Drinking Water Operator Certification Training Instructor Guide

Module 10: General Maintenance

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

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

A Note to the Instructor

Dear Instructor:

The primary purpose of *Module 10: General Maintenance* is to introduce participants to the basics of plant maintenance. This module has been designed to be completed in approximately 4 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the Pa. DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the Pa. DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by Pa. DEP.

Web site URLs and other references are subject to change, and it is the training sponsor's responsibility to keep such references up to date.

Delivery methods to be used for this course include:

- Lecture
- Small and Large Group Discussions
- Experiential Activity
- PowerPoint Slides

To present this module, you will need the following materials:

- One workbook per participant
- Extra pencils
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Flip Chart
- Markers

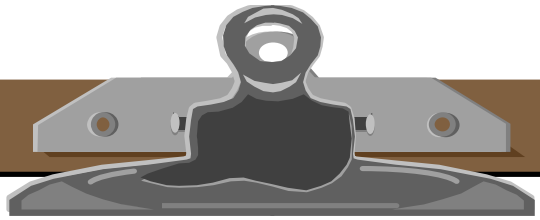
Icons to become familiar with include:

Participant Workbook		Instructor Guide	
	Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.	
	Case Study	**Ans:**	Answer to exercise, case study, discussion, question, etc.
	Discussion Question		PowerPoint Slide
	Calculation(s)		Overhead
	Quiz		Flip Chart
	Key Definition(s)		Suggested "Script"
	Key Point(s)		

Instructor text that is meant to be general instructions for the instructor are designated by being written in script font and enclosed in brackets. For example:

[*Ask participants if they have any questions on how to read the table. Answer any questions participants may have about how to read the table.]*

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.



PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	**Press**
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

Display Slide 1—Module 10: General Maintenance.

[Welcome participants to "Module 10 – General Maintenance." Indicate the primary purpose of this course is to familiarize them with the basics of plant maintenance.

Introduce yourself.

Provide a brief overview of the module.]

This module contains 4 units. On page i, you will see the topical outline for **Unit 1 – Introduction to Maintenance** and **Unit 2 – Structure of a Maintenance Program**.

[Briefly review outline.]

If you turn the page, you will see the topical outline for **Unit 3 – Implementation of a Preventive Maintenance Plan** and **Unit 4 – Maintenance Procedures.**

[Continue to briefly review outline.]

UNIT 1 – INTRODUCTION TO MAINTENANCE: 40 minutes

Display Slide 2—Unit 1: Introduction to Maintenance.

At the end of this unit, you should be able to:

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

OVERVIEW: 20 minutes

Definition of Maintenance

[Review the definition of maintenance by paraphrasing.]

The Role of Maintenance in the Overall Operation

Like everything that is created, a treatment facility will begin to die as soon as it is "born."

[Review the information under "The Role of Maintenance in the Overall Operation" of the workbook.]

Of course, it is not possible to always guarantee individual equipment availability. Take a moment to complete the first discussion question in your workbook. Just write down any answers that you think cause downtime, or keep the equipment from being available when we need it. I will give you about three minutes to write some answers.

[When participants have finished the exercise (3 minutes), write the following four headings on the flipchart:

- *Human Error*
- *Acts of God or Nature*
- *Product Defects*
- *Planned Service Work*

Ask students to share the answers they have written. As they call out answers, write each one under the appropriate heading, or category. You may want to ask students where they think the answer should go.]

The four headings under which your answers fell are the general barriers to full equipment availability at a treatment plant. While you can easily see why we can not always rely on all the equipment working at the same time, a good maintenance program can improve overall plant availability.

Take a minute now to answer the next question in your workbook. Try to think of the ways in which we achieve minimum downtime, or high availability of equipment. Again, I will give you about three minutes to write your answers.

[After students have had an opportunity to think of some answers (3 minutes), write the following three headings on the flip chart. Proceed by asking students to assign some of their answers to the headings.

- *Continuous Monitoring and Assessment of Equipment*
- *"Real Time" Knowledge of Equipment Condition*
- *Analysis of Other Information, such as Equipment History, Operational Protocols, and Manufacturer's Data]*

In essence, we want to take a proactive approach to maintenance.

GOALS OF A MAINTENANCE PROGRAM: 20 minutes

In order to assume our proactive approach, we should understand what we are trying to protect through maintenance. There are five general goals of a maintenance program; in essence, these are the five things we protect by caring for them. Let's review each one. As we review, you will note that each section has at least one "key point" that will help you understand what the goal is about.

Safety and Environmental Protection

[Briefly review the information in this section. Be sure to indicate the importance of the key point.]

Please note Figure 1.1, on page 1-3 of your workbook. This picture represents a safety hazard in the workplace because there is danger of tripping on the cord. When you go back to your own work site, think about the hazards that might be around you. Work carefully!

***[Note to Instructor:** The next few sections (Fixed Asset Management, Maintenance of Design Intent, and Efficiency of Operation) do not need to be discussed in great detail. These topics may go beyond what a new operator needs, but it could be of benefit for them to be exposed to this information.]*

Fixed Asset Management

[Briefly review the information in this section. Be sure to indicate the importance of the key point. After the description, discuss the example below.]

