D5 Corrosion Guide (continued)[10]

Appendix E

Lubrication/Oil Analysis

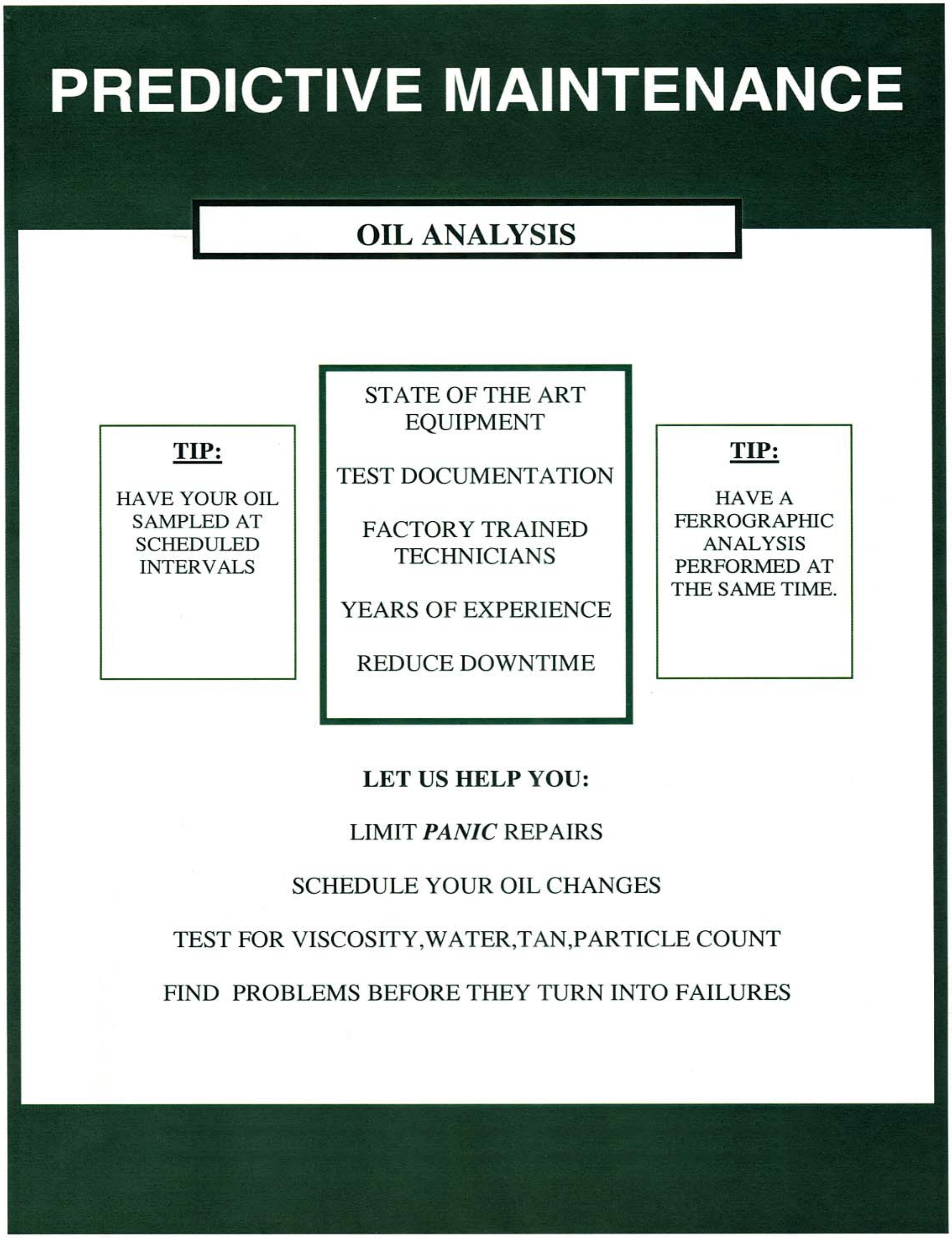


Figure E1 Lubrication Analysis[11]

EQUIPMENT CONDITION REPORT

XYZ MANUFACTURING
CLEVELAND, OH
EXAMPLE REPORT

CRITICAL

SAMPLE ID:	USE-DRYER #4-GB	SAMPLE DATE:	01/24/96
SAMPLE DESC:	C1 AGITATOR	REC'D DATE:	01/26/96
COMPONENT:	Gearcase/Speed Reducer	REPORT DATE:	01/26/96
MANUFACTURER:	FAULK	1st SAMPLE:	06/20/94
LUBRICANT:	MOBIL MOBILGEAR 627	PREV SAMPLE:	12/23/95 [C]
RESERVOIR CAP:	65 Gallons [246.35 Liters]	NO. SAMPLES:	25
LUBE TIME:	1508 Hours MACHINE TIME: 52898 Hours	PROGRAM:	P1

