United States Environmental Protection Agency
Region V
230 South Dearborn
Chicago, IL 60604
EPA-905/2-80-002
May, 1980
Air
PB80-202966

EPA

Design Considerations For Minimizing Operation And Maintenance Problems Of Particulate Control Equipment

DESIGN CONSIDERATIONS FOR MINIMIZING OPERATION AND MAINTENANCE PROBLEMS OF PARTICULATE CONTROL EQUIPMENT

by

PEDCo Environmental, Inc.
Donald J. Henz
Project Director

Contract No. 68-02-2535
Task No. 7

Project Officers

Henry Onsgard and Dr. Indur Goklany
Air Programs Branch

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V
230 S. DEARBORN STREET
CHICAGO, ILLINOIS 60604

March 1980

CONTENTS

CONTENTS (continued)

DISTRIBUTION AND DISCLAIMER STATEMENT

This report is issued by the United States Environmental Protection Agency (U.S. EPA) to report technical data of interest to a limited number of readers. Copies are available free of charge to grantees, selected contractors, and Federal employees in limited quantities from the Library Services Office (MD - 35), Research Triangle Park, North Carolina, 27711, or for a fee from NTIS 5285 Port Royal Road, Springfield, Virginia, 22161.

This report was furnished to the U.S. EPA by PEDCo Environmental, Inc., 11499 Chester Road, Cincinnati, Ohio, 45246, in fulfillment of Contract No. 68-02-2535. The contents of this report are reproduced herein as received from PEDCo Environmental, Inc. The opinions, findings, and conclusions expressed are those of the authors and are not necessarily those of the U.S. EPA. Mention of company or product name is not to be considered as an endorsement by the U.S. EPA.

SECTION 1

INTRODUCTION

This report addresses various operation and maintenance problems frequently associated with three types of air pollution control equipment: electrostatic precipitators, scrubbers, and fabric filters. The discussion presented is limited to a summary of information gathered by the Industrial Gas Cleaning Institute, from its members, for PEDCo Environmental. The purpose of this document is to present the comments and suggestions of major manufacturers of the control equipment as indicated in responses to a questionnaire (see Appendix).

The report discusses instrumentation, materials of construction, and design considerations in particulate control equipment that improve performance. Such improvements include reduction or prevention of malfunction, early detection of malfunction, and easier maintenance and operation of equipment. Because some problems can never be completely eliminated, methods of reducing downtime are also addressed.

SECTION 2

ELECTROSTATIC PRECIPITATORS

2.1 ELECTRODES

Electrostatic precipitators (ESP's) use two types of electrodes: discharge and collection. The discharge electrodes are held at a high electrical potential during precipitator operation to ionize the gas and establish electrical fields for particle charging and precipitation. Collection electrodes are usually solid sheets with a baffle arrangement to minimize gas velocities near the dust surface and provide stiffness to the plate.

Electrode failure usually results from electrical erosion, mechanical fatigue, or hopper buildup. The following are recommendations for prevention of electrode failure and replacement of electrodes.

2.1.1 Prevention of Failure

2.1.1.1 Electrical Erosion--

Electrical erosion can usually be prevented or minimized by a few precautionary measures. Although failure sometimes results from manufacturing defects, this type of failure can be prevented by attention to detail in the design and manufacturing of electrode systems. Abnormal spark rates, high-current arcs, or high-energy sparks can cause electrical erosion. Prevention requires properly sized automatic voltage controls, which keep operating voltage close to the sparking threshold and never allow continuous arcing. Controls should be capable of limiting sparking current surges, so that they are no greater than two or three times the normal peak current. Controls should be closely matched in size to the expected operating power levels, should react quickly to each spark event (within one cycle or less), and should operate effectively at very low sparking rates (i.e., below 10 sparks/minute). The automatic power control equipment should also be checked regularly as part of the preventive maintenance program. Manual operation of controls for extended periods should be avoided.

Discharge and collection electrodes should be properly aligned during equipment erection, and electrical contact between the stabilizing frame and emitting electrode should be good. One manufacturer recommends the use of a rigid frame design to minimize electrical failures. The physical connection of the electrodes to the support frame must be tight to prevent spit-arc erosion. When weighted wire electrodes are used, wires extending above or below the collection plates should have shrouds to prevent erosion. Because close clearances may cause electrode erosion, care must be taken to space plates and wires uniformly throughout the length of the emitting electrode. The edges of all high-voltage and grounded surfaces between electrodes should be smooth and rounded.

2.1.1.2 Mechanical Fatigue--

Mechanical fatigue can be prevented by selecting the proper materials of construction, eliminating welds, especially in high-stress areas, minimizing flexing, reducing cross-sectional area at junction points, and providing strong vibration- and stress-resistant connections to eliminate stress during normal rapping. Rapping frequency and intensity should also be controlled to minimize mechanical fatigue. Mechanical stress can be prevented by ensuring that electrodes are adequately tensioned, having a mounting arrangement that permits the ends of the electrodes to rotate slightly, and keeping the unbraced length of the electrode relatively short. Wire electrodes must not be scratched or nicked during replacement because such accidents can cause fatigue failure. Corrosion resistance is also important to help prevent fatigue failures. In some instances the use of alloys should be considered for electrode wires.

2.1.1.3 Hopper Buildup--

Because high dust levels can cause excessive sparking and undervoltage, high-voltage power systems should provide for automatic shutdown if such levels occur. High dust levels in the hoppers can also cause wire weights to float and wires to slacken; this may lead to kinking and permanent damage if wires are of soft steel. Hard spring wire is recommended to prevent this from occurring. However, if hopper ash levels are allowed to buildup, evacuation of ash will not necessarily result in electrode realignment, possibly necessitating repairs to the high-voltage structure, collecting surfaces, or both.

Dust hopper buildup can be minimized or eliminated in several ways. First, the hopper and removal system must be properly designed. This should include a hopper with the correct valley angle for the material being collected, collecting and discharge electrodes that allow effective rapping, poke holes in the hopper neck, level indicators, adequate insulation and/or heaters for each hopper, and in some instances (e.g., collection of oil soot) insulation for the conveyer system. A properly sized and operating conveying system and hopper vibrators can help minimize dust buildup in the hopper. Also, the power control system must automatically shut down when high dust levels cause excessive arcing.

2.1.2 Minimization of Downtime

When electrodes fail, quick replacement is desirable. Use of weighted wire electrodes can prevent excessive downtime. By contrast, rigid frame electrodes are difficult to straighten when bent, and harp frames are difficult to replace in many designs, although wires can be cut out. If rigid electrodes are used they should be of one-piece construction, so that only top and bottom connections have to be made inside the ESP if replacement is required.