For example, we all know that when you drive a new car off the dealer lot it drops in value. If you take care of the care, after a few years it is worth a certain amount. However, if you rarely change the oil and beat up on the exterior, after a few years the car will be worth much less. In a similar manner, your water system equipment must be maintained so that it depreciates at the predicted rate.

Maintenance of Design Intent

[Briefly review the information in this section. Be sure to indicate the importance of the key point.]

Efficiency of Operation

[Briefly review the information in this section. Be sure to indicate the importance of the key points.]

When plant personnel are constantly running around, trying to solve crises or "put out fires," they can rarely have time for other work. Planning maintenance activities and assigning the correct employees to those activities can actually save time, energy, and money. If we protect the equipment, it will need less "crisis" attention.

We will move on now to the last goal of maintenance, System Reliability.

System Reliability

[Briefly review the information in this section. Be sure to indicate the importance of the key point..]

We have discussed all five goals of a maintenance program. They were, in essence, to protect fixed asset management, the plant's design intent, the efficiency of the plant's operation, safety and environment, and the reliability of the system.

Turn the page now. You will see a set of Key Points. Use it as a tool for remembering and thinking about the information we learned in Unit One. If time permits, we will work on the questions at the end of this training session. If not, I suggest that you answer them in the next day or two so that the information is fresh in your mind.

***[NOTE TO INSTRUCTOR:** If you have time in this section, you may wish to modify the script and have participants work on the review questions in class for about ten minutes.]*

[Have the participants review the Key Points on this page before beginning the exercise.]

UNIT 1 EXERCISE: (10 minutes if desired)

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

Ans: fixed asset management; maintenance of design intent; efficiency of operation; safety and environmental protection; and system reliability

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

Ans: (possible answer) He/She/They want to protect their investment.

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

Ans: (Various answers available)

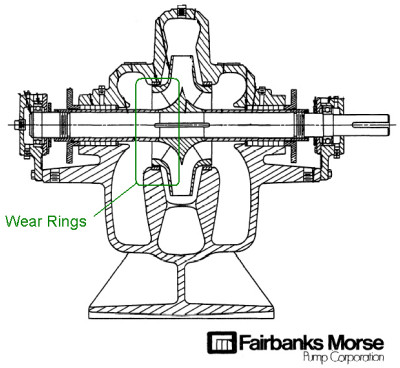
4. How does regular maintenance impact the availability of personnel?

Ans: Management knows how many people to assign to various tasks; keeping crises to a minimum, through regular maintenance, means that staffing is not "hit or miss" but is planned and organized.

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

Ans: Possible answers include valves, meters that read quality standards, equipment that responds to the metered data, etc.

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



Ans: Possible answers include lower pump efficiency; higher power consumption; need for more capacity placed online; increased burden on electrical system

Figure 1.2 Wear Rings

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UNIT 2 - STRUCTURE OF A MAINTENANCE PROGRAM: 85 minutes

Display Slide 3—Unit 2: Structure of a Maintenance Unit.

At the end of this unit, you should be able to:

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

GENERAL GUIDELINES FOR A MAINTENANCE PROGRAM: 45 minutes

Organizational Structure

Let's talk now about the structure of a maintenance program. If we are trying to accomplish the goals of a maintenance program, which we discussed in Unit 1, then we must go about our tasks in an orderly and efficient manner. In Unit 2, we will discuss some of the ways in which we can accomplish this. We start by looking at the way a program fits into the overall organization, or facility.

[Review the information above the questions in this section.

Ask students to answer the following questions. Encourage them to jot in their workbooks any answers that other students may give. Record the students' answers on a flipchart.]

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

[Ans: *Various answers are possible. The overall theme is that operators in a small facility will probably complete many types of maintenance on a routine basis.]*

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

[Ans: *Various answers are possible. The overall theme is that operators in a large facility will probably have a maintenance staff that does most of the maintenance tasks. However, the operator will make some minor adjustments, monitor equipment, and so forth.]*

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

[Ans: *The operators, of course, are involved in the everyday functioning of equipment and systems. They know the equipment well and know how it should perform. They can quickly notice any changes in performance. Also, it makes sense to think that operators know what works in the "real world" environment, as opposed to what works on the design table. Their input is valuable to the maintenance plan.]*

Review the definition of SOPs.

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

[Ans: *Various answers are possible. SOPs ensure that equipment is kept functioning properly, that reports are collected and analyzed, that meters can read the data, and so forth.]*

[Review the information in the workbook.]

Computerized Maintenance Management Systems (CMMS)

*[**NOTE TO INSTRUCTOR:** This topic may go beyond what a new operator needs, but it could be of benefit for them to be exposed to this information. Based on your audience, use your judgment to determine how much to cover.]*

It sounds daunting to convert a paper-based system to a computer system, doesn't it? Well, it is a time, money, and labor intensive process. That is true; however, after the initial adoption phase, data management by computer quickly becomes a very effective tool.

[Some of the basics of Computerized Maintenance Management Systems are covered here.]

[Review the information in this section.]

Assessing the Needs of the Organization with CMMS

Unit 3 of this training module will discuss specific steps for setting up a CMMS. For now, we will look at the benefits to the organization of using CMMS.

[Review the bulleted items, noting especially the reporting functions that are capable with CMMS. The final sub-bullets, for example, highlight the fact that work orders can be generated in any way that the operator chooses; this makes equipment-specific planning quicker and more certain to occur.]

[Review the factors involved in choosing an appropriate CMMS application for a specific facility.]

