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Ash Handling System Maintenance Guide

Technical Report

Plant Maintenance Support

Reduced Cost

Equipment Reliability

Ash Handling System Maintenance Guide

1011684

Final Report, December 2005

EPRI Project Manager
A. Grunsky

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Electric Power Research Institute (EPRI)

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

CITATIONS

This report was prepared by

Electric Power Research Institute (EPRI)
Fossil Maintenance Applications Center (FMAC)
1300 W.T. Harris Blvd.
Charlotte, NC 28262

Principal Investigator
S. Parker

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REPORT SUMMARY

This *Ash Handling System Maintenance Guide* provides fossil plant maintenance personnel with current maintenance information on this system. This guide will assist plant maintenance personnel in improving the reliability and reducing the maintenance costs for the ash handling system.

Background

In 2003, EPRI Fossil Maintenance Applications Center (FMAC) member utilities completed a Maintenance Issues Survey. The topic of "fly ash handling equipment and transport systems" ranked high as a chronic problem with high impact to plant reliability. From the survey responses, the FMAC Steering Committee recommended the development of a guide for the maintenance of ash handling systems. A separate guide is planned for the ash transport systems on the plant site.

Objectives

- To identify preventive and corrective maintenance practices for ash handling system components
- To assist plant maintenance personnel in the identification and resolution of ash handling system maintenance problems

Approach

A Technical Advisory Group was formed that consisted of ash handling equipment owners from EPRI FMAC utility members. Input was solicited for current maintenance issues for ash handling systems. Experience-proven practices and techniques were identified during this effort and are compiled in this report. Key suppliers of fly ash system designs and components were solicited for assistance to ensure that the guidance reflected the latest technologies available in the industry.

Results

This technical report provides an overview of system design parameters and components that make up a typical fly ash handling system. The focus of the report is to provide recommendations for performing preventive maintenance on the various system components. The report includes a preventive maintenance basis. It provides information for repairing and replacing system components, troubleshooting, and removing fly ash from the plant. The report also includes information on personnel qualifications, training, and safety guidelines, and it provides a list of sources for training, repair, and consulting services.

EPRI Perspective

The maintenance of the ash handling system affects the availability and reliability of the operating unit. This technical report provides a single reference document for the identification of ash handling equipment problems and recommended preventive maintenance practices.

Keywords

Ash handling
Ash storage
Dense phase
Fly ash
Preventive maintenance
Preventive maintenance basis

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Technical Advisory Group Members:

Name	**Utility**	**Plant Name**
David Brawner	Entergy	Nelson
Dennis Child	Eskom	Kendal
Mark Litzinger	AmerenUE	Labadie
Danie Odendaal	Eskom	Matimba
Jakes Rosslee	Eskom	Lethabo
Des Sheppard	Eskom	Matimba
Scott Skousen	Eskom	Matimba
Rodney Warner	Public Service of New Mexico	San Juan

EPRI and the TAG were supported in their efforts to develop this report by the following companies and individuals:

Sharon Parker

Sequoia Consulting Group, Inc.
111 Washington Street
Plainville, MA 02762

Principal Investigator:
Mike Tulay

RPA Associates, Inc.
3 Park Plaza
Wyomissing, PA 19606

Principal Investigator:
Rick Aulenbach

In addition, the following individuals and companies provided technical material, the use of figures, and review of the guide:

Lou Zotti
Allen Sherman-Hoff, Inc.
185 Great Valley Parkway
Malvern, PA 19355-1321

Jeff Carpenter
United Conveyor Corporation
2100 Norman Drive West
Waukegan, IL 60085

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1
INTRODUCTION

1.1 Purpose and Scope

The purpose of this guide is to provide maintenance personnel at fossil plants with guidelines for safe and effective maintenance practices for system components associated with fly ash collection, handling, transport, and disposal.