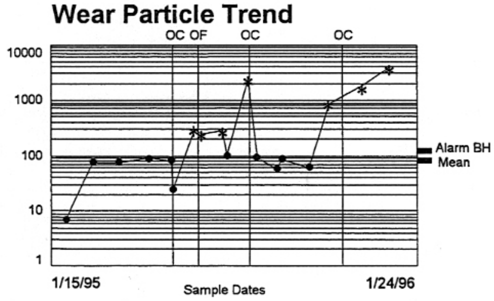
RECOMMENDATIONS:

Consider scheduling an inspection of the bronze bearing retainers and bushings as well as the gear teeth for severe abnormal wear and pitting. Check also for spalling of the bearing rollers and shaft.

Discussion Of Results:

The wear particle concentration increased from 1780 to 3950. Analytical results reveal the continued presence of abnormal wear particles. Cutting, gear, bearing, and spherical wear particles are present. These particles measure up to 150 microns in size and are composed of low alloy steel and copper alloy (bronze). It appears that a bearing retainer is in a severe abnormal wear condition that is causing a misalignment between the bearing and shaft. Large concentrations of ferrous oxides and contaminants are also detected. These particles indicate corrosion and high operating temperatures due to inadequate or poor lubrication. Consider inspecting this agitator for damage to the bearing retainers and bushings. Also, check for severe gear teeth spalling and pitting. Please report any findings to this lab.

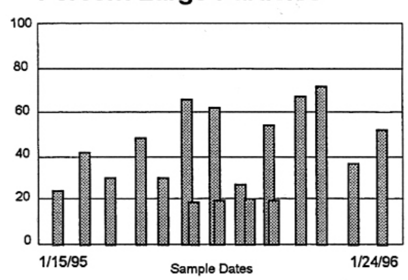
Wear Particle Trend



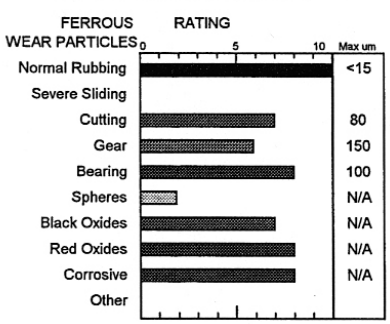
QUANTITATIVE RESULTS:

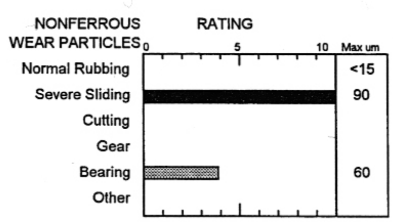
WPC:	3950.0
DL:	3010.0
DS:	940.0
Mean:	76.5
Std Dev:	25.6
Alarm A:	229.4
Alarm BH:	135.3
Alarm BL:	17.7
Alarm MH:	Not Set
Alarm ML:	Not Set
Water KF:	467 ppm
Refrigerant:	NEG
PLP:	52.4%
Viscosity:	14.73 cSt

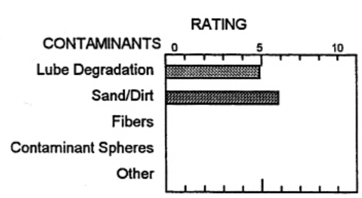
Percent Large Particles



ANALYTICAL RESULTS:







Copper White Lead/Tin Babbitt

Low Alloy Medium Alloy High Alloy Case Hardened

Figure E2 Lubrication Analysis Report[12]

Appendix F

Vibration Analysis

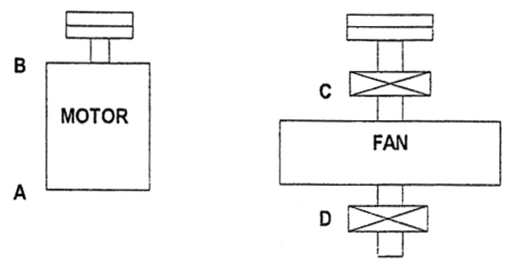
Customer

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 F1 Vibration Analysis[13]

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 F2 Vibration Analysis Report[14]