When you turn the page, you will see an actual screen shot of a CMMS in use. Let's look at that now.

Display Slide 4—Screen Shot.

Notice all the types of information that can be stored in this one screen. The equipment number, type, location, and so forth are listed here. You can see that it is located in the Northside Municipal Plant #1, but look closer and tell me exactly where we could find this unit.

[Ans: *Center Bay]*

See that there is a section for comments at the bottom. Whenever an operator or maintainer would prepare to service this equipment, he/she would interface with the CMMS. There, it would be obvious that the dispatcher must be notified prior to shutdown. How many times have you relied on a scribbled note tacked up on a wall or on the "I told everybody about that" method of communication? Does this look more efficient and professional? Do you think it could save time and trouble—not to mention money—if communication were this certain?

Notice now the tabs across the midpoint of the screen. Each of these tabs leads to a screen that is attached to this one; the individual screens might contain further information about the equipment. For example, what would be under the tab, "History"?

[Ans: *It would contain the service history, from PM through emergency calls that applies to this unit.]*

Implementation of a Maintenance Program with CMMS

To implement, or put into practice, a maintenance program with CMMS, remember the old saying, "Garbage in, garbage out." This means that the information we receive from a computer program is only as good as the information we feed it in the first place.

[Review the information in the workbook.]

Contract Work

There are many reasons that a plant might decide to contract work to outsiders or to bring on contracted staffers.

Balanced Work Load

[Briefly review the information in this section.]

Organization's Size

You are more likely to see contracted workers in a small system. Painting or protective coating application may not be a complicated job, for example, but the time it takes may exceed how much time the available labor pool in a small system has available for big projects.

[Briefly review the information in this section.]

Specialized Work

[Briefly review the information in this section.]

Preventive Maintenance as the Key Effort

Preventive Maintenance really addresses the definition of maintenance that you read in Unit 1. It is what helps us ensure that equipment is available, reliable, and operated with cost efficiency.

[Briefly review the information in this section.]

[Break the class into small groups to work on answering the following questions. After they are done, record their answers on a flipchart:]

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

[Ans: *Various answers are possible; answers vary according to the size and type of facility. Some examples include: adjusting packing gland on a pump seal; checking and recording pressure gauge readings for pumps, exercising valves as part of a semi-annual valve program.]*

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

[Ans: *Various answers are possible, including equipment failure, higher costs, lower available labor pool, operation-wide failures, etc.]*

Be aware that, as the level of diagnostic testing increases through the use of specialized instruments (IR scan, vibration analysis, etc), the term of preventive maintenance changes to more of a predictive nature. As you read professional journals, you will notice this trend in terminology.

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

Display Slide 5—EPM Cost.

[Ans: *When the EPM cost is lowest (for example, we are doing the minimum service and inspection) the operating and repair cost will be greatest. In virtually all cases when talking about major plant equipment, overall costs will be less if we do preventive maintenance. Insufficient PM can result in unplanned shutdowns (unpredictable and disruptive), emergency repairs (always costly) and catastrophic failures (possibly resulting in loss of life and property).*

Many maintenance people comment that, when a good PM plan is in place, their job is boring because the work is predictable and things do not break down. But, that is the type of operation management wants. By the same token, if we perform excessive PM, the costs can exceed the benefits. This is due to a waste of manpower and the replacement of items like belts, filters, and replacement parts when they are not really needed. A more subtle concern is that, statistically, the more we "touch" a piece of equipment the greater the chance of adversely effecting its operation.]

Types of Maintenance: 10 minutes

Preventive Maintenance

[Briefly review information in the workbook.]

Corrective Maintenance

Corrective Maintenance is not as desirable as Preventive Maintenance. However, if staff performs an inspection—either regular or "as needed"—and is able to avert a more serous condition, such as major failure or removal from service, then Corrective Maintenance has done its job.

[Review the information in this section.]

Stay in your groups and answer the next two questions:

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

[Ans: *Various answers are possible. Some include: adjustment of pump/motor alignment after excessive vibration was observed; lubrication of a roller bearing on a conveyor after noise was detected; replacement of an air filter after excessive differential pressure across the filter was observed.]*

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

[Ans: *Various answers are possible. Some include: visual inspection; noise patterns; vibration analyses.]*

Breakdown Maintenance

This is the last kind of maintenance you want to do.

[Review the information in this section.]

Stay in your groups and answer the next two questions:

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

[Ans: *Various answers are possible. Some answers include: replacement of a motor after it overheated and failed; rebuilding a clarifier gear case after oil leaked and gears were damaged from lack of lubrication.]*

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

[Ans: *Various answers are possible, according to the answers given to the previous question. In most cases, regular preventive maintenance and timely corrective maintenance will prevent the need for breakdown maintenance.]*

[Review the information in this section. Perform the following discussion activity in one of these three ways, depending upon your time constraints.

Option 1: *(20 minutes total) Ask students to write answers to each section. Allow ten minutes; then ask for answers to be shared and discussed for ten minutes.* ***Option 2****: (15 minutes total) Arrange students into six groups. Assign each group to write answers to one frequency (daily, weekly, monthly, etc.) Allow five minutes; then ask for groups to share answers. Discussion lasts ten minutes.* ***Option 3:*** *(10 – 12 minutes total) Simply ask students to share answers to each frequency as you call them out. Encourage students to jot in their workbooks any answers they hear that may benefit their own job or plant.*

NOTE: Various answers are possible in all categories. Sample answers are provided below.]