Designs suggested by manufacturers for easy replacement of electrodes include pin-and-loop construction and use of spiral wires in a rigid frame. Also, ribbon electrodes can be so "tuned" in a rigid frame that breakage or removal of an electrode does not distort the frame.

Walkways between the fields should also be provided for quick and easy identification of failed electrodes. Hopper access doors should be wide enough to accommodate ladders, and access platforms at the hopper manhole level should be high enough that a ladder can reach the lower high-voltage frame from the base of the hopper. Installation of individual large-element rigid electrodes requires use of side-access doors and positioning from above. Adequate clearance between collecting surfaces and interior walkways must be provided to permit this procedure.

2.2 DUST REMOVAL

2.2.1 Design

Many of the measures for prevention of dust hopper buildup also apply to dust removal. These include adequate insulation and heaters to maintain flue gas above the dewpoint and prevent condensation, vibrators tied into the ash removal system so that rapping cannot occur unless the hopper is being evacuated, poke holes or strike plates to make pluggage elimination easier, and an adequate hopper level indicator. Although helpful in some cases, vibrators may cause dust compaction leading to clogging. Thus, care must be taken in selecting a vibrator. Installation of hopper vibrator vacuum interlocks may help prevent compaction of collected ash. One manufacturer also suggested installation of activated panels, which act like vibra-screws, on hopper walls where bridging is likely.

Dust removal can also be facilitated by designing the hopper so that the valley angle is greater than 55 degrees, the sides are reasonably smooth, and the transformation from rectangular hoppers to round outlets is accomplished without ledges or projections.

One point particularly stressed by the manufacturers is that hoppers should never be considered a storage device. Operator control and response to alarms is also very important in preventing hopper blockage and ensuring continuous dust removal. Proper design and maintenance of the conveying systems is also important. One recommendation is to use suction, rather than pressure, conveying systems because of wearing of upper valve seats in pressure systems. This wearing allows air leakage through the valves, causing reentrainment and plugging. Another suggestion was that screw conveyers be designed to carry normal amounts of dust at 30 percent loading, so that extra capacity is available for flooded hoppers. Also, all conveyer systems should be powered sufficiently to provide for a flooded, compacted dust load condition. A minimum width of 0.3 m (12 in.) is recommended for conveyors to prevent bridging. If 0.225-m (9-in.) conveyors are used under trough hoppers, however, flared troughs are recommended. Screw conveyers should be operated at speeds from 15 to 30 rpm, because they are likely to require less maintenance than conveyers operated at higher speeds. The conveyer system should be equipped with failure alarms. Zero speed indicators are suggested for screw conveyers, and pressure sensors are suggested for pneumatic systems. In addition, the lateral strength of guide or rapping bars should be sufficient to resist permanent damage when dust pressure causes side thrust. Usually, good operator control and a good preventive maintenance program forestall many problems.

2.2.2 Rapper Operation

Poor ESP performance can result from rapping/vibration forces that are either too mild or too severe. The rapping/vibration sequence and intensity must be variable to optimize dust removal and prevent reentrainment. Each field should be equipped with separate controls for rapping frequency, duration, and intensity. One method of determining whether rappers are properly adjusted is to install recording opacity meters or other optical instruments in outlet ducts to determine severity and interval of rapper puffs. The use of individual rapper ground fault detection and annunciation and accelerometer checks of rapping equipment during initial startup can also help ensure proper adjustment during operation of rappers. Complete electrical instrumentation, such as primary and secondary current and voltage meters, should be used in each electrical section to help optimize rapper intensity and frequency. Unduly mild rapping/vibration forces are normally detectable through a gradual deterioration in the electrical readings. Noting electrical characteristics of given high-voltage electrical sections allows determination of dust buildup, which affects resistivity, power, and collection efficiency. Several weeks may be required to verify dust buildup. When buildup is suspected, rapping intensity should be increased for 1 or 2 hours without deenergizing the precipitator. If the power level increases, the rapping intensity should be reduced to slightly above the original level, and the observations should be repeated.

2.3 INSULATORS

2.3.1 Prevention of High-Voltage Tracking

If an insulator is of adequate length and design, high-voltage tracking is usually caused by moisture and/or conductive dust. A properly designed purge and/or pressurization system should be provided for the insulator compartments in addition to heaters for the insulators. Screen tubes under the insulators can also be used to prevent flow into the insulator. Thermal insulation of the insulator compartments is suggested to reduce heating power requirements. In addition, some designs may require preheating the purge air. Thermocouples and automatic controls to energize heaters and provide continuous temperature readings should be provided, as well as temperature interlocks on transformer/rectifier controls to prevent premature energization.

Condensibles on insulators may be avoided by using heated, unglazed insulators, which are sealed from the flue gas. One manufacturer, however, still recommends positive displacement of air in insulator compartments even when the insulators are not in direct contact with the flue gas. Periodic cleaning of insulators is also recommended to prevent high-voltage tracking.

2.3.2 Detection of High-Voltage Tracking

Insulator problems can be detected by monitoring high-voltage control functions, such as spark rate, amperage, and voltage, with trained operators. With properly functioning controls, voltage should be reduced before any serious damage is done. The location of arcing in an insulator can often be detected audibly, especially with the help of a mechanic's stethoscope. Some designs allow visual detection of insulator arcing by observing reflected light through the air purge holes at the top of the insulator. Insulator housing can also be visually inspected for water leakage.

2.3.3 Minimization of Downtime

Replacement of insulators should be considered in designing the ESP. Adequate access should be provided, and minimal disassembly should be required. Electrode supports should be designed to allow sufficient room inside insulator compartments for easy access and insulator removal and inside the precipitator housing for access and ease in temporarily supporting the electrode support frame during insulator replacement. Some designs provide special holes in the roof and support hooks for temporarily supporting the frame. Replacement is quicker and easier if the proper tools and lifting equipment are on hand and if plant maintenance personnel are properly trained. Also, in some low-temperature installations operating at a moderate negative pressure, insulators can be replaced while the process stays on line.

