Wastewater Operator Certification Training
Instructor Guide

Module 11:
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 this course, *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 DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the 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 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
- Discussion Questions
- PowerPoint slides

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

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

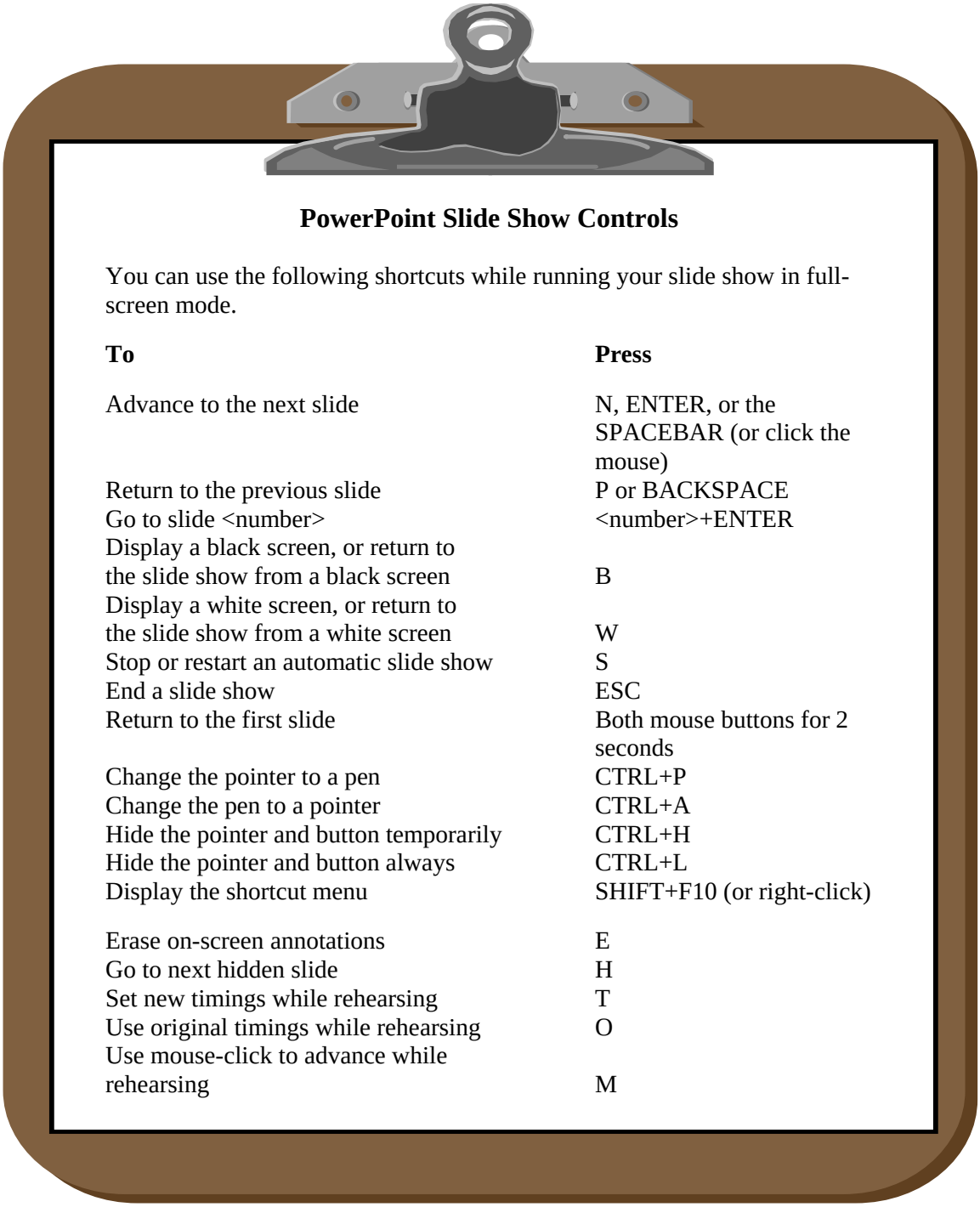
Icons to become familiar with include:

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
 Exercise	 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 11: Maintenance.]