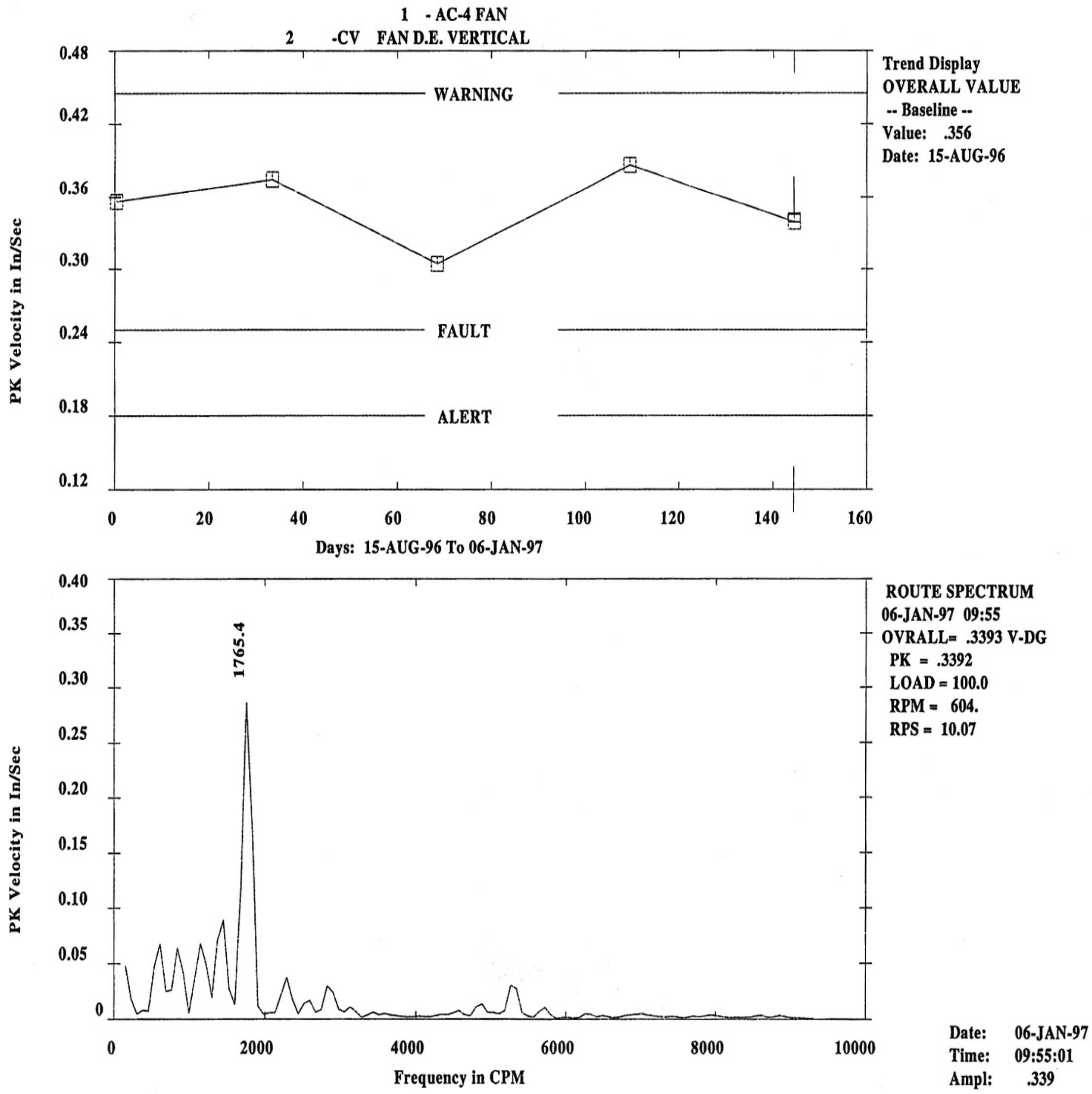
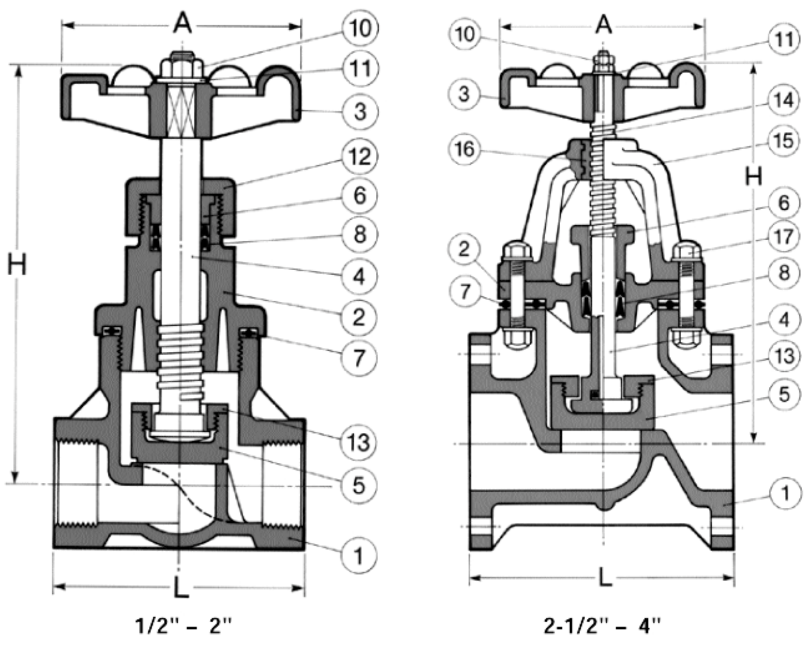