The scope of the report covers equipment typically installed in the following general types of fly ash conveying systems:

- Fly ash pressure conveying systems
- Fly ash vacuum/pressure conveying systems
- Fly ash vacuum conveying systems
- Dense-phase fly ash conveying systems

Inherent to these systems are numerous components, some of which are not common to all of the systems. The general scope of components covered in this report is as follows:

- Abrasion-resistant piping and fittings
- Air compressors
- Air gravity conveyors
- Airlock valves
- Ash storage silos
- Ash transfer bins
- Collectors and filters
- Cut-off gates
- Dense-phase vessels
- Dry dust and pugmill unloaders
- Equalizer valves
- Fly ash transport blowers
- Fly ash vacuum pumps
- Hopper aeration blowers
- Material handling valves
- Relief doors
- Rotary feeders
- Silo aeration blowers
- Vacuum producers
- Vent filters

The following system components are not included in the scope of this report:

- Boilers
- Bottom ash handling systems and components
- Coal pulverizers and transport systems
- Electrostatic precipitators
- Forced draft or induced draft fans
- Sootblowing equipment

1.2 Background

Fly ash was ignored in early ash handling efforts. As boilers became more complex with the addition of air heaters and economizers, significant amounts of fly ash were collected wherever the flue gas stream changed direction or reduced velocity. Initially there were attempts to manually remove and handle the ash collected at these points. Because of the dusting propensity of this ash as opposed to bottom ash, there was a clear need for an alternative method of handling. In about 1928, pipeline conveying was again adapted, this time from a technology developed for coal-burning ships. A steam-powered venturi tube (steam ejector) inducted an air stream through a pipe that transported the ash from collection points to and through the steam ejector. The mixture of steam, ash, and air was discharged into a target box on top of a closed bin made of tile and then elevated for truck discharge. Unfortunately, some ash failed to separate at the impact box and was vented into the atmosphere with the conveying air.

To increase separation efficiency and minimize carryover to the atmosphere, cyclone separators were placed in the conveyor line at the top of the silo, upstream from the steam *ejector* (a device used to induce vacuum in a pipeline by passing high-pressure steam through a convergent–divergent nozzle). This arrangement removed the moisture before it passed through the ejector, so that the ash stored in the silo and unloaded from it was dry. Consequently, there was a problem with dust, particularly during off-site transport in open trucks. In about 1930, the rotary conditioner/unloader was developed, which mixed water with the dry ash and controlled the rate at which ash was loaded into trucks (and later, rail cars).

Because steam ejectors wasted steam, and the vacuum achievable by steam ejectors was limited, water-powered ejectors came into use. This development was particularly useful at plants that either had sufficient space for ash ponds or were situated on waterways. Conveyed ash was passed through a water-powered ejector, and the resulting ash-and-water slurry flowed by gravity through a pipeline to the pond or waterway. This eliminated receiving equipment, silos, and subsequent handling of the ash. Wherever this type of disposal was not possible, collection and storage were accomplished as before but by water-powered rather than steam ejectors.

By the early 1960s, it became necessary to handle much greater quantities of fly ash because of increased boiler sizes, increased collection rates and efficiencies, and the use of precipitators rather than mechanical dust collectors. In addition, as plants became larger, conveying distances became greater. Vacuum systems, particularly those with water-powered ejectors, could no longer provide the required capacity.

Although some installations used multiple vacuum systems, there was an industry trend toward using positive-pressure conveyors that use air lock feeders at the collection hoppers. These airlocks make possible the transfer of material from the low-pressure zone of the collection hopper into the comparatively high pressure of the pipeline conveyor.

Although pressure systems are advantageous from a capacity standpoint, they require significantly greater and more complex maintenance and have a greater initial cost than vacuum systems. Consequently, vacuum systems with greater capacity were developed in the mid-1960s. These vacuum systems used mechanical vacuum pumps rather than water ejectors to power the conveyors.

The 1970s ushered in strict environmental regulations, laws, and enforcement. These regulations essentially dictate that fly ash be transported dry and separated at intermediate collection points. Although the systems have been refined, they are not entirely satisfactory for owners, operators, or maintenance personnel.

During the 1980s, in an effort to reduce installation and operating costs and to enhance reliability, users and vendors began turning to mechanical conveyors and dense-phase—rather than dilute-phase—pipeline systems.

Because of increasing efforts in flue gas desulfurization (FGD), future ash handling systems will have to deal with greater quantities of material than in the past. This material will have different characteristics from current types of ash, including sorbents of various kinds.