2.4 GAS SNEAKAGE

Gas sneakage results when a portion of the particulate-laden gas stream bypasses the collection zones in the ESP. The highest potential for sneakage exists around the outboard sides of collecting surface chambers and in hoppers under collecting surfaces. Proper design and placement of baffles are the primary means of avoiding gas sneakage. Baffles should be placed at the top, bottom, and sides of each active area of the precipitator. Also, hopper design and configuration can help prevent gas sneakage. Suggestions include the use of shadow baffles on outlet fields, sneak baffles at the perimeter of each bay, weir baffling of the inlet field distribution screens, and hopper baffles. Baffles must be solid, and open gaps around structural interferences should be as small as possible. Hoppers should be baffled when a hopper spans more than one mechanical field. Before startup, smoke wands and confetti can be used to ensure the lack of gas sneakage and determine whether airflow through the precipitator is uniform.

2.5 ADDITIONAL COMMENTS

Preventive maintenance and regular inspection are important in ensuring proper equipment performance and long life. Also, copying specifications from one job to another without considering relative size should be avoided, as well as combining features from several manufacturers.

Online washing of air heaters was cited as a potential problem. This sometimes causes cemented fly ash deposits in the first field of the precipitator that require washing to restore normal operations.

Other problems can result from air inleakage and from lack of provisions or improper provisions for temperature expansion. Gas inleakage may occur through the ash disposal system or through holes in the precipitator shell. This can be avoided by proper design of the hopper system and use of proper construction materials to fabricate the ESP.

Clinkers are likely to form at one time or another on discharge electrodes. The clinkers consist partly of oil soot carried over into the ESP after boilers started by oil flameout. These can grow until they contact a collecting surface, electrically grounding the associated power supply. The clinkers can also cause tracking on insulators and create a fire hazard. This problem can be minimized if the precipitator is partially energized to the extent necessary to maintain compliance and if operating voltage is kept below the spark threshold. Precautions should also be taken to prevent carryover of raw oil in the event of a flameout.

SECTION 3

FABRIC FILTERS

3.1 BAG FAILURE

Bag failure can usually be attributed to two major causes: chemical attack and abrasion. A fabric filter may be subjected to highly corrosive environments. Temperatures may range from 121° to 260°C (250° to 500°F), and such gases as sulfur dioxide, sulfur trioxide, and hydrochloric acid may be present, in addition to various other reactive gases and particulates. Complex reactions can occur between the fabric fibers and the gases, liquids, or solids, leading to rapid bag degradation. Below are presented suggestions to extend bag life, detect bag wear, and minimize downtime caused by bag failure.

3.1.1 Reduction

Bag life can be increased by properly sizing the dust collector. This entails using a low filter velocity to keep operating pressure drops small and a conservative air-to-cloth ratio to reduce mechanical agitation. Mechanical agitation and abrasion can also be eliminated by using the proper thimble height and bag tension.

Chemical attack can usually be minimized by proper selection of fabric and fabric finish. Heavier media and stronger fibers can help reduce bag replacement. The bag environment, however, should also be carefully controlled. Because high temperatures generally reduce bag life, gas inlet temperatures should be kept as low as possible without reaching the dewpoint. Startup and shutdown are critical periods for temperature control.

Damper valves should be tight when a single module or compartment in a fabric filter is removed for inspection or maintenance, especially when the system is operating near atmospheric pressure or under positive pressure. If the section is removed and the valve is not tight, hot moist gases from the system leak in and condense on the walls, floors, and hoppers, causing corrosion. When the filter bag is replaced, the condensate can cause severe damage to filter fabric. If a bag is torn, it should be tied off immediately before any chain reaction ensues.

Maintenance people should be well instructed in procedures for keeping the fabric collector operating properly and in good condition. They should also be instructed to maintain a complete inspection, repair, and replacement record for bag life history. Spare bags should be stored where they are not likely to be damaged and extra care should be taken in handling fiberglass bags.

3.1.2 Detection

Many times bag failure can be detected visually. Because the weakest point in a bag is usually the seam, the bag should be installed so that the seam is visible from access walkways. This makes inspection much easier. Pressure gauges can also be used in individual compartments to detect blinding or tearing of bags. Blinding increases backpressure, whereas tearing decreases pressure across the filter. Leaks can also be detected by observing stack discharge or monitoring opacity. If a leak is suspected, it can be located by injecting a special dust sensitive to ultraviolet light, in the exhaust gas stream.

3.1.3 Minimization of Downtime

The initial design of the fabric filter should incorporate features that allow easy maintenance. One suggestion is to minimize the rows of bags between walkways (e.g., four rows between two walkways or two rows between wall and walkway). Another suggestion is to provide a movable ladder for fast access to more inaccessible rows.

The use of compartmentalized fabric filters that allow isolation and shutdown of only one section for inspection or repair was cited as a major way of reducing downtime. Another way is to use bags requiring no tools for replacement, such as those with sewn-in snap bands or clips. The use of prebagged cages and bags requiring no tools for tension adjustment can help minimize downtime. One manufacturer has developed and recommends the use of a cartridge instead of filter bags to reduce changing time by approximately a factor of seven. Provisions for in-place repair of small holes in bags with inside filtration can also reduce downtime.

Forced ventilation cooling systems may be used with high-temperature fabric filters to minimize the cooling time required before maintenance.

3.2 COMPARTMENT DAMPERS

3.2.1 Construction Materials

The type of construction material used depends on the particular application. Although stainless steel is used occasionally, more often a good abrasion-resistant alloy is required.

3.2.2 Design

Dampers should be sized for a conservative flow velocity to minimize valve wear and if possible should be placed on the clean side of the collector. If they are on the dirty side, anti-fouling slide gates are recommended. Dampers should incorporate a self-cleaning mechanism and should be installed such that the mechanism is not located on the bottom of the duct. Designs should allow quick replacement of parts likely to wear, such as bearings and packing glands, which are serviceable from the outside. Adequate power to move the damper under all conditions is essential. Also suggested is the proper design of air-purged packing glands and valve seats.

Several manufacturers recommend poppet valves for high reliability and low maintenance even in highly abrasive and corrosive applications. The following items are recommended for poppet damper designs:

- Rigid shaft support
- Blade flex capability
- Adequate shaft strength
- Shaft guide bearings
- Mechanical lockout
- Adequate air supply
- Heat-traced compressed air lines or desiccant dryer

All gaskets and O-rings in dampers should be replaced periodically (i.e., every 2 years).

Limit switches should be installed to ensure proper valve operation in addition to timer operation. Control panel indicator lights can be used to indicate malfunctions of the damper. Also routine observations of compartment pressures on magnehelic gauges can be used to detect damper malfunctions.