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

- ***Daily***

[Ans: *Pump operation (noise, vibrations, smell); tank levels.]*

- ***Weekly***

[Ans: *Meter readings; check maintenance reports to tweak equipment or order chemicals.]*

- ***Monthly***

[Ans: *Check hours of operation (unit may need periodic servicing); check for animals and rodents; clean the sampler; check filters.]*

- ***Quarterly***

[Ans: *Change out or rotate equipment; generate extra testing as needed; perform required testing from Permit or Regulatory Agency; check, clean, or change HVAC filters; check, clean, or change process filters.]*

- ***Annually***

[Ans: *Check and service all equipment on its yearly anniversary; check large gear cases, motors, and comminutors; inspect vehicles.]*

- ***Seasonally***

[Ans: *Exterior building inspection (cracks, remove wind screens, etc.); change oil viscosity where needed; perform roof inspection; check and make adjustments for changes in seasonal discharge requirements.]*

COMPONENTS OF A MAINTENANCE PROGRAM: 40 minutes

Now you know what general guidelines apply to all types of maintenance—preventive, corrective, and breakdown. So, what specifically do we have to do to ensure that these guidelines are put into practice? We will look at the six components of a good maintenance plan: Scheduled Preventive Maintenance Tasks; Unplanned Daily Activities; Planned Project Work; Record Keeping; Inventory Management; and Purchasing.

You may be responsible for any or all of these functions. Let's start our review by looking at the four most common basic PM tasks. Turn the page.

[Review the information in the workbook.]

Lubrication

Although modern lubricants usually allow a narrower range of products to cover more applications, it is important to meet the equipment manufacturer's recommendations for lubricant type and usage protocol. Using additives without authorization from the manufacturer can alter the lubrication properties to the point where a warranty may be voided.

[Review the information in this section.]

Calibration

Two things are actually calibrated in the PM program. First, we calibrate the process systems.

[Review the information in this section.]

The second calibration is something that might surprise you. We actually calibrate the PM activity! This is where we take a look at the list of unexpected breakdowns or repairs that were necessary before their scheduled PM date. We can correct our PM schedule by relying on our own set of internal monitors and controls.

Condition Assessment and Monitoring

[Review the information in this section.]

Display Slide 6—Vibration Analysis.

Look now at Figure 2.3 on page 12. There are several ways that vibration is measured. This example shows a frequency analysis using a Fast Fourier Transform (FFT) algorithm. The unit tested is a small steam turbine-driven circulating pump that is rotating around 800 or 900 RPM. There is a significant bearing problem noted by the frequency spikes. Rotating equipment all produce a spectrum of frequencies. By establishing a baseline when the unit is new, one can take periodic readings and identify developing problems. Vibration testing meters are available which allow the maintenance staff to take readings and use a software analysis package to identify probable causes. Many can predict into the future when the equipment will actually fail. They can be very accurate.

Prices of vibration testing equipment have dropped in recent years so that they are now in the price range of many plant maintenance departments. Contractors are available who specialize in this field and can be called in periodically to test major equipment. Critical equipment and most medium or large pumps should be tested regularly. Large machines often have vibration sensors permanently mounted to the equipment to sound an alarm and/or shut down the unit when dangerous vibrations are detected.

Later in this module, we will get more information about some of the sophisticated monitoring tools.

The fourth, and final, frequent PM task we will discuss is the replacement of consumable parts. These are parts that are consumed—or used—and then discarded.

[Review the information in this section.]

Unplanned Daily Activities

If you see an increase in this type of problem and these expenditures, there are problems with the Maintenance Plan. It needs to be reviewed, analyzed, and adjusted.

[Review the information in this section. Ask the class to share some responses to the following question.]

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

[Ans: *Various answers are possible. Students may state that their facility has spare parts on hand, duplicates equipment, or has redundant operations.]*

Planned Project Work

[Review the information in the workbook.]

Why might outside contractors work on larger new installations?

[Ans: *Outside contractors may have more expertise; liability issues; in-house staffing constraints; timing of the project.]*

What is the object of equipment overhaul?

[Ans: *Overhaul incorporates major revisions, including cleaning, repair, replacement parts, and updating.]*

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

[Ans: *Does the unit work as it is intended? Does it meet the facility's needs? Are repairs more constantly needed? Is there a better functionality available?]*

Record Keeping

While the staff is running the organization according to the procedures set forth, they must be accountable for their actions. One way to ensure accountability is to keep records of the activities that occur. Not only is information collected in the organization, but it is also managed. Let's take a look at the "Record Keeping" section now, and we will see why this information collection and management is important.

[Review the information in the workbook.]

Keep these three reasons for retaining records in mind. But, record acquisition, storage, and management are priority pieces of business for the plant. Proper documentation can save huge amounts of money, time, and trouble.

Display Slide 7—Routine Tracking.

Look at Figure 2.4 now. What does it tell us? It is a good example of a utility system (wastewater in this case) that shifted from a reactive to a proactive approach. Think back for a moment to what we learned in Figure 2.1 (which is generally applicable to most maintenance activities, not just electrical); this utility—Clearwater—was probably well to the right of that graph-- doing low maintenance but paying higher overall costs. After the new PM program was started, we can see in Figure 2.4's third column that a dramatic reduction in pumping station failures was achieved. We can infer from this that Clearwater: 1) established a realistic PM plan; and 2) did a better job of monitoring (probably a combination of predictive and rapid response efforts).

