

SECTION 2.0

DEVELOPMENT OF O&M PROCEDURES FOR AIR POLLUTION CONTROL EQUIPMENT

Generally, one or more individuals at a plant site are responsible for ensuring that the air pollution controls (APCs) are operated and maintained so they meet design removal efficiencies for air pollutants and keep the plant in compliance with established emission limitations.

Unfortunately, most plant O&M personnel do not receive in-depth training on the theory of APC operation, diagnostic analysis, and the problems and malfunctions that may occur over the life of a unit. Plant personnel tend to learn about the operation of a specific unit, and they gain operating experience as a result of day-to-day operating problems. This so-called "on-the-job" training can result in early equipment deterioration or catastrophic failures that could have been avoided.

This section presents the basic elements of an O&M program that can prevent premature APC failure. This program is not all-inclusive; nor does it address all potential failure mechanisms. Nevertheless, it provides the user with enough knowledge to establish a plan of action, to maintain a reasonable spare parts inventory, and to keep the necessary records for analysis and correction of deficiencies in APC operation.

The components of an O&M plan are management, personnel, preventive maintenance, inspection program, specific maintenance procedures, and internal plant audits. The most important of these are management and personnel. Without a properly trained and motivated staff and the full support of plant management, no O&M program can be effective.

2.1 Management and Staff¹

Personnel operating and servicing the APCs must be familiar with the components of the units, the theory of operation, limitations of the device, and proper procedures for repair and preventive maintenance.

For optimum performance, one person (i.e., a coordinator) should be responsible for APC O&M at small or medium-sized plants, this individual could be the Plant Engineer or Environmental Manager. Except in very large plants, the APC coordinator would have other plant/environmental assignments. All requests for repair and/or investigation of abnormal operation should go through this individual for the coordination of efforts. Upon completion of repairs, final reports also should be transmitted to the originating staff through the APC coordinator. Thus the coordinator will be aware of all maintenance that has been performed, any chronic or acute operating problems that occur, and any work that is in progress.

The coordinator, in consultation with the operation (process) personnel and management, also can arrange for and schedule all required maintenance. He/she can assign priority to repairs and order the necessary repair components, which sometimes can be received and checked out prior to installation. Such coordination does not eliminate the need for specialists (electricians, pipe fitters, welders, etc.), but it does avoid duplication of effort and helps to ensure an efficient operation.

Many APC failures and operating problems are caused by mechanical deficiencies. These are indicated, for example, by changes in differential pressures and temperatures, by opacity readings, and by changes in flow rates. By evaluating process conditions, pressure and temperature readings, inspection reports, and the physical condition of the unit, the coordinator can evaluate the overall condition of the APC and recommend process modifications and/or repairs.

The number of support staff required for proper operation and maintenance of a unit is a function of unit size, design, and operating history. Staff requirements must be assessed periodically to ensure that the right personnel are available for normal levels of maintenance. Additional staff will generally be needed for such activities as a major

rebuilding of a unit or structural changes. This additional staff may include plant personnel, outside hourly laborers, or contracted personnel from service companies or APC vendors. In all cases, outside personnel should be supervised by experienced plant personnel. The services of laboratory personnel and computer analysts may also be needed. The coordinator should be responsible for final acceptance and approval of all repairs. Figure 2-1 presents the general concept and staff organizational chart for a centrally coordinated O&M program.

2.2 Training

As with any highly technical process, the O&M staff responsible for APC equipment must have adequate knowledge to operate and repair that equipment.

Many components of APCs are not unique, and special knowledge regarding the components themselves is not required; however, the arrangement and installation of these components are unique in most applications, and special knowledge and care are needed to maintain their optimum performance.

Many plants have a high rate of personnel turnover, and new employees may be assigned to work on an APC who have had no previous contact with such equipment. To provide the necessary technical expertise, management must establish a training program for each employee assigned to APC O&M.

An optimum training program should include the operators, supervisors, and maintenance staff. Changes in operation that affect composition, temperature, oil or moisture content, acid dew point, and the particulate abrasiveness of the gas stream entering the unit can have a detrimental effect on the operation of APC equipment. The process operator has control over many of these variables. An understanding of the cause-and-effect relationship between process conditions and the APC can help to avoid many performance problems. Safety is also an important aspect of any training program. Each person associated with the unit should have complete instructions regarding confined-area entry, first aid, and lock-out/tag-out procedures.