1.3 Report Structure and Content Overview

Figure 1-1 illustrates the general structure and content of this technical report. It identifies key sections in the report that provide guidance to owners for effectively addressing fly ash system maintenance issues.

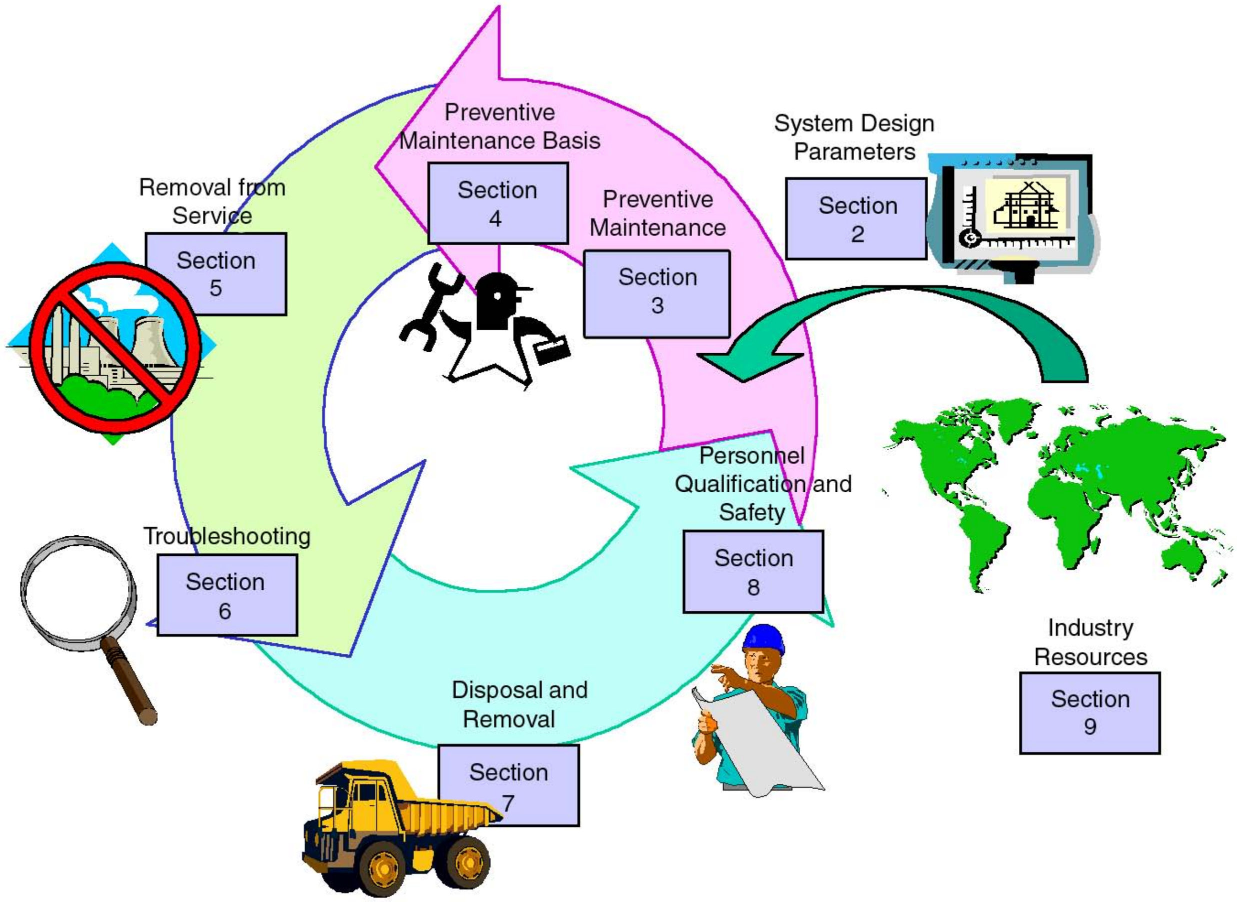


Figure 1-1
Scope and Content of This Report

This section provides an introduction to the report.