[Welcome participants to "Module 11 – Maintenance." Indicate the primary purpose of this course is to familiarize them with general 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 Maintenance Plan and the beginning of Unit 4 – Typical Maintenance Procedures.

[Continue to briefly review outline.]

 Turn the page once more and you will see the rest of Unit 4's outline.

[Finish the review of the outline.]

UNIT 1: 35 minutes

[Display Slide 2—Unit 1: Introduction to Maintenance.]

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

- 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.

OVERVIEW: 15 minutes

Definition of Maintenance

Maintenance is composed of a series of tasks which will reduce the potential for unexpected problems that might prevent us from using equipment or systems.

[Review the definition of maintenance.]

[Review the bulleted items, using the examples and clarifications listed below:]

- *[Review a schedule.]*

Make sure that you know what needs to be done, and when. This can be as simple as changing lubrication when the seasons change. For some exterior gear cases, a different weight lubrication is necessary to compensate for different ambient temperature. Also, you want to schedule heating system inspections in the fall, before the system is called into use.

- *[Review expendable items.]*

Do not start a maintenance task unless you are sure you can complete the task; for example, if you change oil in a crankcase but fail to have sufficient replacement lubrication, the unit will sit out of service until you obtain the necessary product.

- *[Issue work orders or schedule tasks.]*

A work order can be verbal or written. In smaller plants, the supervisor may simply notify a mechanic that a system has operated for 150 hours and needs to be inspected.

- *[Review completed tasks.]*

Completing a task may trigger a follow-up or secondary task. For example, if you change the oil in a vehicle, you should check the oil level after the engine has operated for a few minutes.

- *[Modify PM schedule, if necessary.]*

If equipment is starting to show a trend of breaking down frequently, the maintenance schedule must be adjusted to reflect the needs of that equipment.

- *[Budget management.]*

A budget must allow for maintenance to be performed on units and systems throughout the facility. Failure to generate sufficient funds for the program will result in eventual failure. Additionally, the budget should reflect the upgrading or replacement of inefficient equipment.

The Role of Maintenance in the Overall Operation

Maintenance must deal with "real world" problems. When a piece of equipment or a system is designed—and when it is purchased for use at your facility—there is a specific mode of operation intended for it. In other words, it is designed and purchased for ideal conditions. But, as we know, ideal conditions are not the norm in the real world. Think about a sump pump that is installed in a basement area and discharged into the raw wastewater wet well. You have to be careful not to use the sump pump as a method to transfer chemical to the headworks by allowing a dripping of chemical into a flow drain, which goes to the sump pump and eventually to the headworks. This kind of unanticipated modification of the system will impact its service life. Then, we would have to replace it earlier than originally intended.

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. Remind participants that maintenance, done systematically, reduces cost and labor crunch, and can increase the reliability of the overall system.]

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.

[Ask participants to share the answers they have written.]

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

Ans: Many possible answers are available. Generally, the answers will fall into these categories:

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

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.

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

[After participants have had an opportunity to think of some answers (3 minutes), ask them to share responses.]

Ans: Many possible answers are available. Generally the answers will fall into these categories:

- 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.

Fixed Asset Management

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

To be good stewards of the assets, we must take responsibility for several things. First, we sometimes postpone equipment replacement and try to maximize the service life of every piece of equipment.

We must practice inventory control methods. In this case, we do not want to have too much inventory on hand, because if newer or better products become available, we would have to use all the old inventory before we could buy the new piece. On the other hand, we cannot operate with too little inventory because we may need spares on a moment's notice. Also, we should date the material when it is received so that we can rotate our inventory regularly.

Finally, we need to practice proper storage techniques. Excessive heat can degrade grease, electrical insulation, and seals. And, some inventory can "spoil" if kept too long. Think about grease that separates if stored improperly for long periods.

Maintenance of Design Intent

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

You will recall that we already discussed the impact that modifying equipment can have on its original intent and its longevity.