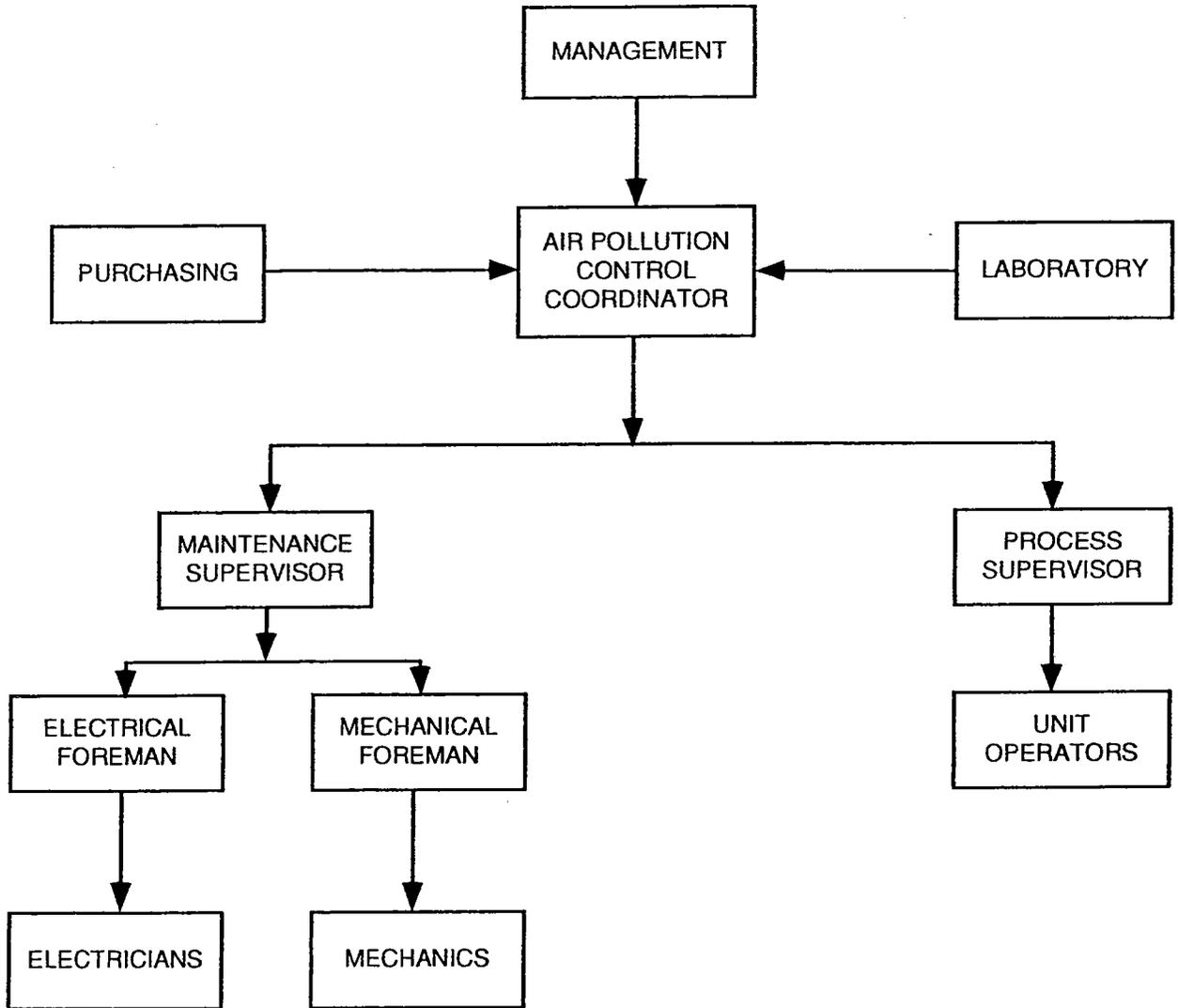


Figure 2-1. Organization chart for centrally coordinated O&M program.

Thus, a typical APC training program should include safety, theory of operation, a physical description of the unit, a review of subsystems, normal operation indicators, abnormal operations (common failure mechanisms), troubleshooting procedures, a preventive maintenance program, and recordkeeping.