3.3 SHAKERS

Because shakers are dynamic devices, they tend to last a limited time. The reasons for shaker failure include misaligned components, insufficient lubrication, improperly tensioned bags, and improper maintenance of filter media. The following are design recommendations and operating suggestions to prolong shaker life and reduce downtime during failures.

3.3.1 Design

The shaker should be designed for anticipated load to prevent overstressing. The thickness of the metal composing the shaker shaft, method of construction, bearing linkage, size of connection pins, and number and size of bags hung from any single shaft should be carefully evaluated. Heavy-duty construction is suggested for bearings, bag suspension hooks, and bag clamping devices. Materials of construction are also important. Shaker fabric filters used where chlorides are present should not be of stainless steel.

Shaker systems should include as few moving parts as possible. One design involves many bags mounted on a single pan rather than individual rows of shaker shafts. Another design using an intermittent pneumatic cleaner totally eliminates shaker parts and replaces them with a compressed air system.

Proper installation of a shaker requires careful attention to manufacturer instructions to ensure appropriate design tolerances and accurate initial dimensions.

Overshaking should be avoided to minimize shaker failures. In addition, damper seals should be tight, so that cleaning compartments are not subjected to airflow in the filtering direction during shaking. If the latter condition exists, the shaker is overworked. Resilient bushings in the shaker mechanism should be replaced as soon as they wear out.

3.3.2 Minimization of Downtime

All mechanical parts, such as linkages, bearings, and drives, should be located on the exterior shell of the collector to allow for quick maintenance and replacement of shakers. Knife edge bearings are recommended, because they can be replaced quickly. Shaker design incorporating zone isolation features also permit on-line repair of most items.

3.4 ADDITIONAL COMMENTS

The most prevalent problem cited by manufacturers is the tendency of plant personnel to ignore maintenance of the fabric filter system because it is not productive process equipment. Manufacturers stressed that maintenance personnel should be thoroughly educated in all aspects of fabric filter operation and maintenance and given adequate time to perform preventive maintenance. Operation and maintenance manuals should contain complete operation and maintenance information on the fabric filter and auxillary components, as well as suggestions for preventive maintenance and stocking of spare parts to reduce downtime. Fabric filter vendors should retain contact with buyers and provide components and systems that reduce maintenance and downtime.

Many problems occur because a fabric filter is not the correct equipment for a job or is improperly applied (e.g., the correct ratio, fabric, or type of cleaning is not used). Because the supplier is responsible for providing information about proper application, the buyer should make sure that the supplier is reputable and proven.

The use of a second collector in series with the primary one was suggested for critical applications. This can provide a means to keep the process on-line if the first collector fails or is being serviced.

Other recommendations include minimizing the frequency that bags pass through the sulfuric acid dewpoint (the maximum is four times per year) and increasing efforts to develop a low-cost replacement for teflon-coated fiberglass bags. One candidate material noted was Aramid.

Finally, only abrasion-resistant materials should be used at points subject to errosion. An alternative is to use bolted, replaceable surfaces of less costly metal.

SECTION 4

DUST HOPPERS AND CONVEYORS

The following subsections discuss common problems affecting dust hoppers. They suggest ways of detecting these problems and of eliminating or reducing them with a minimum of downtime.

4.1 PLUGGING OR JAMMING IN HOPPERS AND SCREW CONVEYORS

Various design features can help prevent dust hopper clogging. The hopper should be designed with as steep a valley angle as possible. Angles from 55 to 60 degrees are recommended. The design should also include as large a discharge opening as possible, smooth coatings (e.g., epoxy or teflon) on inside surfaces, and a minimum of ledges or other obstructions on sidewalls. The top of the hopper slope should be at least one bag diameter below the tube plate to allow proper dust discharge, and at least one foot of clearance should be provided between hopper walls and any internal partitions to provide easy discharge.

Adequate heaters and insulation should be installed in the hoppers to prevent condensation and caking. Additionally, jets of hot air will keep the material in the hopper in a fluid state. A temperature of 121°C (250°F) is recommended for the inner walls.

Plugging can be prevented if the hopper is not used as a storage vessel and if filter bags (in the case of fabric filters) are frequently cleaned to avoid large slugs of material falling into the hopper. Continuous evacuation of the hopper can be facilitated by properly sized airlocks and conveyors.

In some applications (e.g., where dust agglomerates easily), vibrators can be used to prevent plugging. Several manufacturers recommended against the use of vibrators in most applications, claiming that they tend to pack the dust. Devices such as sledge hammer plates and poke holes are helpful. The provision of inspection doors and other means of access to hoppers and conveyors also helps in the event of plugging.

Pressure indicators on pneumatic conveying systems, motion switches for rotary valves, and hopper level indicators can signal hopper buildup, but no known device can predict a hopper buildup. Inspection doors can be provided to allow periodic visual inspection.

A screw conveyor should be adequately sized to prevent plugging or jamming. Although no more than 30 percent loading should be required to carry normal amounts of dust at aerated density, a conveyor should be powered for 100 percent loading at compacted density. One manufacturer suggests that the screw conveyor be designed with a reserve capacity to allow for catch-up in a reasonable time when the conveyor system is shut down and the dust collector continues to operate. The conveyor should also be designed to allow expansion, as well as easy accessibility during maintenance or repair. In one design, the trough can be dropped down for easy access. Care must be taken, however, to reseal the trough properly, so that dust and air cannot leak into it.

Other design considerations can help eliminate plugging or jamming. A minimum of parts should be used in the dust area (e.g., use of piggyback screw conveyors avoids internal hanger bearings). Special consideration should be given to shaft size and support bearing spacings for conveyors. Also, internal hangers and moving components should be minimized. Conveyors and hoppers should be heated to prevent condensation. Vibrators or aeration stones are recommended for some applications to prevent formation of large clumps and ensure a free flow of material into the conveyor system. A coarse screen should be installed to keep large foreign objects from falling into the screw conveyor. Oversized rotary valves and rotary valve motors are also recommended. One manufacturer recommends that screw conveyors installed under trough hoppers should have ribbon flight to ensure uniform drawdown and to prevent tooling of dust surfaces. Box conveyors should be a minimum of 0.3 m (12 in.) wide, and flared troughs should be used where 0.225-m (9-in.) conveyors are used. Although price increases with decreasing conveyor speeds, a conveyor run at lower speeds (i.e., 15 to 30 rpm) requires much less maintenance than a conveyor run at higher speeds (i.e., 45 to 60 rpm). The use of Redlar conveyors instead of screw conveyors is suggested for some applications. Some suggestions for prevention of hopper buildup also apply to prevention of plugging or jamming in screw conveyors.