It is a safe bet that instances where crews responded on overtime at 2 a.m. to a pumping station trouble call were greatly reduced. The resources once obligated to emergencies now are applied to more productive tasks. Some of that money is now going to PM.

Often, the first place money is cut from a budget is preventive maintenance because people do not see the relationship of proactive efforts as illustrated in Figure 2.3. Keeping detailed, accurate records and then managing that data can focus attention and resources on PM efforts and their payoffs.

Inventory Management

Remember that too much, or too little, inventory can both be problematic. When possible, redundant units should be available. Also, spare parts should include, at a minimum, oil and grease, wear rings, packing material, replacement filters, hoses, and drive belts.

[Review the items in the workbook.

After reviewing the standard inventory items, ask the students following question:]

Can you think of any other standard inventory items?

[Allow any students who wish to contribute an answer to do so.]

Purchasing

[Review the information in the workbook. Remind students that it may be necessary to secure a certain number of bids, bid through certain vendors, or follow other local, state, and federal guidelines for some purchases. They should always seek management's input when soliciting large projects.

Allow students to share answers to the following question.]

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

Now you know the basic components of a maintenance plan. How do we actually put it into practice? That question is the topic of Unit 3.

[Have the participants review the Key Points on this page.]

UNIT 2 EXERCISE: (15 Minutes)

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

[There is no need to discuss the references on this page.]

[This page was intentionally left blank.]

UNIT 3: 55 minutes

Display Slide 8—Unit 3: Implementation of a Maintenance Plan.

At the end of this unit, you should be able to:

- Name three processes 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.

DEVELOPMENT OF AN EQUIPMENT DATABASE: 40 minutes

In the development of a preventive maintenance plan, we can broadly divide it into three major components.

- First, a *database* of equipment within the system is created.
- Second*, procedures* are developed to maintain that equipment.
- Third, the procedures are *scheduled* to put the PM plan into action. It should be understood that this process is dynamic in nature. Over time, equipment changes, better PM practices are crafted, and modifications to task frequencies are warranted. This is a result of experience gained during the actual execution of the program and should be encouraged.

An accurate database is a fundamental element of the maintenance program. The maintenance program itself is structured and staffed according to the equipment used and the equipment's level of required service. Knowing your equipment is important for developing the process and using the database to simplify its management.

Database management is an ongoing process. As equipment, systems, and processes are changed or replaced, the database must be updated to reflect the changes. While most plants will have staff to program and run the database, field personnel are a key resource for ensuring that the database accurately reflects existing conditions.

[Briefly review the bulleted items in this section.]

Master Equipment List

To create a paper-based or computerized database, first we must list all the equipment. List the equipment data and the source of your information.

Equipment Identification

Equipment is numbered to indicate its type, location, function, and key components. However, many plants have not synchronized their identification methods. Simply updating or changing an identifier does not avoid the confusion inherent with these changes.

[Review the information in the workbook.]

Display Slide 9—Labels.

Looking at the picture, how many types of identification systems can you find?

[Ans: *Various answers are possible. Be sure the students see, at a minimum, the following tags: function (in blue duct tape); manufacturer's number (black plastic tag); facility's pump number (written on the equipment with a marker); components (duct tape).]*

What are the possible consequences of this kind of labeling?

[Ans: *Various answers are possible. Make sure students note, at a minimum: safety issues; confusion when identification is required.]*

[Depending upon time constraints, have the students complete this activity (10 minutes) and then have one or two share their answers by writing them on the flipchart (10 minutes) for a total of 20 minutes, OR simply lead them through the process by writing on the flip chart.]

☑ 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.

Number Code:

[Ans: *Various answers possible. The earliest purchases should have the lowest number. An example:*

Trash Rack (Brunning facility)	*2355*
Trash Rack (Main Street facility)	*2356 (this was bought the same day as the other trash rack; therefore, it is probably tagged with the next available number)*
Backwash Pump	*4200 (this was purchased two years after trash racks)*
Air Filter	*5203 (this was purchased the year after the pump)]*

Alpha-numeric Code:

[Ans: *Various answers are possible. The earliest purchases will have a lower number, according to the type of equipment. An example:*

Trash Rack (Brunning facility)	*TR2355 (TR stands for trash rack in this example)*
Trash Rack (Main Street facility)	*TR2356 (this was bought the same day as the other trash rack; therefore, it is probably tagged with the next available number)*
Backwash Pump	*BP4200*
Air Filter	*AF5203]*

Smart Number Code:

[Trash Rack (Brunning facility)	*TR032355 (TR stands for trash rack in this example; 03 is the facility; and 2355 is the identification number)*
Trash Rack (Main Street facility)	*TR042356 (TR stands for trash rack; 04 is the facility; and 2356 is the identification number, indicating it was the purchase made directly after the previous trash rack purchase, therefore, it is probably tagged with the next available number)*
Backwash Pump	*BP024200 (BP stands for backwash pump; 02 indicates the Lee Highway facility; 4200 is the identification number for this piece of equipment)*
Air Filter	*AF045203 (AF is Air Filter; note that the next two digits, 04, are the same as the trash rack in the Main Street facility; the 04 indicates the location of the equipment)]*

COMPONENTS OF A PREVENTIVE MAINTENANCE PLAN: 15 minutes

Create a Library of Procedural Tasks

Realizing the importance of preventive maintenance, we need to consider in some detail the process of establishing a program that dependably issues accurate PM work orders when required. Whether they are triggered by run hour totals, calendar days, or equipment condition, we need to know what to do when required. This is pre-established and the typical process is outlined in the coming section.