The O&M program should emphasize optimum and continuous performance of the unit. The staff should never get the impression that anything less than optimum performance is acceptable. Redundancy is established in the unit solely to provide a margin of safety for achieving compliance during emergency situations. Once a pattern is established that allows a less-than-optimum condition to exist (i.e., reliance on built-in redundancy), less-than-optimum performance becomes the norm and the margin of safety begins to erode.

The training program should be reinforced by the preparation of followup written material. Each plant should prepare and continually update APC operating maintenance manuals for each unit. A generic manual is usually inadequate because each vendor's design philosophy varies. The use of photographs, slides, and drawings aids in the overall understanding of the unit and reduces lost time during repair work.

2.3 Maintenance Manuals

Specific maintenance manuals should be developed for each APC at a source. The basic elements of design and overall operation should be specific to each APC and should incorporate the manufacturer's literature and in-house experience with the particular type of unit. The manual should relate to the physical aspects of the unit. Descriptions should be brief and to the point; long narratives without direct application should be avoided.

Figure 2-2 presents a suggested outline for a typical manual. The manual should begin with such basic concepts as the APC description and operation. These can be followed by a section on component parts, which should include detailed drawings and an explanation of the function of each component.

- I. GENERAL DESCRIPTION OF AIR POLLUTION CONTROL
 - A. Equipment Components
 - B. Auxiliary Equipment (e.g., fan, ash removal system)
- II. DESCRIPTION OF OPERATION
 - A. Pollutant Collection Mechanisms
 - B. Pollutant Removal from APC
- III. SAFETY EQUIPMENT
 - A. Gas-Monitoring Equipment
 - B. Personal Protection Equipment (e.g., hearing protection, protective clothing)
- IV. COMPONENT DESCRIPTION
 - A. Specific Descriptions of Equipment Components (from vendor)
 - B. Details on Materials of Construction, Housing, Valves, Dampers, Motors, Pumps, Fans
- V. EXTERNAL INSPECTION AND MAINTENANCE
 - A. Housing Components (e.g., gaskets, expansion joints)
 - B. Monitoring Equipment
 - C. Control Cabinet
 - D. Interlocks
- VI. INTERNAL INSPECTION AND MAINTENANCE
 - A. Internal APC Components (e.g., bags for fabric filter)
 - B. Inlet and Outlet Ducts
 - C. Hoppers or Sumps

APPENDIX

- A. Inspection and Maintenance Checklist
- B. Layout Details

Figure 2-2. Outline for air pollution control maintenance manual.

The section on external inspection and maintenance includes all supporting equipment, such as cleaning mechanisms, instrumentation, and air compressors (where applicable). The next section should cover procedures for internal inspection and maintenance, as these are extremely critical in maintaining performance. In a fabric filter, for example, periodic checks are necessary to maintain bag integrity, to remove accumulated ash deposits, and to prevent air inleakage. Each of these sections should provide a procedure for evaluating the component. The manual should identify key operating parameters, define normal operation, and identify indicators of possible deviations from normal condition. Fabric filter key operating parameters, for example, include temperature, pressure, cleaning cycle, opacity, or other parameters that can be used to establish the basic operating condition of the unit.

After conditions are evaluated, a procedure must be presented to replace, repair, or isolate each component. If proper procedures are not followed, the corrective action could result in further damage to the unit, excessive emissions, or repeated failure.

2.4 Operating Manuals

Whereas maintenance manuals are designed to facilitate physical repairs to the APC, operating manuals are needed to establish an operating norm or baseline for each unit. Maintenance of the physical structure cannot ensure adequate performance of the unit because gas-stream conditions such as temperature, composition, and volume can cause the APC to malfunction and rapidly decrease collection efficiency.

The operating manual should parallel the maintenance manual in terms of introductory material so that the operators and maintenance personnel have the same basic understanding of the components and their function and of the overall operating theory. Additional information should be provided on the effects of major operating variables such as gas volume, gas temperature, and pressure drop. Figure 2-3 presents a generic outline for an operating manual.