Conveyors should also be designed for easy access to the screw to minimize downtime in case of clogging. Conveyor housing should be equipped with removable bottom plates for this purpose. Also important are the inclusion of as few moving parts (such as intermediate screw shaft bearings) as possible and the adequate supply of spare parts for quick repairs. Operation of the conveyor is another factor to consider. Vibrators should never be operated with hopper valves in the closed position. If a free flow can be achieved, metering devices such as dump or rotary valves are recommended to make certain that gathering screws are never more than 90 percent loaded. Venting should be provided for escape of overload materials; or automatic shutdown should occur in case of overload or lack of material movement.

An inoperative conveyor can be detected by the installation of zero speed switches on the conveyor or discharge valve shaft. Motion switches should be interlocked to shut off motors when the conveyor stops to prevent drive burnout. Pressure drops in the collector should also be monitored closely, so that a failure in the cleaning mechanism can be detected. Failure of the cleaning mechanism causes material buildup on the bags that could overload the conveyor. Adequate inspection doors are also recommended for visual detection of failures.

4.2 HOPPER VIBRATOR FAILURE

Several manufacturers recommended against the use of hopper vibrators. If not properly installed, vibrators may cause failures at welds and in metal corners. The installation should allow transmission of vibrations throughout the hopper and should be dampened to maximize equipment life. Recommendations for installing vibrators include using hoppers and pads of double thickness metal with rounded corners on all vibrator pads and welding according to specified techniques. It was also suggested that vibrators be used only periodically and that aeration stones or live-bottom bin devices be substituted for constantly required vibrators. Heat tracing equipment is required if the hopper is located in a cold environment.

The primary means of preventing hopper vibrator failure is frequent inspection and proper maintenance in accordance with manufacturer instructions. Resetting or replacement of gap shims should be done at regular intervals. Vibrators should be of heavy-duty design with a mounting mears that allows quick replacement. Some types of air or electric vibrators require only simple bolt-on attachment, and downtime is shortest with total unit replacement. Some electric vibrators, however, are difficult to repair because of construction features that prevent dust, oil, and water ingress. The use of teflon piston liners may also help reduce maintenance.

Hopper vibrator failure may be detected with instrumentation that measures electric vibrator coil current or air vibrator exhaust pressure. One suggestion is to place a light emitting diode (LED) in parallel with a set of contacts to note operation. Alarms or hopper level indicators can also be used to detect a possible vibrator malfunction. Downtime can be reduced by mounting vibrators on brackets for fast replacement.

4.3 HOPPER HEATER FAILURE

Hopper heater failures are often caused by hotspots in the heater system, which may be prevented by equal heat distribution in the system. Two suggestions for prevention of hopper heater failure are better design and placement of the heater. Design recommendations included using low-watt-density heaters that allow uniform heat input over relatively large surface areas (e.g., electric blanket type heaters). Heaters with panelized insulation are also recommended for easy removal, which allows better access to heaters. Improper installation is another cause of heater failure. Heaters should be installed in such a way that they are not subjected to high levels of moisture and vibration. Heaters and thermostat sensors should also be installed so that the thermostat sensor is not in a cooler location. If a heater is located between a filled portion of the hopper and good insulation and if the thermostat sensor is in a cooler location, the heater may overheat and malfunction. This problem can also be aggravated if the heater is not attached to the hopper steel in a manner that enhances dissipation of heat into the steel.

Proper sizing and thermostatic control of heaters is essential for good performance and long life. Use of circuit breakers in hopper heater contactors is important in preventing premature failures. One manufacturer recommends external tracing with steam or by electrical means to avoid abrasion and condensate that internal heaters may be subjected to. Another method of avoiding this problem is to circulate air at 400°F between inner and outer walls with an electrically powered or steam-driven heat exchanger. This method is, however, more expensive. It should also be noted that although in some installations the use of steam coils rather than heaters can eliminate potential for overheating, condensate can cause freezing problems.

Heater failure can be detected most easily by using temperature monitors to note low temperatures. Hopper heater operation can also be determined by monitoring element current. Modular or blanket heaters, instead of cable heaters, are recommended to reduce downtime because they are more easily serviced and replaced.

4.4 DUST VALVE FAILURE

Dust valves must be properly sized for compatibility with the conveying system to prevent failure. If a conveying system is unable to remove material at the same rate the dust valve operates, the valve is forced to operate against a full head of dust, which may result in severe abrasion. Designing extra large dust valves to be run at slow speeds is the best preventive step. The dust valve should also be operated continuously to keep the hopper empty at all times.

Dust valve failure may result from excessive weight on counterweight arms, failure to lubricate linkage, bridging of dust in the hopper directly above the valve, and erosion of valve discs or gates by abrasive fly ash. Periodic inspection and proper maintenance reduces or eliminates such valve failures. Bridging of dust in the hopper can also be prevented by providing proper insulation and heating to deter condensation and by preventing dust buildup in the hopper. The valves should be of a good, rugged design with easy access to replace seals and bearings. Hardened valve discs or gates such as Ni-Hard adjustable seats on rotary valve rotors help eliminate or minimize dust abrasion. Other suggestions are that rotary valves not be used in abrasive dust applications and that they be checked at the highest anticipated operating temperature for free movement after maximum expansion of the rotor. Use of oversized valves and/or motors can also help prevent dust valve failures.

Dust valve failures also occur when foreign objects get caught between the rotor and housing. If discharged dust is exposed to moisture, a pumice-type material may be formed, causing dust valve jamming. Screens can be installed to prevent foreign objects or large pieces of particulates from falling into the valve. Care must be taken, however, to prevent plugging of the hopper throat in this area when screens are used. Also, care should be taken to prevent moisture from entering or forming in the system.

Walkby inspections should be performed daily to make sure the system is operating properly. Dust valve rotation indicators with pilot lights on the control panel can be installed to detect valve failures.

Dust valves should be easily accessible for maintenance to minimize downtime. Rotary valves should be fitted outboard bearings for ease of maintenance, and extra valves should be kept on hand for fast replacement. Dust valve failures can be detected with zero speed switches.

4.5 FAN FAILURE

Fan failure usually results from system vibration or from blade or wheel cracking and failure. Vibration can be caused by a shift of the impeller on the shaft, but is usually caused by a buildup of waste material on the impeller. Buildup of materials on the impeller can be prevented by regularly maintaining fan filters, starting fans with dampers closed, and having damper controls interlocked to amperage control on the motor. Vibration detectors and continuous vibration analysis should reduce unscheduled downtime. In addition, fan performance can be determined by monitoring amperage, and fan failures can be detected by using motion switches.