- Section 2, "Fly Ash System Design Parameters," provides an overview of system design parameters and describes the components comprising a typical fly ash conveying system and describes the functions of those components.
- Section 3, "Preventive Maintenance for Fly Ash System Components," provides guidance for performing preventive maintenance on the numerous system components.
- Section 4, "Preventive Maintenance Basis," describes the criteria that were used to establish the preventive maintenance guidance.
- Section 5, "Removal from Service and Repairs," provides guidance regarding the repair or replacement of system components and details which components are typically repaired or refurbished on site.
- Section 6, "Fly Ash System and Component Troubleshooting," provides the owner with troubleshooting guidance.
- Section 7, "Fly Ash Disposal and Removal from the Plant Site," describes the removal and disposal of fly ash from the plant.

- Section 8, “Personnel Qualification, Training, and Safety Issues,” provides personnel qualification and safety guidelines.
- Section 9, “Industry Resources for Fly Ash System Training, Consulting, and Repair,” lists sources of training, repair, and consulting services related to fly ash conveying systems.
- Section 10, “References,” provides a complete listing of references that were used during the development of this report.
- Appendix A, “Fly Ash Material Safety Data Sheet,” is a material safety data sheet that describes fly ash.
- Appendix B, “Listing of Key Information,” reiterates key points made throughout this report.

1.4 Glossary of Terms and Acronyms

1.4.1 Industry Definitions and Nomenclature

Corrective maintenance. Maintenance tasks that are generated as a result of equipment failure. Corrective tasks are generated when equipment is purposely operated to failure and also when equipment failure is not desired or planned. It is the most basic—and the most expensive—form of maintenance. Most plants are moving away from corrective maintenance, but there will always be a portion of maintenance being performed as a result of equipment failure.

Elective maintenance. The classification of any work on power block equipment in which identified potential or actual degradation is minor and does not threaten the component’s design function or performance criteria.

Facilities. Structures, systems, and components not associated with power generation. Structures can include training facilities, warehouses, maintenance shops, and administrative offices. Systems can include fire protection, plumbing, lighting, sewer, and drainage.

Periodic maintenance. Time-based preventive maintenance actions that are taken to maintain a piece of equipment within design operating conditions and to extend its life.

Predictive maintenance. Maintenance tasks that are performed based on equipment condition. Predictive maintenance relies on technologies to determine the current condition of the equipment so that only the required maintenance is performed before equipment failure.

Preventive maintenance. Maintenance tasks that are performed based on a time or interval to avoid catastrophic equipment failure. Preventive maintenance performs maintenance tasks on a planned rather than reactive basis and avoids the losses associated with unplanned downtime. The penalty of preventive maintenance is that some tasks are performed that are unnecessary and costly.

Proactive maintenance. Maintenance tasks that determine the root cause of an equipment problem. Chronic problems require advanced technologies, additional resources, and time to provide a final solution for an equipment problem. The problem can be the result of poor design, inadequate maintenance practices, or incorrect operating procedures.

Qualified individual. For the purposes of concurrent verification and independent verification, a person who has been determined by station management to be qualified to perform verification activities. As a minimum, this individual shall be trained in human performance verification techniques.

Work instruction. Instructions for performance of the work to be accomplished, the level of detail of which depends on the assigned planning level. When applicable, approved procedures can be referenced and might suffice as work instructions.

Work order. A document used to control work activities, testing activities, or both.

1.4.2 Acronyms

AA-GF	atomic absorption-graphic furnace
ACAA	American Coal Ash Association
ACGIH	American Conference of Governmental Industrial Hygienists
CAER	Center for Applied Energy Research
CARRC	Coal Ash Resources Research Consortium
CBRC	Combustion Byproducts Recycling Consortium
CCP	coal combustion products
CPCA	Canadian Portland Cement Association
EPRI	Electric Power Research Institute
ESP	electrostatic precipitator
FBC	fluidized-bed combustion
FGD	flue gas desulfurization
FMAC	Fossil Maintenance Applications Center
GFAAS	graphite furnace atomic absorption spectrometry
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
ICAR	International Center for Aggregates Research
ICCI	Illinois Clean Coal Institute
ICP-AES	inductively coupled plasma atomic emission spectroscopy