With regard to fuel combustion sources, for example, the manual should discuss the effects of such process variables as burner conditions, burner alignment, and

- I. DESCRIPTION OF CONTROL DEVICE
 - A. Equipment Components
 - B. Auxiliary Equipment (e.g., fans, ash removal system)
- II. DESCRIPTION OF OPERATION
 - A. Pollution Collection Mechanisms
 - B. Pollutant Removal from APC
- III. OPERATIONAL FACTORS
 - A. Gas Characteristics (e.g, volume, temperature, composition)
 - B. Differential Pressure and Other Key Monitoring Parameters
 - C. Stack Visuals (e.g., opacity, plume color)
- IV. AUXILIARY SYSTEM MALFUNCTION
(e.g., fan, particulate removal system dampers)
 - A. Plugged Hoppers
 - B. Fan Noises
 - C. Pump and Motor Malfunctions
- V. STARTUP
 - A. Safety Check
 - B. Specific Procedures
- VI. SHUTDOWN
 - A. Specific Procedures
 - B. Differentiate Between Short (Overnight) and Long (Several Days) Shutdowns

Figure 2-3. APC operating manual outline.

pulverizer fineness, which can change the ash particle properties and size distribution. An expected normal range of values and indicator points should be established as reference points for the operator.

Startup and shutdown procedures should be established, and step-by-step instructions should be provided to ensure sequenced outage of equipment to aid in maintenance activities and to eliminate startup problems.

2.5 Spare Parts¹

An inventory of spare parts should be maintained to replace failed parts as needed. Because all components or subassemblies cannot be stocked, a rational system must be developed that establishes a reasonable inventory of spare parts. Decisions regarding which components to include in the spare parts inventory should be based on the following:

1. Probability of failure
2. Cost of components
3. Replacement time (installation)
4. Whether the part can be stored as an individual component or subassembly (e.g., shaker assembly for fabric filter)
5. In-house technical repair capabilities
6. Available space

The probability of failure can be developed from outside studies, vendor recommendations, and a history of the unit. It is reasonable to assume that components subjected to heat, dust, weather, or wear are the most likely to fail. Components of this type are no different from those in process service, and reasonable judgment must be used in deciding what to stock. Maintenance staff members should be consulted for recommendations concerning some items that should be stocked and the number required. Adjustments can be made as operating experience is gained.

Another factor that enters into decisions regarding a spare parts inventory is the cost of individual components. Maintaining an extensive inventory of high-cost items that have low probability of failure is not justified.

The time required to receive the part from the vendor and the time required to replace the part on the unit also influence whether an item should be stocked. If the lead time for a critical part is a matter of weeks or months, or if a component must be specially built, stocking such items is advantageous.

Many plants have an electronics and mechanical shop whose staff can repair or rebuild components to meet original design specifications. The availability of this service can greatly reduce the need to maintain component parts or subassemblies. In these cases, one replacement can be stocked for installation during the period when repairs are being made. For example, many printed circuit boards can be repaired internally, which reduces the need to stock a complete line of electronic spare parts.

2.6 Work Order Systems¹

A work order system is a valuable tool that allows the APC coordinator to track unit performance over a period of time. Work order and computer tracking systems are generally designed to ensure that the work has been completed and that charges for labor and parts are correctly assigned for accounting and planning purposes. With minor changes in the work order form and in the computer programs, the work order also can permit continuous updating of failure-frequency records and can indicate whether the maintenance performed has been effective in preventing repeated failures. In general, the work order serves three basic functions:

1. It authorizes and defines the work to be performed.
2. It verifies that maintenance has been performed.
3. It permits the direct impact of cost and parts data to be entered into a computerized data handling system.

To perform these functions effectively, the work order form must be specific, and the data fields must be large enough to handle detailed requests and to provide specific responses. In many computerized systems, the data entry cannot accommodate a narrative request and specific details are thus lost.

Most systems can accommodate simple repair jobs that do not involve multiple repairs, staff requirements, or parts delays. Major repairs, however, become lost in the system as major events because they are subdivided into smaller jobs that the system can handle. Because of this constraint, the tracking system may show a large repair project with many components (e.g., a cleaning system failure or control panel repair) and a common cause as a number of unrelated events.

For diagnostic purposes, the work order system requires a subroutine that links repairs, parts, and location of failure in an event-time profile. The exact location of component failures also must be clearly defined. In effect, it is more important to know the pattern of the failure than its cost.

In summary, the goals of the work order system are as follows:

- To provide systematic screening and authorization of requested work.
- To provide the necessary information for planning and coordination of future work.
- To provide cost information for future planning.
- To instruct management and craftsmen in the performance of repair work.
- To estimate manpower, time, and materials for completing the repair.
- To define the equipment that may need to be replaced, repaired, or redesigned (work order request for analysis of performance of components, special study, or consultation, etc.).