Purpose

[Review the information in the workbook.]

Specific Format

[Review the information in the workbook.]

Content

[Review the information in the workbook.]

For instance, two identical vertical pumps may be used in the same plant. One draws from a clearwell and the other may be a raw water intake. Several things, including the need to check for impeller wear and the frequency of strainer cleaning will be different for these identical pieces of equipment.

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Written Procedures

[Review the information in the workbook.]

Maintenance Schedule

After we know what needs to be done to keep equipment in good repair, the tasks must be scheduled with the appropriate frequency for issuing the tasks. Again, while the manufacturers' recommendations provide a good starting point for acquiring this information, frequencies are heavily dependent upon the actual conditions at the facility. In this section, we'll discuss what you should consider to create a plan for tasks.

1. Determine how often the task should be performed

Calendar-based tasks are scheduled on a daily, weekly, or monthly type basis. This is a simple approach that can result in a even distribution of the labor effort. The down side is its limited flexibility. Actual real-time conditions cannot be easily accommodated in this schedule.

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

For example, consider a standby diesel drive on a high service pump. Changing the lubricating oil can be done once a year (by the calendar) or when the upper limits of contamination are reached (based on the condition), which may be several years. In the condition based PM, we avoid changing perfectly good oil and we reduce the associated downtime of the equipment. Calendar-based PM does have many valid uses, especially as a trigger to conduct condition testing.

[Review the information in the workbook.]

2. Estimate how long each task takes

The second consideration, besides how often the task should be done, is how long it takes.

[Review the information in the workbook.]

- Accessibility of Equipment

Do tanks have to be drained? Is equipment overhead, requiring man-lifts?

- Complexity of Startup/Shutdown and Isolation Procedures

Is the work in an area considered to be a confined space? Does equipment have to be switched over and put online first?

- Location of Equipment

Is the plant large, requiring travel time to get people and tools to the equipment? Is some equipment at distant facilities?

- Coordination with Contractors and other Departments

Will in-house personnel have to work with contracted personnel? Does, for example, Distribution have to be notified and procedures coordinated?

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

Staffing Needs

Time estimates are useful in scheduling the workload. For instance, we can print estimated PM hour requirements to see how much time the maintenance department will have available for other tasks. This would also mean that we could not start a PM on a Friday afternoon if the expected time to complete the task would be 6 hours.

Remember our previous discussion about recordkeeping and its importance to the PM effort.

[Review the information in the workbook].

You have had a brief overview of establishing a maintenance database, looked at the various equipment identification systems, and thought about the requirements for scheduling maintenance. You have even created three different identification systems for several pieces of equipment.

These first three units, I hope, have given you an opportunity to think about an organized and managed approach to maintenance and have helped you to understand the importance of being proactive. When we go into Unit 4, we will have the chance to discuss some of the most common types of equipment and the maintenance that is required to keep them available for operations.

[Have the participants review the Key Points on this page.]

UNIT 3 EXERCISE

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

2. All pieces of equipment should receive a unique **identification** code.

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

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

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

UNIT 4: 60 minutes

Display Slide 10—Unit 4: Typical Maintenance Procedures.

At the end of this unit, you should be able to:

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

CENTRIFUGAL PUMPS AND MOTORS: 18 minutes

The first unit mentioned reasons for performing maintenance, including such issues as maintaining the design intent and preserving the value of assets. Later units detailed the theory of how to go about this. Now we can look at some of the physical tasks that can help achieve the goals we have discussed so far.

Our first section concentrates on centrifugal pumps. Attending to several basic preventive maintenance tasks will help ensure trouble-free operation of these important units. They are: shaft seal adjustment; lubrication; and condition assessment. We will deal with each of these topics in detail.

Pump Performance Issues:

Before we get into actual procedures, let's review some pump performance issues.

[Review the information under Pump Performance Issues]

In a given one-hour period, do you think it is better for a pump to allow it to run continuously, or is it better to shut it off and restart it when it is needed?

***[Ans:** It is better for it to run continuously to lesser wear on the pump.]*

Shaft Seal Adjustment

Standard Packing Seals

The key to trouble-free standard gland seals is packing adjustment.

Display Slide 11 – Centrifugal Pump Components during this discussion.

[Review information in the workbook].

Display Slide 12 – Stuffing box for a more detailed discussion of the lantern ring.

The shaft/sleeve wear from over-tightening will make it impossible to maintain an adequate seal.

When the seals are too loose, there may be plant safety and environmental concerns if chemicals are being pumped and are leaking. We can see evidence of this in Figure 4.1 on the next page.

[This page contains Figure 4.1. Point out the evidence of a leaking gland in this pump.]

Mechanical Seals

In some situation, the packing material is not adequate for sealing the shaft. In this case, a mechanical seal is used.