Efficiency of Operation

In Maintenance, we can actually generate efficiency in the treatment plant. We might notice an indication of a pump or compressor that may not be operating efficiently. This means the unit's operation increases, capacity decreases, and electrical consumption increases. You can help the plant save money by taking maintenance efforts seriously. You might also practice benchmarking; if the performance or efficiency is outside the allowable range, find out what needs to be done to bring operation into recognized ranges. Check the actual performance of a unit against a known standard from time to time. The frequency of these checks can depend upon the criticality of the unit or the cost to operate it.

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.

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

Safety and Environmental Protection

[Briefly review the information in this section. Be sure to indicate the importance of the key point. Remind participants to look at Appendix A when time permits. Special information is included there on isolation distances and hot work permits.]

Please note Figure 1.1 on page 1-7 of your workbook. This picture represents a safety hazard.

What safety hazards can you identify in the photograph?

Ans: No shaft guard on pump; leaking oil or water on the floor; limited clearance in the area; limited lighting in the area (the flash photography brings out some details that would be missed in a low-lighting area).

When you go back to your own work site, think about the hazards that might be around you. Work carefully!

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

System Reliability

Ideally, an easily replaced, and inexpensive, device should be installed whenever possible to protect a key item or expensive component. For example, a shear pin is used on a piston pump or a drive, and this pin should break before more significant damages occur if a valve is closed or a rake drive jams.

[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 review questions. 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.]

UNIT REVIEW: (10 minutes if desired)

1. List the five goals of a wastewater treatment 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. 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.

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

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

5. 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.

UNIT 2: 90 minutes

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

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

- 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.

GENERAL GUIDELINES: 45 minutes

Organization

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 participants to answer the following questions. Encourage them to jot in their workbooks any answers that other participants may give.]

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.]

To have an organization, we have to have staff to run it. Let's look at three types of staff.

[Briefly review the information in this section. Indicate that Contract Workers are discussed in more detail in a later section.]

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 how this information collection and management is important.

[Review the information in this section. Refer participants to Figure 2.1, "Paper-based Repair History." Note the amount and type of information that is kept on this log. Point out to participants that a variety of other paper-based logs are included in their workbooks' Appendix B. Indicate that participants should familiarize themselves with these products so that, in the event that they are not properly tracking activities, they can take with them some knowledge and resources to start implementing a tracking process.]

How many of you use paper-based systems at your plant? How many use computers?

In a paper-based system, each activity and each piece of equipment must have its own records. The records cannot be easily changed, manipulated, or merged with other records. With a simple computer program, record keeping is simplified.

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. 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.

[Briefly review the information in this section.]

On page 2-6, you will find a screen shot from a CMMS in use today. All the information needed about this piece of equipment is available in one place. We can see where it is located, what it is, the model number, and much more. Take note of the tabs, "General Info," "Components," "Schedule & Procs," and so forth. By clicking on a tab, you can go into specific details of the equipment. A single screen holds more information than any paper-based log. Also, you can use the computer program to merge data about different equipment, compare items, schedule tasks, and so much more.

Be sure to look at Appendix C when you have the chance. Some interesting screen shots are included there for your review.

Contract Work

Remember that we discussed the different types of staff that are found in a typical plant. One of those staffing components was contracted workers. 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 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.]

We will look in detail at PM in the next section of Unit 2. Now that you have an idea about the general guidelines for structuring a maintenance program, let's look at the components of the maintenance program. Turn the page now to see a list of maintenance duties in a typical plant.

COMPONENTS OF A MAINTENANCE PROGRAM: 45 minutes

[Briefly review the bulleted items in this section.]

To realize the components of a maintenance program, we will examine the following subjects in this section: activities of a maintenance program; the frequency with which we engage in these activities; scheduled repairs; emergencies; preventive maintenance; capital improvements; records; and inventory and purchasing requirements

Activities

Preventive Maintenance

[Review the information in this section. Ask a few participants to answer aloud the following questions:]

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.

[Remind participants that they should also 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 they read professional journals, they will notice this trend in terminology.]

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. Ask a few participants to answer aloud the following 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. Ask a few participants to answer aloud the following 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.

Frequency

[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 participants 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 participants 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 participants to share answers to each frequency as you call them out. Encourage participants to jot in their workbooks any answers they hear that may benefit their own job or plant.]