Repairs to the unit may be superficial or cosmetic in nature, or they may be of an urgent nature and require emergency response to prevent damage or failure. In a major facility, numerous work order requests may be submitted as a result of daily inspections

or operator analysis. Completing the jobs in a reasonable time requires scheduling the staff and ordering and receiving parts in an organized manner.

For effective implementation of the work order system, the request must be assigned a level of priority regarding completion time. These priority assignments must take into consideration plant and personnel safety, the potential effect on emissions, potential damage to the equipment, and the availability of maintenance personnel, parts, and the boiler, process, or control equipment. Obviously, all jobs cannot be assigned the highest priority. Careful assignment must be made as quickly as possible after requests are received. Figure 2-4 is an example of a five-level priority system.

A work order request that is too detailed will require extra time to complete, and a complex form can lead to superficial entries and erroneous data. The form should concentrate on the key elements required to document the need for repair, the response to the need (e.g., repairs completed), parts used, and manpower expended. Although a multipage form is not recommended, such a form may be used for certain purposes. For example, the first page can be a narrative describing the nature of the problem or repair required and the response to the need. The maintenance staff must indicate the cause of the failure and changes that could prevent recurrence. Simply making a repair to malfunctioning system controls and responding that "the repairs have been made" is inadequate. Unless a detailed analysis is made of the reason for the failure, the event may be repeated several times. Treating the symptom (making the repair or replacing parts) is not sufficient; the cause of the failure must be treated.

In summary, the following is a list of how the key areas of a work order request are addressed.²

1. Date - The date is the day the problem was identified or the job was assigned if it originated in the planning, environmental, or engineering sections.
2. Approved by - This indicates who authorized the work to be completed, that the request has been entered into the system, and that it has been assigned a priority and schedule for response. The maintenance supervisor or APC coordinator may approve the request, depending on the staff and

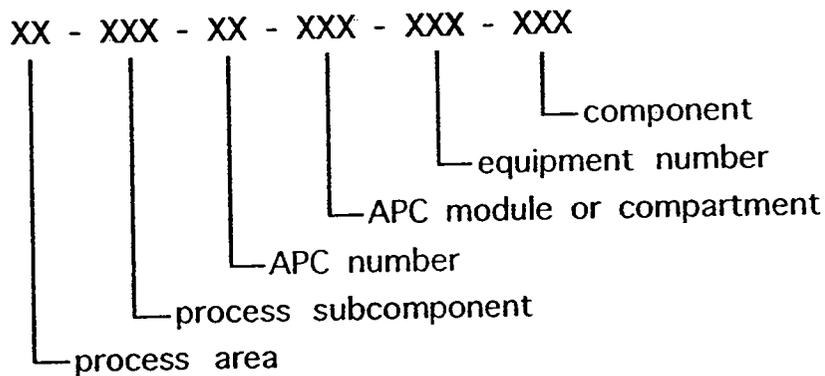
WORKORDER PRIORITY SYSTEM

PRIORITY	ACTION
1	Emergency Repair
2	Urgent repair to be completed during the day
3,4	Work that may be delayed and completed in the future
5	Work that may be delayed until a scheduled outage

Figure 2-4. Example of five-level priority system.

the size of the facility. When emergency repairs are required, the work order may be completed after the fact, and approval is not required.

3. Priority - Priority is assigned according to job urgency on a scale of 1 to 5.
4. Work order number - The work order request number is the tracking control number necessary to retrieve the information from the computer data system.
5. Continuing or related work order numbers - If the job request is a continuation of previous requests or represents a continuing problem area, the related number should be entered.
6. Equipment number - All major equipment in an APC should be assigned an identifying number that associates the repair with the equipment. The numbering system can include the process area, major process component, APC number, APC module compartment, equipment number, and process subcomponent. This numeric identification can be established by using a field or grouped numbers. For example, the following could be used:



If the facility only has one APC and one process, the first five numbers (two groups) may not be required, and the entry is thus simplified. The purpose of the ID system is to enable analysis of the number of events and cost of repair in preselected areas of the APC. Greater detail in the equipment definition will allow more detail in later analyses.