Figure F3 Vibration Analysis Graphical Report[15]

Appendix G

Restricted Passage Valves

Figure G1 Butterfly Valve[16]



PARTS

No.	Part
1	Body
2	Bonnet
3	Handwheel
4	Stem
5	Disc
6	Gland
7▲	Bonnet Seal
8▲	Stem Packing
10	Nut
11	Washer
12	Gland Nut
13	Disc Retainer
14	Stem Top
15	Yolk
16	Yolk Sleeve
17	Bolt & Nut
18	Stud & Nut

Figure G2 Globe Valve[17]

Figure G3 Check Valve (Double Door)[18]

Figure G4 Flapper Valve[19]

Figure G5 Flapper-Swing Check Valve[20]

Appendix H

Open Bore Valves

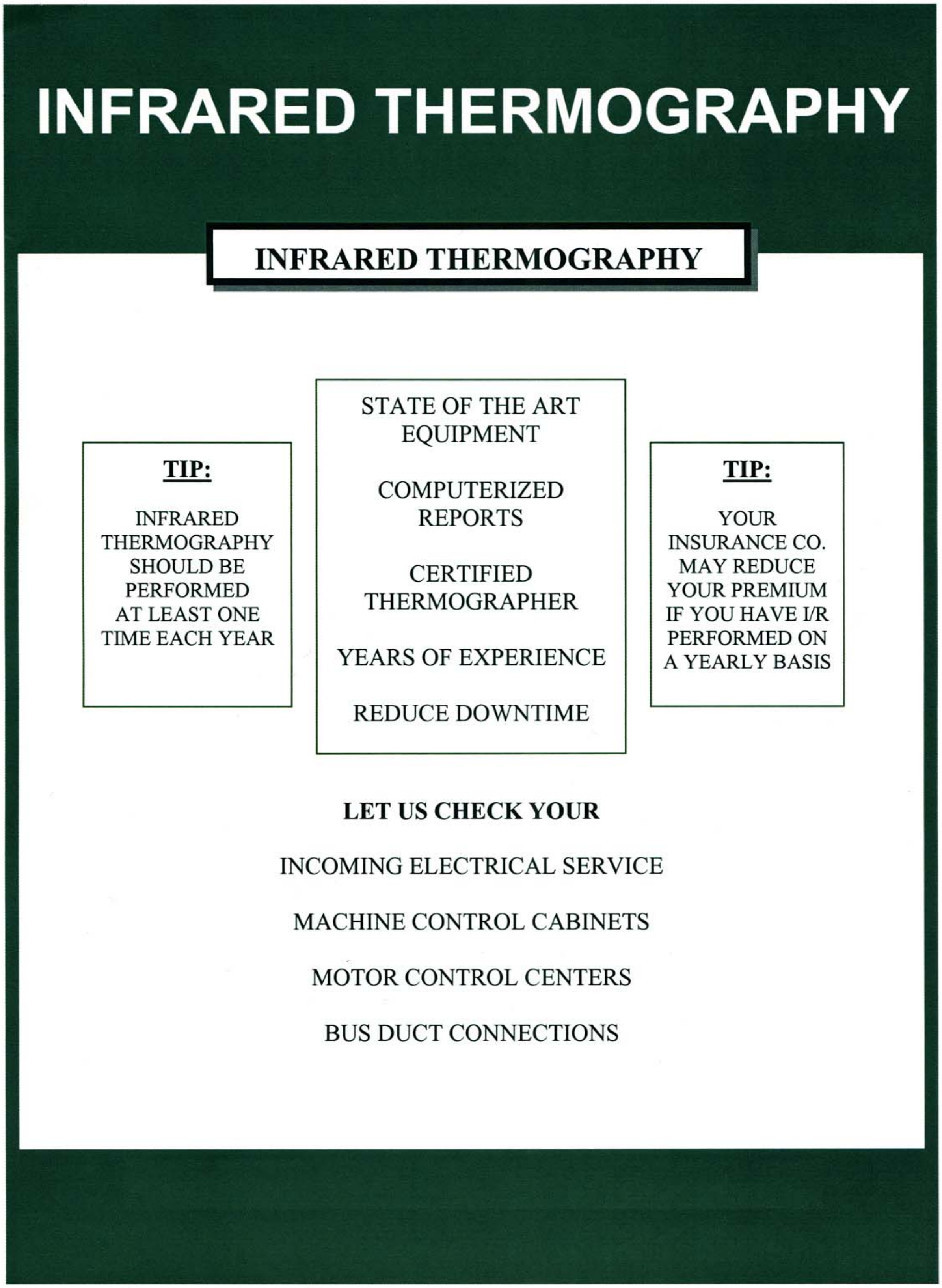
Figure H1 Ball Valve[21]