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

[NOTE: Various answers are possible in all categories. Make sure the participants list, at a minimum, the answers given below.]

- *Daily*

Ans: Pump operation (noise, vibrations, smell); tank levels; and aeration patterns on tank.

- *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 such as groundhogs; check embankments of ponds; clean the sampler; check filters on aeration blowers.

- *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 year anniversary; check large gear cases on clarifier drives, bar screens, mixer motors, and comminutors; inspect vehicles.

- *Seasonally*

Ans: Exterior building inspection (cracks, remove wind screens, etc.); change oil viscosity for aeration mixer motors; roof inspection; check and make adjustments for changes in seasonal discharge requirements.

Scheduled Repairs

Scheduled repairs are much preferred over unscheduled, or emergency, repairs.

[Review the information in this section.]

Emergencies

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. Participants may state that their facility has spare parts on hand, duplicates equipment, or has redundant operations.

Preventive Maintenance

One of the objectives of this unit, as you may recall, is to list four PM tasks. Four that you probably encounter routinely are discussed on page 2-13.

Lubrication

Modern lubricant properties allow a narrower range of products to cover more applications. However, 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.]

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

Consumable Replacement

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.]

Capital Improvements

Earlier, you had a chance to discuss why operators, in addition to maintenance department personnel, may be involved in suggesting large improvements to a facility.

[Review the information in this section.]

Record Keeping

[Review the items in this section, up to the key point.]

We discussed earlier in this unit the basic reasons for keeping records. Note the key point in your 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.

[Review the information under the key point's bulleted section.]

Inventory

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.

Can you think of any other standard inventory items?

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

[Review the information in this section.]

Purchases

[Review the information in this section. Be sure to refer participants to the appropriate agency and documentation for purchasing requirements, such as those outlined in the last two bullet points.]

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.

UNIT 3: 55 minutes

[Display Slide 4—Unit 3: Implementation of a Maintenance Plan.]

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

- 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.

DEVELOPMENT OF 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 under our care 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.

[Briefly review the information in this section.]

Maintenance Master Equipment List

[Briefly review the information in this section.]

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.

[Display Slide 5—Unit 3: Labels.]

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

Ans: Various answers are possible. Be sure the participants 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 in black Magic Marker); components (blue duct tape).

What are the possible consequences of this kind of labeling?

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

[Review the information on three types of numbering in this section.]

[Depending upon time constraints, have the participants 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:

Bar Screen (Brunning facility)	2355
Bar Screen (Main Street facility)	2356 (this was bought the same day as the other bar screen; therefore, it is probably tagged with the next available number)
Sump Pump	3888 (this was purchased two years after bar screens)
Aeration Blower	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:

Bar Screen (Brunning facility)	BS2355 (BS stands for bar screen in this example)
Bar Screen (Main Street facility)	BS2356 (this was bought the same day as the other bar screen; therefore, it is probably tagged with the next available number)
Sump Pump	SP4200
Aeration Blower	AB5203

Smart Number Code:

Bar Screen (Brunning facility)	BS032355 (BS stands for bar screen in this example; 03 is the facility; and 2355 is the identification number)
Bar Screen (Main Street facility)	BS042356 (BS stands for bar screen; 04 is the facility; and 2356 is the identification number, indicating it was the purchase made directly after the previous bar screen purchase, therefore, it is probably tagged with the next available number)
Sump Pump	SP024200 (SP stands for sump pump; 02 indicates the Lee Highway facility; 4200 is the identification number for this piece of equipment)
Aeration Blower	AB045203 (AB is Aeration Blower; note that the next two digits, 04, are the same as the bar screen in the Main Street facility; the 04 indicates the location of the equipment)

COMPONENTS OF A MAINTENANCE PLAN: 15 minutes

To institute the PM plan, we must consider seven factors. Let's go over them now.

- *Expected completion time for each PM.*

  As the predictability of a task increases, the *estimated* time to complete the task should be refined so that it is close to the *realistic* time that it takes. However, a time estimate should not govern how thoroughly the task is completed; the task must be 100% finished. If the estimate was not valid, it should be revised.