7. Description of work - The request for repair is usually a narrative describing the nature of the failure, the part to be replaced, or the work to be completed. The description must be detailed but brief because only a limited number of characters can be entered into the computerized data system. Additional pages of lengthy instruction regarding procedures may be attached to the request (not for computer entry).

8. Estimated labor - Assignment of personnel and scheduling of outages of certain equipment require the inclusion of an estimate of manhours, the number of in-house staff needed, and whether outside labor is needed. The more complex jobs may be broken down into steps, with different personnel and crafts assigned specific responsibilities. Manpower and procedures in the request should be consistent with procedures and policies established in the O&M manual.
9. Material requirements - In many jobs, maintenance crews will remove components before a detailed analysis of the needed materials can be completed; this can extend an outage while components or parts are ordered and received from vendors or retrieved from the spare parts inventory. Generally, the cause of the failure should be identified at the time the work order request is filled, and specific materials needs should be identified before any removal effort begins. If the job supervisor knows in advance what materials are to be replaced, expended, or removed, efficiency is increased and outage time reduced. Also, if parts are not available, orders may be placed and the parts received prior to the outage. Material requirements are not limited to parts; they also include tools, safety equipment, etc.
10. Action taken - This section of the request is the most important part of the computerized tracking system. It should provide a narrative description of the repair conducted in response to the work order request. The data must be accurate and must clearly respond to the work order request.
11. Materials replaced - An itemized list of components replaced should be provided for tracking purposes. If the component has a preselected ID number (spare parts inventory number), this number should be included.

Actual man-hours expended in the repair efforts can be indicated by work order number on separate time cards and/or job control cards by craft and personnel number.

Copies of work orders for the APC should be retained for future reference. The APC coordinator should review these work orders routinely and make design changes or equipment changes as required to reduce failure or downtime. An equipment log also should be maintained, and the work should be summarized and dated to provide a history of maintenance on the unit.

2.7 Computerized Tracking

2.7.1 Work Orders

If the work completed and parts used in the APC have been entered in the computerized work order system with sufficient detail, maintenance and management personnel can evaluate the effectiveness of APC maintenance.

Preventive maintenance (PM) man-hours and repair man-hours also can be compared to evaluate the effectiveness of the current PM program. The level of detail may allow tracking of the impact of PM on particular subgroups (e.g., fans, hoppers) as changes are made in PM procedures. The effectiveness of the PM program may be further evaluated by comparing the required number of emergency repairs with scheduled repairs over a period of time (i.e., priority 2 versus priority 5, etc.).

The purpose of the computerized tracking system is not to satisfy the needs of the accountants or programmers or to state that the plant has such a system. Rather, the purpose of a computerized tracking system is to provide the necessary information to analyze APC maintenance practices and to reduce component failures and excess emissions. The maintenance staff and APC coordinator must clearly define the kind of data required, the level of detail needed, and the type of analysis required prior to the preparation of the data-handling and report-writing software. Examples of output may be man-hours by department, man-hours by equipment ID, number of repairs, number of events, number of parts, and frequency of events.

2.7.2 APC Operating Parameters

In addition to tracking work orders, the computer can be used to develop correlations between process and APC operating parameters and observed emission profiles. Depending on the type of cycles expected in process operation, the data may be continuously input into the system or it may be entered once or twice a week from operating logs or daily inspection reports.

For example, the key data for tracking performance are pressure differentials, opacity (i.e., 6-minute averages), boiler load (or associated parameter proportional to

gasflow volume), flue gas temperature, and fuel quality data (i.e., fuel source, ash, fineness, etc.).

2.8 Procedures for Handling Malfunction

Many malfunctions are of an emergency nature and require prompt action by the maintenance staff to reduce emissions or to prevent damage to the unit. On some units, predictable but unpreventable malfunctions can be identified; for example, such malfunctions for baghouses would include hopper pluggages, bag failure in fabric filters, and cleaning system failure. These problems and corrective actions are discussed in the sections specific to each control device.

An effective O&M program should include established written procedures to be followed when malfunctions occur. Having a predetermined plan of action reduces lost time, increases efficiency, and reduces excessive emissions. The procedures should contain the following basic elements: malfunction anticipated, effect of malfunction on emissions, effect of malfunction on equipment if allowed to continue, required operation-related action, and maintenance requirements or procedure.

REFERENCES FOR SECTION 2

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