Figure H2 Knife Gate Valves[22]

Figure H3 Pinch Valve[23]

Appendix I

Thermography (Infrared) Reports



INFRARED THERMOGRAPHY

INFRARED THERMOGRAPHY

TIP:

INFRARED THERMOGRAPHY SHOULD BE PERFORMED AT LEAST ONE TIME EACH YEAR

STATE OF THE ART EQUIPMENT

COMPUTERIZED REPORTS

CERTIFIED THERMOGRAPHER

YEARS OF EXPERIENCE

REDUCE DOWNTIME

TIP:

YOUR INSURANCE CO. MAY REDUCE YOUR PREMIUM IF YOU HAVE I/R PERFORMED ON A YEARLY BASIS

LET US CHECK YOUR

INCOMING ELECTRICAL SERVICE

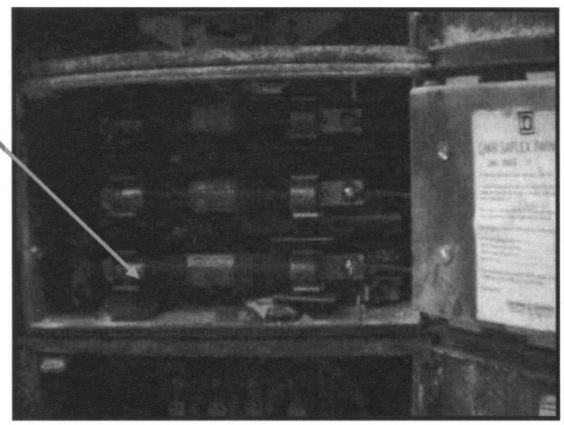
MACHINE CONTROL CABINETS

MOTOR CONTROL CENTERS

BUS DUCT CONNECTIONS

Figure I1 Thermography Report Cover Sheet[24]

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:

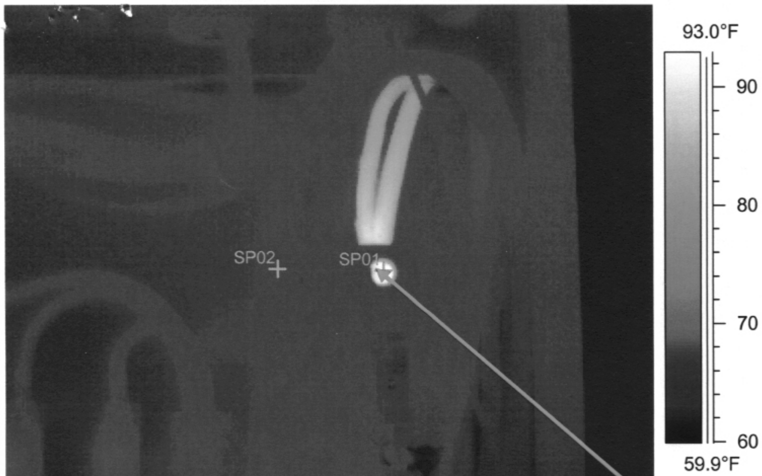
C Phase line side of breaker is overheated

PHASE TO PHASE CURRENT:

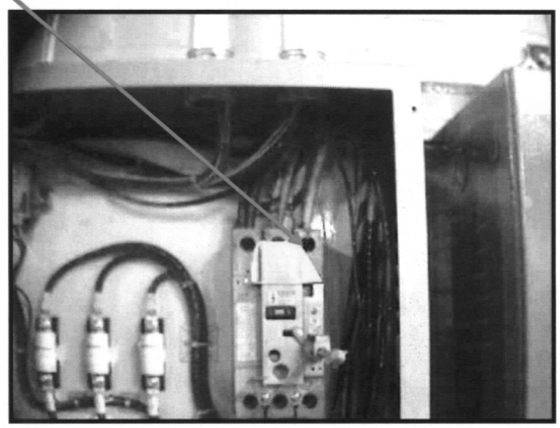
RECOMMENDATIONS:

Clean and tighten bad fuse clip or replace fuse block

Figure I2 Thermography Report #1[25]



FRAME NUMBER	C1210-13.img
AMBIENT TEMP	70.0°F
SPOT 1	94.0°F
SPOT 2	64.5°F
DELTA SPOT1 & SPOT 2	-29.5°F
DATE	12/10/2002
TIME	11:10:10 AM



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

EQUIPMENT:	Main drive cabinet main breaker
AREA:	142 flexo

PROBLEM:

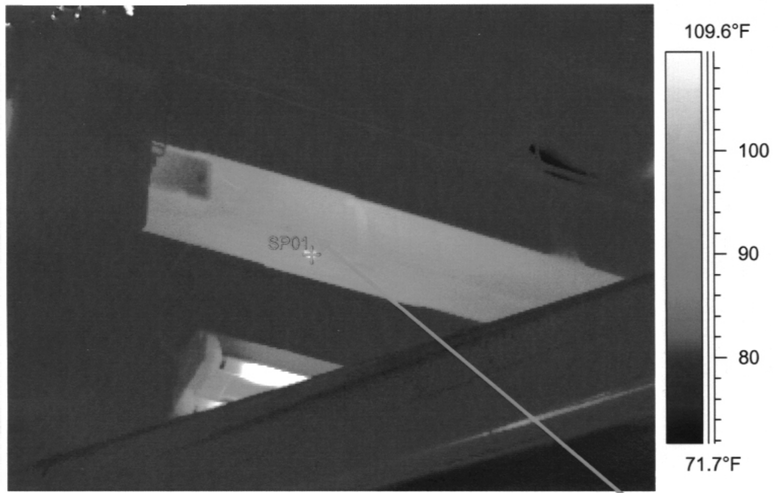
C Phase line side of breaker is overheated

PHASE TO PHASE CURRENT:

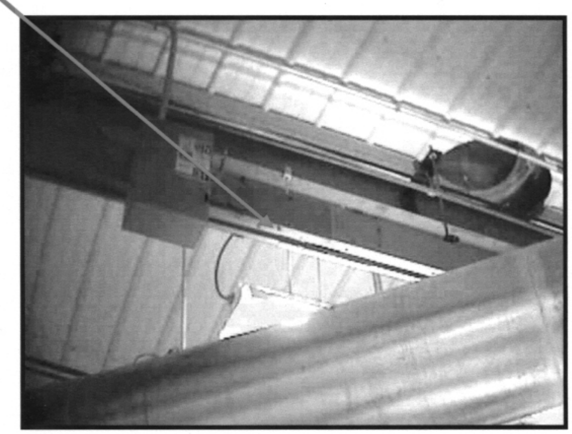
RECOMMENDATIONS:

Disassemble clean and retighten bad connection

Figure I3 Thermography Report #2[26]



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 I4 Thermography Report #3[27]

Appendix J

Gauges

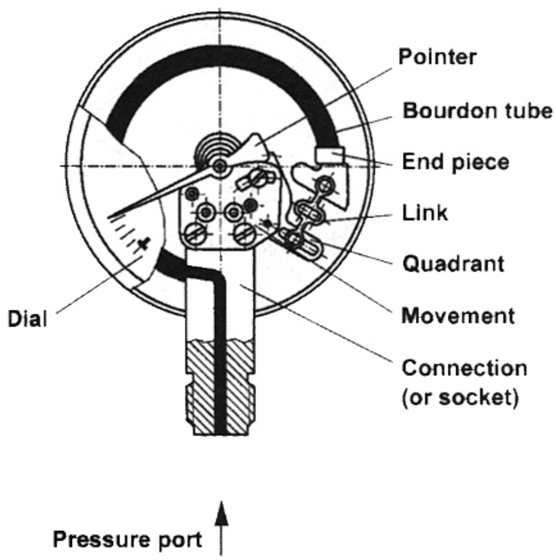


Figure J1 Pressure Gauge[28]