- *Staff requirements.*

  Ask yourself these questions: How many staff should it take to complete the task? What level of specialization is required? Who has the expertise do a specific function? How will maintenance of the unit impact other staff abilities? (For example, will operational staff be unable to adjust chemical dosage when instrument calibration is being performed?)

- *Elapsed operational time.*

  The time it takes to complete a task may determine when it can be done.

- *Seasonal requirements.*

  Think about the special requirements that winter or summer can bring; seasonal viscosity affects gear case oil.

- *Elapsed calendar time.*

  Sometimes we can use a calendar date as a "catch-all" in case PM is not triggered by another factor.

- *Diagnostic testing results.*

  Monitoring those tests should provide insight into necessary adjustments to the PM schedule.

- *Adjustment to former PM schedule, if necessary.*

  Using all the criteria we just discussed, as well as your accurate records, will allow a PM schedule to be flexible and dynamic. Do not be afraid to assess the schedule and admit when it is not working.

Create a Library of Procedural Tasks

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

Purpose

[Review the information in this section.]

Specific Format

[Review the information in this section.]

Content

[Review the information in this section.]

Written Procedures

[Review the information in this section.]

Updates/Revisions

[Review the information in this section.]

Calculating Task Frequencies

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.

How Often is the Task Performed?

[Review the information in this section.]

How Long Does the Task Take?

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

[Review the information in this section.]

Establish Preventive Maintenance Hour Requirements

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.

[Review the information in this section.]

UNIT 4: 60 minutes

[Display Slide 6—Unit 4: Typical Maintenance Procedures.]

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

- 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.

PUMPS: 13 minutes

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

This unit will provide you with a general overview of the various types of equipment, components, and configurations of a typical wastewater treatment facility. We will not create detailed procedures for each type of equipment; there are too many types in circulation to train you on all of them in this brief period. Instead, we will focus on the critical task of recognizing similar and dissimilar features of units.

When you are familiar with your equipment, and the components of them, you can begin to develop your own detailed procedures for maintenance. The manufacturer's recommendations are always the minimum and starting point for maintenance procedures.

It is possible that you may not be aware of the types of equipment installed at your plant. It is essential that you recognize how some units have similar properties to other units. Conversely, there are significant differences, too. For example, closing a discharge valve for brief periods on most centrifugal pumps will not damage them; however, closing a discharge valve on a positive displacement pump will result in damage to pump, piping, or personnel.

Types of Pumps

Let's look at the two types of pumps you may encounter.

Centrifugal Pumps

Think about a carousel, or merry-go-round. As you get towards the outer edge, the speed increases. In a centrifugal pump, the speed of the water increases from the inner ring to the outer edge, where it leaves the pump. That is why we need to be concerned about cavitation in a centrifugal pump. For example, an air bubble might form inside a pump and then collapse. This cycle would happen several hundred times per minute. Damage to the pump impeller is caused by the high pressure when the air bubble rapidly collapses.

[Review the information in the workbook.]

*[Note the definition of **impeller**.]*

[Call attention to Figures 4.1, 4.2, and 4.3—the three types of impellers pictured in the workbook.]

At the cutout in the pump casing, the fluid leaves under higher pressure. If the openings are too close, the pump may clog.

[Allow participants to discuss the following questions aloud, or in small groups.]

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

Ans: The appropriate choice would be an open type because it would tend not to clog.

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

Ans: The appropriate choice would be a closed impeller because there should be no solids in the treated water that could clog it. Using the closed impeller would yield a more efficient pump system.

Positive Displacement Pumps

Look at this page of your workbook. If you see a pump here that looks like what you are using, then you use a positive displacement pump.

One interesting note is that a progressive cavity pump tends to have less of a hydraulic surge effect than a piston pump. However, they are more expensive to purchase and rebuild.

Chemical Compatibility

[Review information in the workbook, reminding participants to be aware of the fluids used in each pump.]

☑ *[In this exercise, participants will refer to the corrosion guide in Appendix D of the workbook. A wide range of answers will be possible. An example of how to perform the activity is below:]*

Ans: [Refer to the row marked, "Alum," and have participants note whether alum would negatively affect each of the pump types. For example, a pump with a "C" listing would receive severe effects, whereas the pumps with an "A" listing would substantially resist the chemical.]