IGCC	Integrated Gasification Combined Cycle
MRI	Materials Research Institute
NIOSH	National Institute of Occupational Safety and Health
O&M	operations and maintenance
OCDO	Ohio Coal Development Office
OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
PM	preventive maintenance
psig	pounds per square inch gauge
RCM	reliability-centered maintenance
RTD	resistance temperature detectors
SCFM	static cubic feet per minute
SRM	Standard Reference Materials (Program)
TLV	threshold limit value
TPH	tons per hour
TR	technical report

1.5 Relationship with EPRI FMAC and to Other EPRI Reports

The development of this report was made possible through the close working relationship between EPRI Fossil Maintenance Applications Center (FMAC) member utilities and industry vendors. EPRI FMAC continues to serve as a key resource for maintenance personnel by providing a wide range of products, including technical reports addressing maintenance processes and system and equipment maintenance guidance, with a focus on improving equipment reliability.

During the development of this report, a number of EPRI products were identified that already provide detailed guidance regarding fly ash system components and their functions. These EPRI reports were primarily used as source material to ensure consistency of applied guidance among users and include the following:

- *Bottom Ash System Maintenance Guide*, 2000. 1000617.
- *Compressed Air System Maintenance Guide*, 2002. 1006677.
- *Electrostatic Precipitator Maintenance Guide. Volume 1 of a Two-Volume Set (E213676)*, 2003. 1007436.
- *Electrostatic Precipitator Maintenance Guide. Volume 2 of a Two-Volume Set (E213676)*, 2003. 1007690.

- *Flexible Shaft Couplings Maintenance Guide*, 2003. 1007910.
- *Fly Ash Exposure in Coal-Fired Power Plants*, 1993. TR-102576.
- *Gearbox and Gear Drive Maintenance Guide*, 2004. 1009831.
- *Guideline for System Monitoring by System Engineers*, 1996. TR-107668.
- *InPlant Ash Handling Reference Manual*, 1987. CS-4880.
- *Metrics for Assessing Maintenance Effectiveness*, 2003. 1007604.
- *Sootblowing Application and Maintenance Guide*, 2001. 1004005.
- *System and Equipment Troubleshooting Guideline*, 2002. 1003093.

1.6 Conversion Factors for Units Used in This Report

Table 1-1 presents conversion factors used in this report to convert values between English and Standard International (SI) units.

> **Note**: SCFM is standard cubic feet per minute at 60°F (16°C) at 14.7 psia (101 kPa). Because not all countries convert SCFM to SI units in the same way, these units are not converted to SI units in this report.

Table 1-1
Conversion Factors Used in This Report

Parameter	English to Standard International	Standard International to English
Length	1 in. = 25.4 mm 1 in. = 2.54 cm 1 in. = 0.0254 m 1 in. = 25,400 µm (micron) 1 ft = 304.8 mm 1 ft = 30.48 cm 1 ft = 0.305 m 1 ft = 304,800 µm (micron)	1 µm (micron) = 0.00003937 in. 1 mm = 0.394 in. 1 m = 3.28 ft
Pressure	1000 kPa = 1 MPa 1 psig = 7 kPa 1 in. Hg = 3.3864 kPa	
Temperature	°C = (°F – 32) x 5/9	°F = (°C x 9/5) + 32 °F = 1.8 (°C) + 32
Velocity	1 ft/min (fpm) = 0.3048 m/min	
Weight	1 lb = 0.4536 kg 1 ton = 900 kg	1 g = 1000 mg = 0.0353 oz 1 kg = 0.00110231131 ton

1.7 Key Points

Throughout this report, key information is summarized in “Key Points.” Key Points are bold lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to take action for the benefit of their plant. The information included in these Key Points was selected by FMAC personnel, consultants, and utility personnel who prepared and reviewed this report.

The Key Points are organized according to three categories: operations and maintenance (O&M) cost points, technical points, and human performance points. Each category has an identifying icon, as shown below, to draw attention to it when quickly reviewing the guide.