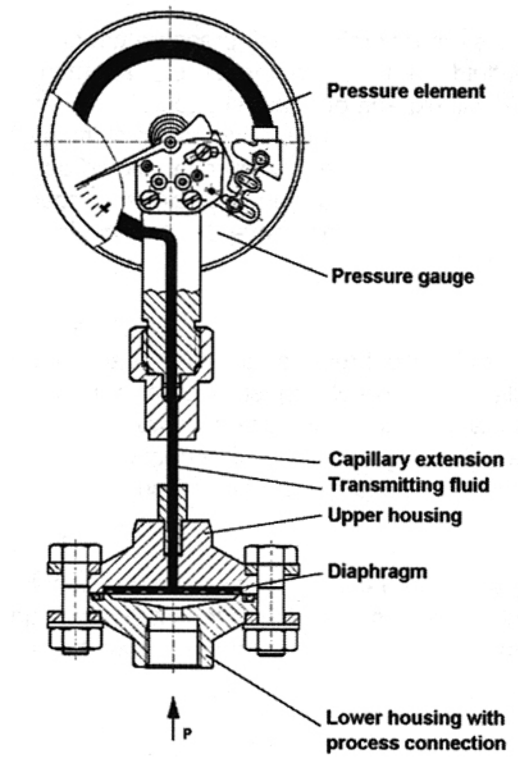
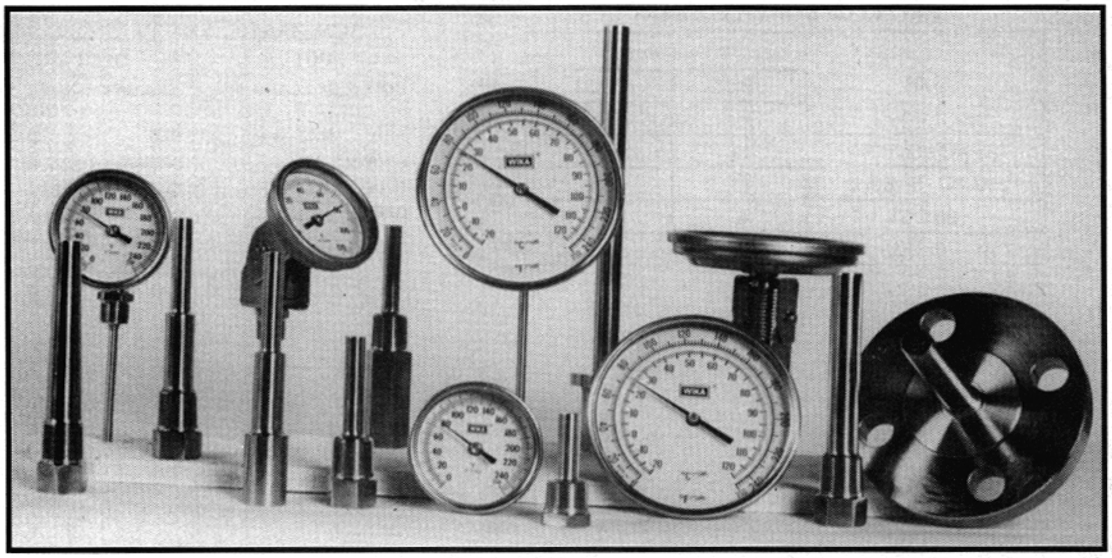


Figure J2 Pressure Gauge Diaphragm[29]

Appendix K

Thermometers



The temperature is measured with a bimetal system inside the thermometer stem. The bimetal system consists of two metal strips bonded together that have different expansion coefficients. Therefore, one strip will expand faster than the other causing the bimetal strip to curl in proportion to its temperature. The bimetal system is helically wound and heat treated for long term stability. Temperature variations cause the bimetal strip to unwind or wind tighter which in turn rotates the pointer.