Overheating

[Refer participants to the introductory example about closing valves on a centrifugal pump. This helps to highlight the importance of knowing your equipment.]

If the pump overheats for a very long time, the motor will be damaged. If the breaker is oversized and the protection does not trip out the breaker, damage can also be caused to the pump or motor. In a centrifugal pump, you may be able to close the discharge valve for a few minutes without any damage. If left closed for a prolonged period, the pump will overheat. However, closing a discharge valve on a positive displacement pump for even a second can result in major damage. The pump will not have a chance to overheat before damage results.

[Review information in the workbook.]

Packing Gland and Mechanical Seal

[Review information in the workbook, noting the two types of seals commonly found in treatment plants, as shown in Figure 4.10 (packing gland) and 4.11 (mechanical seal).]

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

Lubrication

[Review information in the workbook.]

Take a look at Figure 4.12, Lubrication Analysis Report. This report is from a company that provides lubrication analysis. This figure is called a "Manager's Summary" because it contains a brief overview of the analysis, and highlights any significant or urgent trends.

When time permits, look at Appendix E at the back of your workbook. You will see a cover sheet touting the benefits of lubrication analysis. The next page contains an "Equipment Condition Report." In narrative form and in graphical form, the results of the analysis are conveyed in greater detail here than in the manager's summary. Look, for example, at the "Recommendations" and "Discussion of Results" sections. It shows the wear particle concentration and the abnormal wear effects of those particles. This should give you some good ideas for maintenance revisions at the facility. Even more in-depth information is contained in a "Lubrication Analysis" document; this is useful when a problem is severe or chronic and you must determine the cause of the problem.

Pump Curve

The pump curve can allow isolation of problems and also indicate operational range for healthy pump performance. Always operate within range.

[Review information in the workbook.]

BLOWERS AND COMPRESSORS: 7 minutes

There are two common types of blowers and compressors: centrifugal and positive displacement. In the centrifugal type, you can see in Figure 4.13 the blower, air filter, and valves that are common to both types of blower.

Different components require different maintenance. For example, the filter may be changed once per quarter, but the actual blower is rebuilt once every five years.

Centrifugal

[Review information in the workbook.]

Excessive vibration can shorten the life of the blower or pump. 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.

[Review the two bullet points in the workbook.]

You can see that Figure 4.14 shows a vibration analysis that is similar in scope to the lubrication analysis we recently discussed. When you have time, glance at the information that can be gathered from this type of predictive maintenance analysis. Also, when you have time, flip back to Appendix F for the rest of this sample report.

Positive Displacement

[Review information in the workbook.]

Valves might be inadvertently closed if an operator is not aware that the blower is running, or is unaware that this type of unit cannot allow that action. Although Figure 4.13 on page 4-8 shows a valve on a centrifugal blower, the valve location would be the same for a positive blower.

[Point out the picture of a rotary blower and the diagram of the internal workings of a positive displacement blower (Figures 4.15 and 4.16).]

Periodic Exercise

It is tempting to allow a well-functioning piece of equipment to keep working. However, it is harmful to the equipment if we do not allow all equipment to be used on a regular basis. Don't assume that you should just use one blower until it requires major service. Rotate the units and keep them all regularly maintained.

[Review information in the workbook.]

Chemical Compatibility

Like humans, equipment is designed to operate best under a specific set of circumstances. And, like us, they do not function well with chemical gases and high airborne particle levels. Think of compatibility like this: if you would not operate well in a certain environment, the equipment probably will not operate well, either, unless of course you had taken special precautions for the environment.

[Review information in the workbook.]

VALVES: 5 minutes

Now let's take a few minutes to review some of the types of valves you might see. Appendix G has pictures of each of these valve examples. As with the other equipment we have talked about, it is important for you to identify the overall category of components with which you work so that you will be able to understand the characteristics of maintenance that are required to keep them functioning.

[Refer participants to Appendix G and Appendix H. Allow a few minutes for them to identify some valves with which they are familiar.]

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

Periodic Exercise

[Review information in the workbook.]