Key O&M Cost Point

Emphasizes information that will result in overall reduced costs or increased revenue through additional or restored energy production.

Key Technical Point

Targets information that will lead to improved equipment reliability.

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent personal injury or equipment damage or to improve the efficiency and effectiveness of the task.

Appendix B, “Listing of Key Information,” contains a listing of all key points in each category. The listing restates each key point and provides a reference to its location in the body of the report. By reviewing this listing, users of this guide can determine whether they have taken advantage of key information that the writers of this guide believe would benefit their plants.

2
FLY ASH SYSTEM DESIGN PARAMETERS

2.1 Fly Ash Types and Characteristics

This section describes the various types of fly ash and their sources at a typical fossil power plant. A detailed material safety data sheet describing fly ash is provided in Appendix A, “Fly Ash Material Safety Data Sheet.”

2.1.1 Economizer Ash

Economizer ash, although often classified as a fly ash, frequently contains pebble- and stone-like particles from 1/4 to 2 in. that mainly result from sootblowing. Ash sometimes sinters while in a collection hopper. This is due to operation of the boiler that results in either high-carbon ash or high excess air. Collected economizer ash particles have no typical size. The temperature of this ash ranges from 600 to 900ºF.

2.1.2 Air Heater Ash

Air heater ash is usually finer and more uniformly sized than economizer ash. The particle sizes range from 100 to 600 microns, while the ash temperature ranges from 250 to 400ºF.

2.1.3 Electrostatic Precipitator Ash

This size of fly ash particles entering the electrostatic precipitator (ESP) can range from 0.01 to 1000 microns for eastern coals and from 0.01 to 200 microns for western coals and lignite.

The precipitator catch, however, is classified by size in the various field hoppers. With low-carbon ash, the coarsest fraction is in the front hopper and the finest fraction is in the rear. High-carbon ash from some boilers burning eastern coals has most of the large-diameter (100+ microns) carbonaceous particles collected in the rearmost hopper, thus reversing the usual trend.

Because the tendency for individual fly ash particles to agglomerate is greater in cold-side precipitators, it is usually perceived that the larger ash particles predominate in the catch. Conversely, the lesser tendency to agglomerate in hot-side precipitators leads to the observation that the collected fly ash is the fine or free-flowing particles. In fact, any size differences in the collected particles is due principally to the combustion of different coals rather than to the collection temperatures.

The emphasis here is on the ash as seen by the ash system after agglomeration has occurred. In general, this ash has particle sizes that range from 50 to 400 microns at 225–350ºF in cold-side ESPs and are about 100 microns at 400–800º F in hot precipitators.

2.1.4 Baghouse Ash

Baghouse ash is very similar to hot-side precipitator ash except that the temperature range is approximately 250–350ºF. The particle sizing in the various hoppers is quite uniform, with little or no segregation, except for the inertially induced distribution. Particle size and size distribution depend on the characteristics of the fuel, mill, burner, and furnace.

2.1.5 Typical Chemistry of Coal Fly Ash

Table 2-1 illustrates the typical chemistry of coal fly ash in weight percentages.

Table 2-1
Typical Chemistry of Coal Fly Ash

Courtesy of Fly Ash Resource Center

Chemical Compounds	Class F (Weight %)	Class F (Weight %)	Class C (Weight %)	Class C (Weight %)
	Low-Fe	High-Fe	High-Ca	Low-Ca
SiO_2	46–57	42–54	25–42	46–59
Al_2O_3	18–29	16.5–24	15–21	14–22
Fe_2O_3	6–16	16–24	5–10	5–13
CaO	1.8–5.5	1.3–3.8	17–32	8–16
MgO	0.7–2.1	0.3–1.2	4–12.5	3.2–4.9
K_2O	1.9–2.8	2.1–2.7	0.3–1.6	0.6–1.1
Na_2O	0.2–1.1	0.2–0.9	0.8–6.0	1.3–4.2
SO_3	0.4–2.9	0.5–1.8	0.4–5.0	0.4–2.5
LOI	0.6–4.8	1.2–5.0	0.1–1.0	0.1–2.3
TiO_2	1–2	1–1.5	<1	<1

Note: Chemical analysis by atomic absorption, inductively coupled plasma atomic emission spectroscopy (ICP-AES), or "wet" methods. Much of SiO_2, Al_2O_3 and Fe_2O_3 is present in glassy amorphous form. SO_3 is usually present as calcium sulfate or alkali sulfates. Most of the CaO/MgO is not free. LOI is presumed to be carbon (check with LECO carbon analyzer). Class C fly ashes are usually self-cementing (hydraulic).