Blade or wheel failures may be caused by inadequate material properties (i.e., failure of fan to resist erosive, corrosive, and expansive forces), structural inadequacy resulting from poor welding procedures and materials, and engineering design problems such as fatigue or stress.

Erosion, not corrosion, is the usual problem with precipitator fans, because the gases passing through the fan are often dirty and abrasive. Where fans are in dirty air, fan speed should be lowered (a maximum of 680 rpm is suggested). Sometimes, applying wear pads to all or part of the fan blades may be desirable to minimize erosion. Wear pads are made of materials with high Brinell numbers, such as Firmex or Wearaloy. On highly abrasive applications, tungsten carbide may be used to cover the wear areas of the blades and centerplate.

Structural weaknesses in the fan caused by poor welding procedures and/or materials can be prevented only by a good quality control program at the manufacturing plant.

Fan bearings are another source of system failure. Such failure can be prevented by minimizing thrust loads through proper design of inlet and outlet ducts. The use of forced lubrication systems and temperature detectors on fan bearings can also help prevent bearing failures.

Fans should also be properly sized. Oversized fans operating in medi-stable conditions may surge and become self-destructive.

Other methods to eliminate downtime in case of fan failure include fan redundancy and provision of adequate access for fan wheel removal.

4.6 REENTRAINMENT

The most common cause of reentrainment is the buildup of high dust levels in the hopper. The hopper must be evacuated continuously with a properly sized conveying system to avoid this. A drum should always be kept under the hopper of units designed for intermittent dumping.

Baffling is important in the design of dust hoppers. Proper baffling can prevent reentrainment of dust by reducing large eddies and preventing gas from "diving" into the hopper. This can be done by installation of baffles to direct airflow away from the dust in the hopper. Baffles should be placed both parallel and perpendicular to gas flow direction. Another recommendation is the installation of a tight link-chain-type baffle that deflects to allow easy dust flow, but at the same time minimizes gas sneakage in this region. The velocities of gases containing abrasive materials, such as clinkers and alumina, should be kept below 15.2 m/s (3000 ft/min) to avoid reentrainment and prevent excess wear.

Uniform gas distribution throughout the gas cleaning unit is important. Proper hopper design, flue geometry, and treatment velocities help ensure uniform gas distribution. Main gas streamlines should not be forced to turn abruptly near the unit, because this may create hopper crossflows. Less restrictive duct geometries and/or perforated plates allowing variable porosity should be used to eliminate crossflows. Also, gas velocities should be kept below 1.65 m/s (5.5 ft/s), because greater treatment velocities may result in hopper eddy flows.

Air inleakage should be kept to a minimum to deter reentrainment. All seals and gaskets should be properly maintained. Equipment of hoppers with positive sealing dust valves, such as rotary locks, tipping valves, or motor-operated double-flap gates, is suggested. These should be regularly inspected for wear.

Inadequate static periods in a fabric filter's cleaning cycle may result in reentrainment by not allowing adequate time for dust to settle in the hopper. Timing between the cleaning cycles for this type of unit should be increased to remedy this problem. Other recommendations include the following: installing ash handling system vents. These vents should be goose-necked, bell-mouthed, and aimed upstream; using ceilings on dust handling equipment; and timing vibrators to be compatible with the hopper evacuation system.

SECTION 5

SCRUBBERS

5.1 WATER MALDISTRIBUTION

A scrubber removes particulates basically by impingement of particulates upon water droplets. The efficiency of particulate removal depends mainly on the physical contact of solids and water, thus dictating the importance of water distribution in the scrubber. A variety of devices and mechanisms can be used to distribute the water. Spray nozzles are the most common type of distribution device. Various types of nozzles are used alone or in conjunction with other devices or mechanisms to atomize the water. Another common water distribution method involves use of a venturi throat to atomize the water for contact with a high-velocity influent gas stream; the water is usually injected tangentially just before the venturi throat. This method, referred to as gas atomization, may be used alone or with nozzles.

The most obvious cause of uneven water distribution is pluggage or erosion of nozzles or pipes. Another cause might be an insufficient number of properly operating water inlets for the size of the scrubber throat. An improperly leveled scrubber with a tangential liquid inlet may alter water distribution. A sharp radius turn in the ductwork before a tangential liquid inlet may also cause uneven water distribution by diverting a majority of the gas to one side of the scrubber and thus drying up the liquid on that side. Several suggestions to prevent uneven water distribution, as well as methods to detect and correct this problem, have been noted. These are discussed below.

5.1.1 Design

Various design alternatives can be used to minimize uneven water distribution. The throat section, for example, should be properly sized; an opening of 27.9 to 35.6 cm (11 to 14 in.) has been suggested. Nozzles and pipes should be designed to avoid clogging; large-diameter feed openings and use of clean water help minimize plugging. One manufacturer includes a disc around which are injection points that feed water to the scrubber throat. This disc is flooded with water from large-diameter feed pipes. Provision of an adequate number of water inlets in relation to the throat size is also important for even water distribution across the scrubber throat.

For round venturis in which water enters tangentially at the top, injection of water onto a shelf is recommended to ensure even distribution of water. Also, scrubbers with tangential liquid inlets should be equipped with leveling adjustments to prevent uneven water distribution. The use of splash or deflection plates onto which water is sprayed may help spread the water evenly. In addition, the use of underflow weirs to prevent solids deposition in the liquid distribution system should help prevent maldistribution of the water. Weep holes should be used to minimize buildup in weirs, and water pressure should be kept low to prevent hydraulic heads.

In large scrubbers a plumb bob can be used to help distribute the water evenly over the scrubber throat. This is done by placing a spray nozzle over the apex of the plumb bob. As the water flows down the conical sides of the plumb bob, an annular throat is created that distributes the water evenly in the scrubber throat.