Chemical Compatibility

[Review information in the workbook. If time permits, you may want to ask participants to identify the valves with which they work, and have them refer to Appendix D, which applies to pumps and valves, to note some possible corrosion issues.]

Backseat

[Review information in the workbook.]

Limitations

[Review information in the workbook. Give special emphasis to the key point.]

DRIVES: 5 minutes

Types of Drives

Let's talk now about the drives. Again, it is important to identify the type of drive so that you understand the way it works and what maintenance it requires.

Close Coupled

[Review information in the workbook.]

Split Shaft

[Review information in the workbook.]

A sheave is a pulley that may have numerous grooves on it. By moving the belt to a different groove, the speed can be changed. One example is the sheave arrangement on drill presses. Another use for sheave selection is to determine the desired speed of a pump, then being able to change the pump you have to a different driven speed (such as from 1750 to 500 rpm) with the proper sheave selection.

Drive Protection

A shear pins is a small metal shaft (maybe 1/16 inch in diameter) and costs about a dollar. It is placed into the shear pin hole. If excessive load is applied to the pump, the shear pin will be broken, thereby protecting the rest of the system from damage.

[Review information in the workbook.]

Alignment

You will see in your workbook three examples of alignment techniques. The first one is the cheapest and will only yield a rough idea how well the sheaves or shafts are aligned. In some cases, you may only need this level of alignment. However, as the speed increases and the size of equipment increases, it may be necessary to step up to dial or laser alignment.

[Review information in the workbook.]

HVAC: 5 minutes

Some of you may remember the Legionnaire disease problem many years ago, when microbial or similar activity in an HVAC system caused the deaths of several people. Regular cleaning and maintenance of HVAC systems is vitally important for health reasons. If staff start to develop an increase in illness, maybe the ducts are contributing to the problem.

Of course the systems themselves also benefit from proper attention.

Cleaning

[Review information in the workbook.]

Unrestricted Intake and Exhaust Louvers

[Review information in the workbook.]

Preventive Maintenance

[Review information in the workbook.]

The bulleted item reminds us that staff observations can be helpful in HVAC maintenance brings up a good point that applies to all PM work in the facility.

[Ask participants the following question. You may want to write their 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? Think of all the systems in your plant.

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

ELECTRICAL: 15 minutes

A moment ago, we discussed using senses to detect problems. This is important in the electrical services at your facility. Be aware at all times of possible problems; remember that our goal is to prevent serious problems by handling minor ones quickly and correctly.

Visual Inspection

[Review information in the workbook.]

Diagnostic Testing

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.

There are several non-destructive testing methods used for electrical service. These are important, as they allow us to "see" what is going on without actually disassembling any equipment. Operating voltage, to a certain extent, influence how and by whom maintenance on electrical systems is performed. Some jobs will be contracted to outside electricians.

Amperage Pulled

[Review information in the workbook.]

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. Have you ever heard this: "Here, put this fuse in to get the motor running. We'll get the right one later." Be sure to take fuse compatibility seriously.

Megger Test

[Review information in the workbook.]

GFI

[Review information in the workbook.]

Next we will talk about the last of our non-destructive testing methods. Thermographic scans are carried out while the equipment is live and under load. As with other PM programs, regular testing is advised in order to build a history that will reveal trends or verify sudden abnormal conditions. Some facilities may have access to a handheld device that shows, in very limited scope, the temperature readings. But, a professional scan will show pictures of a wide area. The handheld devices can also be used to recheck a small area after a problem has been fixed.

Thermographic Scan (Infrared)

Think back to our discussions of vibration and lubrication analyses. Another such tool is for data collection and management of maintenance issues is the thermographic scan, or IR scan or test. IR stands for infrared, and that is the name some of us are more familiar with, but thermographic testing is the preferred name. Look at the thermographic scans in Appendix I of your workbook. I will show a color version of the scans on the screen.

[Display Slide 7—Thermographic Scan #1. (Participants should refer to Figure I2 of the workbook.)]

What was being scanned?

Ans: The scan shows a 440 volt distribution panel secondary mixer fuse block.

What is the problem? How does it show on the scan?