[Review information in the workbook on the components of a mechanical seal.]

What does this setup sound similar too? In other words, what could be another name for a mechanical seal?

***[Possible Answer:** Bushing or bearing]*

Mechanical seals can provide long and dependable service. It is important that they be properly installed. Many seals fail because of installation problems; most often, this is caused by contaminating or damaging the mating seal faces.

[Review information in the workbook.]

Lubrication

Our upcoming discussion of lubrication is applicable to other equipment, such are motors, as well as to pumps. Lubricating theory is simple: a thin viscous film is maintained between the bearing surfaces to prevent metal-to-metal contact. Two factors are necessary to achieve this: ensuring an adequate supply of lubricant to the surfaces; and maintaining the lubricant quality.

Ensure an Adequate Supply of Lubricant to the Surfaces

[Review information in the workbook.]

Relief Plugs

[Review information in the workbook.]

Removing the plug will prevent excessive pressure buildup that can increase friction and force seals out, which is a special concern in motor applications where the lubricant can infiltrate the windings.

Bearings

{Review information in the workbook.]

Chain Drives

A fluid that is too light or too heavy will not ensure a dependable film between the contact surfaces. Always check the manufacturer's recommendations.

[Review information in the workbook.]

Maintain the Lubricant Quality

[*Review information in the workbook.]*

Condition Assessment

[Review the first paragraph in the workbook.]

[Ask the following question, asking participants to answer aloud. You may want to write answers on a flipchart.]

What are the "first line of defense" tactics that you can use to detect trouble by using only your own senses?

[Ans: *Various answers are possible, including: smelling hot wires; seeing leaking valves; hearing excessive vibration noises.]*

[Finish reviewing information in the workbook. Be sure to point out the information on what can cause excessive vibration, which is stated below:]

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

In a predictive maintenance program, vibration analysis is used to note changes in the vibration characteristics of equipment. Readings should be taken when the equipment is new and then regularly during the life of the unit. The idea is to identify these vibration changes well before they develop into an abnormal situation so that remedial action can be planned. Depending on the size and nature of the maintenance operation, vibration analysis may be handled in-house or by contract. Either way, for best results it is important to establish and continue this program over the long term.

Look at Figure 4.2, showing a vibration analysis point. In this case, the facility has in place a periodic testing protocol. There is nothing about this motor that would indicate that it has a vibration problem. Note the screw-in test point for sensor placement. This ensures more accurate readings.

Turn the page now to begin looking through some vibration analysis reports.

Motor Technology, Inc. is a company that provides predictive maintenance analyses. On page 4-8, you will see a document that is called a Manager's Summary. This letter summarizes the findings of an analysis. Notice under "Heat Plant" number 1 that they are trending; they compare previous data to the data gathered during the current inspection. Another good example of this comes under "2nd Floor Machine Space," Number 3.

Throughout, you should note that the analysis report gives only their findings and their suggestions for what most likely is causing the problems. These analysis companies do not actually perform repairs. The ultimate responsibility for maintenance lies with the customer.

[Allow a few minutes for the students to read the report.]

Next, on page 4-9, you will see the Vibration Analysis Check Sheet, which is Figure 4.4. This is an example of the types of information the company looks for. Notice that each piece of equipment will have its own check sheet. Here, a specific fan, AC-4, is being checked. General notes about the equipment are made in the right column. This helps bring clarity to any inconsistencies they might find.

[Allow students a minute or two to become familiar with this check sheet.]

On this page, you will find graphical representations of the data. You can see that several target areas, including “Alert” and “Fault” are represented. Some people find graphs easier to read, understand, and compare than the written word. Most companies present the data both ways. On the next page, you will see a columnar representation of data collected. Turn the page now to view the last piece of the analysis.

[Allow students a few minutes to view the information in Figure 4.6, the Vibration Analysis Detailed Report.]

METERING PUMPS: 10 minutes

[Review information in the workbook.]

[Note (bullet point #2) that leaks can become a safety issue for personnel and the environment. Additionally, leaking can lead to units becoming encrusted with dried chemicals; this makes it difficult to work on the unit.]

[Note (bullet point #3) that many pumping problems are traceable to the piping.]

[Note (bullet point #8) that strokes per minute can be an indicator of performance and can indicate worn pistons and valves.]

[Note that, by knowing the history of the pumps under their care, it is possible to anticipate problems and replace renewable parts before the entire system fails.]

VALVES: 10 minutes

Valve maintenance is often overlooked in the care of the overall plant operation. Many valves are critical in ensuring the availability and reliability of plant operations. Several points about valve care that should be remembered are: include valves in the PM program; exercise them regularly; and assess their performance. Let's look at these topics now.

Include Valves in PM Program

[Review information in the workbook.]

Valve Exercise

Valves often require simple PM tasks, and the PM cost is low in relation to repair or replacement costs.

[Review information in the workbook.]

You should be able to see by now that one of our "rules to live by" is, "Be proactive!" The other rule that we are stressing is, of course, "Follow the manufacturer's recommendations, at minimum."

Special Considerations

Plug Valves

[Review information in the workbook, pointing out the sealant grooves in Figure 4.7.]

Low Head Valves

[Review information in the workbook.]

Performance Assessment

[Review information in the workbook, noting especially the key point.]