5.1.2 Detection and Correction

The most straightforward way to determine maldistribution across the scrubber throat is by visual observation when the scrubber is off stream. This problem, however, might be detected while the scrubber is on stream. Although a change in stack opacity can signal a water distribution problem, it is not a selective signal and can result from other problems. Maldistribution can be more definitively detected by installing a pressure differential instrument across the scrubber throat or a pressure gauge or sensor on the pipe header leading to the spray nozzles. If the pressure gauge on the pipe header shows an abnormally high pressure, a plugged nozzle is indicated, whereas an abnormally low pressure indicates nozzle erosion. Also, the installation of a flowmeter in the water line can help determine maldistribution. Low water flow indicates a plugged nozzle. Using the saturation temperature downstream of the scrubber throat as an indicator of water distribution has also been suggested. Poor throat coverage might be indicated by a higher temperature than adiabatic saturation. Usually maldistribution can be remedied by replacing or reaming out the defective nozzles. One manufacturer prevents plugging by using nozzle reamers that are operated by an air cylinder that sequentially clears each water jet. If insufficient nozzles are available for the throat size, additional water injection points are required. As previously discussed, improper duct design may also cause maldistribution. One way to remedy the specific problem mentioned (i.e., a sharp radius turn prior to the scrubber throat) is to install turning vanes in the duct to channel the gas properly.

5.2 EROSION AND CORROSION

A major concern of scrubber manufacturers is to avoid scrubber erosion and corrosion. In most applications, one or more of the following conditions are encountered:

Low pH
High pH
High abrasive materials
High temperatures

The most erosive and corrosive conditions in a scrubber system seem to exist downstream of the mist eliminator. Harsh conditions, however, can also be found in the scrubber inlet, scrubber section before the mist eliminator, and scrubber water system. The following are suggestions to prevent erosion and corrosion and to minimize downtime during repair of eroded and corroded parts.

5.2.1 Prevention

The consensus of manufacturers is that erosion and corrosion can best be prevented by good design and proper selection of materials of construction for the operating environment. Economic considerations prompt many buyers to purchase equipment that requires lower capital investment, but may need increased maintenance because of improper construction materials. Materials of construction should be chosen to withstand the abrasiveness and chemical nature of the substances handled.

If the solution is very acidic or contains chlorides, equipment either should be lined with rubber, glass, or fiber-reinforced plastic (FRP) or should be made of FRP. If this type of equipment is not suitable, high-nickel alloys such as Hastelloy C or Inconel should be used. Rubber lining is also desirable on scrubber pumps and valves for erosion and corrosion protection, and Teflon material can be used in nonclogging spray nozzles.

Venturi scrubbers for abrasive applications such as blast furnaces and basic oxygen furnaces require special designs to protect against erosion. High-alumina tile or silicon carbide lining systems provide exceptional erosion protection in these applications.

The use of wet or flooded elbows before an entrainment separator and the use of pinch valves rather than ball, plug, or diaphragm valves can alleviate erosion and corrosion of internal surfaces. Also, the use of Teflon-type materials in nozzles can reduce erosion and corrosion. Other steps to prevent erosion and corrosion include:

- Use of low-speed pumps
- Prevention of pump cavitation
- Installation of proper filters in the pump line
- Reduction of solids concentrations by using tanks or thickeners or by increasing bleed stream from the scrubber
- Maintenance of proper pH control systems
- Installation of spray headers with timers that intermittently spray mist eliminators and fan impellers
- Low pipeline velocities (but not low enough to cause settling)
- Periodic maintenance of equipment

5.2.2 Minimization of Downtime

The most obvious way to reduce downtime during repairs is to provide backup systems and spares. The use of easily replaceable wear plates has also been suggested as a means to reduce downtime. Parts and equipment most likely to require periodic replacement or maintenance should be made easily accessible (e.g., mist eliminators and spray headers should be removeable through manholes for servicing). Downtime may also be minimized by the detection of a problem before it has caused much damage. For instance, devices to monitor reductions in thickness can be mounted on the outside of equipment. With these devices, zones requiring maintenance could be detected before they corroded or eroded away completely. These devices are, however, costly.

5.3 BLOWDOWN LINE CLOGGING

Because of negative pressure in a scrubber system, a water head equal to the negative pressure must be maintained to ensure proper drainage. If the vertical drainage section below the scrubber is too short, liquid backs up in the scrubber shell, causing problems with air distribution and efficiency. Solids buildup in blowdown lines, resulting in clogging, is another problem frequently encountered. Solids buildup may result from physical action such as settling or from chemical action such as the precipitation of a low-solubility compound. Measures to prevent and detect blowdown line clogging and to minimize downtime caused by clogging are discussed below.

5.3.1 Prevention

Several plumbing guidelines should be followed in designing a blowdown line system. As many elbows, tees, and other potential "dead spots" as possible should be eliminated. One way to accomplish this is by using 45 degree fittings rather than 90 degree fittings. Solids buildup in the lines can also be minimized by designing pipe sizes to maintain relatively high velocities [2.12 to 2.42 m/s (7 to 8 ft/s)]. If settling is a problem, installation of pipe with smaller diameter increases pipe velocity and prevents settling. The blowdown lines should also be designed with an adequate slope to the discharge point. The use of pinch valves instead of other restrictive valves (e.g., ball, gate, and butterfly valves) is another suggestion.

The chemistry of the blowdown water is another important consideration for preventing clogging. Limiting solids concentration in the water and controlling pH help prevent solids buildup and precipitation. Solids buildup can be prevented by increasing the bleed rate of the blowdown water and using decant and thickener systems to minimize the solids recirculated. Dissolved solids should not be concentrated above 50 percent of their solubility at design temperature. This prevents localized precipitation in wet-dry zones of the scrubber, which can potentially plug the drain.

5.3.2 Detection

Clogging of blowdown lines can be detected by measurement of flow of the blowdown. Sight flowgauges or magnetic flowmeters may be used in the blowdown lines, and a low-flow alarm may be installed. High-liquid-level sensors may be used in a scrubber with an integral recycle tank to detect buildup in blowdown lines. Pressure gages with/without high-pressure alarms could also be used to detect buildup in pipeline. An increase in pressure indicates solids buildup.

5.3.3 Minimization of Downtime

As noted with prevention of line plugging, the plumbing of the blowdown system is important in reducing downtime if a line becomes plugged. Suggestions for blowdown lines include placing cleanout ports at strategic locations (e.g., crosses with blind flanges at all turns) using many unions and flanges for easy disassembly and cleaning of lines, using flexible connectors for fast disconnection at lines, using quick-connection fitting piping (Dresser or Victaulic), and using rubber hoses at long-radius turns (blockages can be broken up by external hammering).

If a line becomes clogged, the best method of cleaning depends on the nature of the deposit. In many cases, running clean water through the system or injection of compressed air suffices to clean the line. If using water and air fails or is not applicable, rodding out the pipe or acid cleaning may be required. In many instances, replacing a plugged line with a clean one and then cleaning the plugged lines may be preferable. This can reduce downtime significantly. In installations where downtime costs are high, a standby blowdown system may be justified.