Ans: C Phase line side of the breaker is overheated. (Point out the "hot spot" indicated by color change.)

What is the ambient temperature? What is the temperature of the overheated area?

Ans: Ambient temperature is 70º F; the overheated area reads 99.2º F.

[Display Slide 8—Thermographic Scan #2. (Participants should refer to Figure I3 of the workbook.)]

What is being scanned here? What is the problem, and what solutions are suggested?

Ans: Main drive cabinet main breaker is overheated. The suggested solution is to disassemble, clean, and retighten bad connection.

Remember that these analysis companies simply report their findings and recommendations. They do not fix the problem. It is up to the customer to decide what to do with the findings they receive.

[Display Slide 9—Thermographic Scan #3. (Participants should refer to Figure I4 of the workbook.)]

What do we see here? What is the temperature difference? Can you point out the "hot spot?"

Ans: The scan shows a main buss duct. Ambient temperature is 74.2 F and hot spot shows 110.5 F.

[Allow participants to discuss aloud what the benefits of this analysis might be. Would they have overlooked these things with their visual inspections?]

Other Testing

[Review information in the workbook.]

GAUGES AND THERMOMETERS: 3 minutes

Can anyone tell me why gauges and thermometers warrant a section of this training? What is so important about their maintenance?

Ans: They regulate other equipment; without them working properly, other equipment would not work properly. Also, they are important control indicators for process functions. Finally, like valves, they are usually inexpensive components that are easily serviced to protect other equipment failure.

Types of Gauges and Thermometers

Gauges

[Review information in the workbook.]

Thermometer

[Review information in the workbook.]

Vibration Isolation

Keeping the gauges and thermometers stable is important in order to ensure that their readings are accurate. Keep them from vibrating with the equipment.

[Review information in the workbook.]

Calibration

[Review information in the workbook.]

Periodic Reading and Recording

[Review information in the workbook.]

DETAILED INSPECTION (TANK DEWATERING): 5 minutes

Dewatering offers us the opportunity to take a good look inside the tank.

*[Review the definition of **dewatering** in the workbook.]*

Frequency

[Review information in the workbook.]

If a tank is never dewatered and inspected, and then it fails, you may have no option but to remove the tank from service at a less than desirable time. This may lead to a process upset and violation of limits in the NPDES permit.

Scheduling

[Review information in the workbook.]

[Ask participants to share aloud the answer to the following question that is found in the workbook.]

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

Ans: Various answers are possible; make sure participants list, at a minimum, the following answers:

- During summer months, the flow into most WWTPs is lower. This may provide some flexibility in removing tanks from service.
- However, discharge limits in the NPDES permit may become more stringent in the summer. This may create some concern about when tanks can be removed from service without fear of permit violations.
- If a major storm is expected (such as a hurricane), you may need to put a tank back into service with only partially completed repairs. For example, painting may not have been finished on all submerged parts, but the storm is expected to arrive within the next 24 hours. Here it is important to document the service completed and then finish it as soon as possible after the crisis situation.

ALARMS: 3 minutes

Our final section in this unit deals with alarms. Alarm maintenance is easily overlooked because they are often located out of sight, and they rarely call attention to themselves unless there is an emergency. We just *expect* them to operate correctly.

By now, though, you should be aware that one of our "rules to live by" is, "Be proactive!" This is especially important with alarms. We want to be sure they are working all the time.

Level of Sensitivity

[Review information in the workbook.]

Testing of Sensor or Probe

[Review information in the workbook.]

Full Test

Remember to notify local authorities of the pending test. Aside from inconvenience and a possible fine for unnecessary response by emergency personnel, real emergencies may not get the attention they need if response teams are busy responding to a false alarm at the plant.

You know the two most important rules of PM: Be proactive, and follow manufacturer's recommendations at a minimum. By completing this unit, you also have some general notions about the different types of equipment and their components. Choose equipment carefully to ensure that it meets the needs of your facility, and then be vigilant in maintaining that equipment. This PM information backs up all the goals and components of maintenance that was discussed in early units.

Thank you for your attention. Are there are follow-up questions that I can answer before we conclude this session?

[This page contains references used in this unit.]