You are now seeing some of the theory we have discussed throughout this module put into practice. For example, we earlier mentioned that, while PM is a great way to save money, time, productivity, and labor, the simple act of touching a sensitive piece can, in itself, do some damage. Benefits and detriments must be weighed.

ELECTRICAL SYSTEMS: 12 minutes

This section covers two broad areas of electrical maintenance: motors and controllers/switchgear.

Electric Motors

Cleaning

Seemingly simple tasks can be very important in the maintenance plan.

[Review information in the workbook. End with the comment that vertical units are especially susceptible to solvent flowing down into the insulation or the bearings.]

Lubrication

Again, it cannot be reiterated too often: look to each unit's manufacturer's recommendations for type, quality, and frequency of all things related to lubrication.

[Review information in the workbook.]

Testing (Nondestructive)

Vibration Analysis

You should have a good understanding of vibration analysis from our discussion during centrifugal pumps.

[Review information in the workbook.]

Amperage and Resistance Testing

[Review information in the workbook.]

Operating Temperature

[Review information in the workbook.]

Electric Controllers and Switchgear

Operating voltage, to a certain extent, influences how and by whom maintenance on electrical systems is performed.

[Review the key point. Be sure to point out that electrical equipment should only be serviced by qualified individuals]

Some common electrical maintenance tasks include: cleaning; mechanical checks; functionality checks; and insulation integrity checks.

Cleaning

[Review information in the workbook.]

Mechanical Checks

We say that all electrical terminations must be retorqued from time to time. Why is this so?

[Ans: *Various answers are possible, including: cyclic thermal changes; vibration and stresses from short circuit conditions contribute to a reduction of clamping forces at connections.]*

[Review information in the workbook, noting the key point at the bottom of the page.]

Functionality

[Review first bullet point.]

You could make this page into a checklist for your system if you would like. This page should give you a basis to start the checklist.

Unfortunately, it is common to find the wrong fuse installed; this could happen because of the lack of the correct type or because there is a lack of understanding of the importance of using the right fuse. How often has it happened that someone says, "Here, put this fuse in to get the motor running. We'll get the right one in later."

It is very important to have the correct amperage and type of fuse installed.

[Continue reviewing the second and third bullet points.]

You may find that someone had a motor tripping and, instead of finding the cause, simply turned up the trip point.

[Continue reviewing information in the workbook.]

Insulation Integrity

At the most basic level, we perform electrical maintenance so that current flows only through its proper conducting path. Factors such as environmental conditions, age, overloading, and stresses causing actuation of short circuit protection devices affect the effectiveness of the insulation system.

[Review the information in the workbook. Point out the testing equipment in Figure 4.8 that was mentioned in the discussion.]

Thermographic Testing

This section is provided for your information. Most likely, you will not be conducting these tests yourself due to the high cost of the equipment and the training involved. However, this section will help you deal with engineers and interpret their analysis.

Think back to our discussion of vibration analysis. Lubrication analysis is another data collection and management tool. The third such tool is thermographic testing, or IR testing. IR stands for infrared, and that is the name some of us are more familiar with, but thermographic testing is the preferred name.

Display Slide 13—Thermographic Testing.

A thermographic scan works on the principle that, as electrical resistance through a circuit increases, heat is generated as energy is lost. This heat is visible as an infrared signature. The naked eye cannot see these changes in heat; nor can they usually be felt.

On this picture you will see a fuse 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.

Display Slide 14—Thermographic Testing #2.

Figure 4.10 illustrates a hot spot that you would never see on visual inspection. Notice how, in addition to pictures, the report gives specific details of the time, date, and exact location of each unusual incident. Notice the temperature reading of 110.5 degrees Fahrenheit, and compare that to the ambient temperature.

Thermographic testing is carried out while the equipment is live and under load. As with other predictive programs, regular testing is required to build a history that will reveal trends or verify sudden abnormal conditions.

DIESEL ENGINES: 10 minutes

***[NOTE:** Before you begin this section, determine if anyone in the class uses diesel engines at his/her system.]*

You may see equipment like the one pictured here at your facility. Diesel engines are a good example of the value gained from predictive maintenance. These tests are noninvasive and do not require the disassembly of equipment. It is important to test periodically to form a history that will allow developing situations to be addressed before they become problems.

[Review information in the workbook.]

Review information in the workbook.

Note Figure 4.12 showing an oil/lubrication analysis. Although this report is from a different vendor than the other vibration and thermographic analyses we have seen, the information is of the same scope. We can see testing criteria, graphical interpretations of the results, and a narrative interpretation of the results. See the final bulleted list for some of the reasons we use lubrication analyses.

[Note (bullet #1) that the result is savings in labor and material costs.]

[Note (bullet #2) that, on average, less lubricant is being disposed because it is being used longer.]

[Note (bullet #3) that bearing and gear wear can be detected by analyzing the specific oil contaminates.]

[Have the participants review the Key Points on this page.]

Unit 4 Exercise

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

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

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

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

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

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

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

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

[There is no need to go over the references on this page.]

[NOTE: If the participants did not complete the exercise at the end of unit one, you may ask them to complete it now if time permits.]

This concludes the General Maintenance training module. You should have gained some familiarity with common types of equipment, their general needs, and the best proactive stances to keep them in good condition. Take some ideas from this session and your fellow classmates back to work with you: keep yourself, your plant, and your environment in good condition and safe. Thank you.