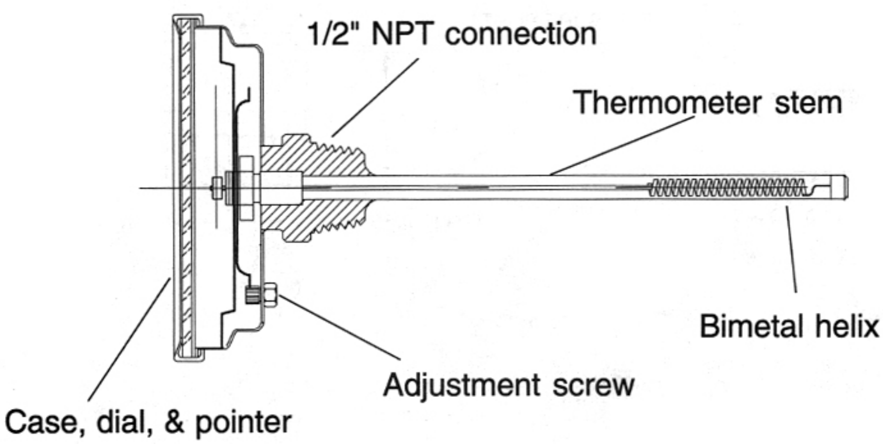
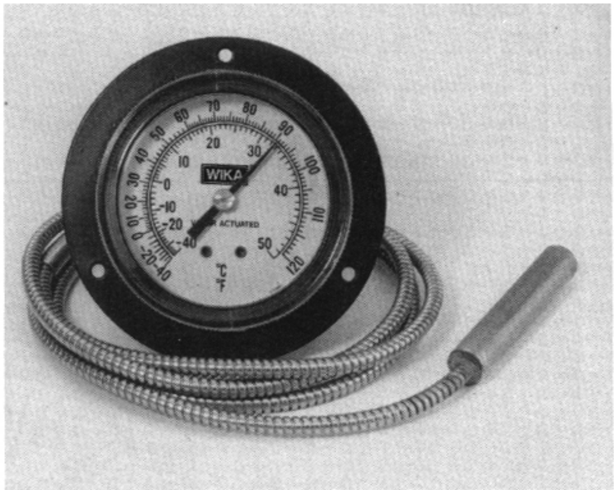


Figure K1 Bi-Metal Thermometer[30]



Shown above is a Model V25F Front Flange Case, with stainless steel interlocking armor on an 8' capillary, a plain stainless steel 2-5/8" bulb, with a range of -40/120°F & -40/50°C dual scale range.

Figure K2 Vapor Actuated Thermometer[31]

Figure K3 Electronic Probe Thermometer[32]

[1] Mark Earley, Joseph Sheehan, Jeffrey Sargent, John Caloggero, and Timothy Croushore, *NEC® 2002: National Electrical Code Handbook,* (2002).

[2] Mark Earley *et al*.

[3] "APWA Temporary Marking Guidelines," Pennsylvania One-Call System, http://www.paonecall.org (accessed 5/25/03).

[4] "Hot Work Permit," Factory Mutual System, 2630 (5-92) PUBS, Factory Mutual Engineering.

[5] "Hot Work Permit."

[6] Robert E. McCabe, *Metering Pump Handbook*, (New York, NY: Industrial Press Inc., 1984), p. 264.

[7] Robert E. McCabe, p. 265.

[8] Robert E. McCabe, p. 266.

[9] Robert E. McCabe, p. 267.

[10] Robert E. McCabe, p. 268.

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

[12] Motor Technology, Inc.

[13] Motor Technology, Inc.

[14] Motor Technology, Inc.

[15] Motor Technology, Inc.

[16] "Butterfly Valve," Dezurik Manufacturers, http://www.tek-sales.com, (accessed 5/15/03).

[17] "Globe Valve," Chemline Plastics Limited, www.chemline.com/PDF%20Files/ WebGlobePDF.PDF, (accessed 5/27/03).

[18] "Double Door Check Valve," APCO Willamette, http://www.apcovalves.com/checkva2.htm, (accessed 5/29/03).

[19] "Rubber Flapper," APCO Willamette, http://www.apcovalves.com/bulletin100.htm, page 2, (accessed 5/25/03).

[20] "Rubber Flapper Swing Check Valve," APCO Willamette, http://www.apcovalves.com /checkva1.htm, (accessed 5/25/03).

[21] "Ball Valve," Chemline Plastics Limited, http://www.chemline.com/PDF%20Files/WebGlobePDF.PDF, (accessed 5/18/03).

[22] "Knife Gates," Red Valve Company, Inc., http://www.redvalve.com/knife-gates.html, (accessed 5/29/03).

[23] "Pinch Valve," Red Valve Company, Inc., http://www.redvalve.com/manual.html, (accessed 5/29/03).

[24] Motor Technology, Inc.

[25] Motor Technology, Inc.

[26] Motor Technology, Inc.

[27] Motor Technology, Inc.

[28] WIKA Instrument Corporation, Catalog, p. 9

[29] WIKA, p. 195.

[30] WIKA, p. 136.

[31] WIKA, p. 168.

[32] WIKA, p. 328.