5.4 ADDITIONAL COMMENTS

Adequate and properly maintained instrumentation is considered necessary for the efficient operation and maintenance of a scrubber system. Proper instrumentation allows close observation of system operation and quick detection of changes in performance. That operating personnel know what is happening at the time it is happening is essential. All instrumentation should be checked for operation and calibration on a routine schedule. One manufacturer recommends that this be done through a maintenance and service contract with a major instrument vendor. Another recommendation is that all instrumentation come from one source to ensure compatibility of equipment and enable quick assessment of equipment malfunction. A specific suggestion was use of temperature detection devices in conjunction with emergency spray activation in high-temperature scrubbers. Also suggested was the use of detectors for fan vibration and fan bearing temperature. A good operation and maintenance manual and a good preventive maintenance program were cited as important considerations for efficient scrubber operation and long life. On the other hand, poor plant management attitudes and policies were cited as frequent causes of shorter equipment life and increased unscheduled downtime.

APPENDIX

QUESTIONNAIRE SENT TO MANUFACTURERS

INSTRUCTIONS FOR FILLING OUT THE QUESTIONNAIRES

The questionnaires are designed to address different operation and maintenance problems associated with three types of air pollution control equipment. They are general questions and are not meant to apply to any one industry or source within an industry. The questionnaires are not exhaustive but simply illustrative of some common problems. Seperate questionnaires have been drafted for each of the following types of control equipment: electrostatic precipitator, scrubber, and fabric filter.

Responses to the questions should point out instrumentation, materials of construction and methods of improving design of particulate control equipment which will either reduce or prevent malfunction, detect malfunction before they occur, enable easier and faster troubleshooting and allow for quicker and easier maintenance and operation of such equipment. Since it is realized that many problems and failures of the equipment can never be completely eliminated, emphasis should be placed on methods that allow for the quickest repair of the equipment. When possible incremental costs that could result from such design changes and instrumentation requirements should be noted.

ELECTROSTATIC PRECIPITATORS

1. What measures can be taken to prevent electrical erosion, mechanical fatique, and dust hopper buildup which are three (3) common causes of electrode failure? Also, what are the best methods or construction techniques that allow for quick electrode replacement.

2. Inadequate dust removal is a major cause of precipitator malfunctions and is usually a result of either improper adjustment of the hopper vibrators, failure of the conveyor system or low flue gas temperature which permits moisture condensation and plugging of the hopper. This dust buildup can cause excessive sparking and sometimes pushes internal components out of position. What design measures or operation and maintenance procedures can help reduce this problem or rectify the problem quickly?

3. Poor performance can result from rapping/vibrator forces that are either too mild or too severe. What instrumentation can be used to detect and help adjust rappers properly?

4. Problems with insulators such as high-voltage tracking on the insulators as a result of the formation of condensables is often a problem. What design features can help prevent this or what instrumentation can detect this before it becomes to severe? When insulators must be replaced, what methods allows for quickest replacement?

5. What construction methods are available to reduce gas sneakage to a minimum?

6. Additional comments - types of construction, material, instrumentation, operating practices, or preventative maintenance not covered above or relating to other problems?

FABRIC FILTERS

1. Bag replacement is the most expensive maintenance operation. What procedures or materials are available to reduce bag replacement, possibly predict bag re-place-ment, or reduce or eliminate downtime during bag replacement?

2. Filter compartment dampers are a high-maintenance problem. What construction and/or materials can be utilitized to reduce problems with dampers or detect and/or troubleshoot problems with dampers and repair or correct the problem quickly?

3. Dust hoppers are a common problem in any fabric filter. What type of special construction or materials can be used to prevent clogging a buildup? What type of instrumentation can be used to predict such a problem before it becomes an operational problem or what methods allow for corrections of the problem?

4. What construction methods are available to help reduce shaker mechanism failures or to allow for quick replacement or maintenance?

5. Additional comments - types of construction, materials, instrumentation, operating practices, or preventative maintenance not covered above or relating to other problems?

SCRUBBERS

1. Uneven water distribution across scrubber discs can cause low efficiency. What construction methods exist to help prevent this? What methods or instrumentation permits detection of such an occurrence and/or permit quick correction of the problem?

2. Erosion and corrosion of internal surfaces such as, nozzles, demisters, valves, pumps, and impellers can cause malfunctions. Except for repairing as necessary are there any other means of preventing this situation or reducing downtime during repair?

SCRUBBERS (contd)

3. Solids can buildup in blowdown lines. What means exist for preventing this from occuring or detecting it in its early stages of development? Which methods of cleaning allow for the shortest downtime?

4. Additional comments - types of construction, materials, instrumentation, operating practices, or preventative maintenance not covered above or relating to other problems?

QUESTIONS PERTAINING TO BOTH ELECTROSTATIC PRECIPITATORS AND FABRIC FILTERS

The following items are common problems with both ESP's and fabric filters. What methods of construction or instrumentation can help eliminate or reduce these problems and what practices allow to repair with the shortest downtime?

A. Plugging or jamming of screw conveyors in hoppers?

B. Hopper vibrator failures?

C. Hopper heater failures?

D. Dust valve failures?

E. Fan failures?

F. Reentrained dust from dust hoppers?

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-905/2-80-002	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Design Considerations for Minimizing Operation and Maintenance Problems of Particulate Control Equipment		5. REPORT DATE 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO
9. PERFORMING ORGANIZATION NAME AND ADDRESS PEDCo Environmental, Inc. 11499 Chester Road Cincinnati, Ohio 45246		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-2535, Task No. 7
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency - Region V Air Programs Branch 230 S. Dearborn Street Chicago, Illinois 60604		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Project Officers: Henry Onsgard and Dr. Indur Goklany

16. ABSTRACT

This report addresses various operation and maintenance problems frequently associated with three types of air pollution control equipment: electrostatic precipitators, scrubbers, and fabric filters.

The report discusses instrumentation, materials of construction, and design considerations in particulate control equipment that improve performance. Such improvements include reduction or prevention of malfunction, early detection of malfunction, and easier maintenance and operation of equipment. Because some problems can never be completely eliminated, methods of reducing downtime are also addressed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Air Pollution Control Equipment Electrostatic Precipitators Dust Collector Scrubber Design	Fabric Filters Particulates	13B

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS (This Report) None 20. SECURITY CLASS (This page) None	21. NO. OF PAGES 50 22. PRICE

EPA Form 2220-1 (9-73)