Class F fly ash has a glassy phase and inert crystalline phases: quartz, mullite, magnetite spinel, hematite. For example, it has been reported for a high-Fe Class F fly ash from Eastern Canadian bituminous coal 9.6% quartz, 20.4% mullite, 4.5% magnetite spinel, 5.4% hematite, and 58% glass (Hemmings, Berry, Cornelius, Sheetz, "Speciation in Size and Density Fractionated Fly Ash. Characterization of a Low-Calcium, High-Iron Fly Ash," Materials Research Society Symposia Proceedings, *Fly Ash and Coal Conversion By-Products: Characterization, Utilization and Disposal*, Vol. 86, 1987.)

Class C fly ash can have the ingredients of Class F fly ash as well as anhydrite, alkali sulfates, dicalcium silicate, tricalcium aluminate, lime (Portlandite if ash has been exposed to moisture), melilite, merwinite, periclase, sodalite. For example, it has been reported for a low-Ca Class C fly ash from western Canadian subbituminous coal 6% quartz, 14% mullite, and 80% glass. (Berry, Hemmings, Cornelius, "Speciation in Size and Density Fractionated Fly Ash. The Influence of HCL Leaching on the Glassy constituents of a High-Ca Fly Ash," Materials Research Society Symposia Proceedings, *Fly Ash and Coal Conversion By-Products: Characterization, Utilization and Disposal*, Vol.113, 1988.)

Table 2-2 illustrates the typical chemistry of Standard Reference Materials (SRM) Program and lignite coal fly ash in weight percentages.

Table 2-2
Chemical Composition of Standard Reference Materials Program Fly Ash Samples and Lignite Coal Ash

Courtesy of Fly Ash Resource Center

Chemical Compounds	SRM 1633a (Weight %)	SRM 2689 (Weight %)	SRM 2690 (Weight %)	SRM 2691 (Weight %)	Lignite (Weight %)
SiO_2	48.8	51.5	55.3	36	28.9
Al_2O_3	27.0	24.5	23.3	18.5	11.1
Fe_2O_3	13.4	13.3	5.1	6.3	11.1
CaO	1.6	3.0	8.0	25.8	18.9
MgO	0.8	1.0	2.5	5.2	6.0
Na_2O	0.2	0.3	0.3	1.5	8.0
K_2O	2.3	2.6	1.2	0.4	0.9
TiO_2	1.3	1.3	0.9	1.5	
P_2O_5		0.2	1.2	1.2	
SO_3		0.7		2.1	6.83
LOI		1.76	0.52	0.23	0.42

Note: SRM 1633a is from bituminous coal. SRM 2689 is from bituminous coal from Western Kentucky. SRM 2690 is from subbituminous coal from Craig, Colorado. SRM

2691 is from subbituminous coal from Gillette, Wyoming. The lignite coal source is from North Dakota.

Table 2-3 lists the trace elements found in Class F coal fly ash.

Table 2-3
Trace Elemental Analysis of Coal Fly Ash (Class F)

Courtesy of Fly Ash Resource Center

Element	Trace Amount (mg/kg)	Range (mg/kg)
Aluminum	140,000	(80,000–140,000)
Arsenic	286	(100–300)
Barium	1003	(100–1000)
Boron	290	(NA)
Cadmium	<0.5	(NA)
Chromium	218	(NA)
Cobalt	NA	(10–90)
Copper	185	(30–200)
Lead	114	(120–270)
Lithium	270	(NA)
Manganese	290	(NA)
Molybdenum	46	(NA)
Nickel	169	(30–200)
Selenium	11	(5–30)
Silver	14	(NA)
Phosphorous pentoxide (P_2O_5)	3800	(NA)
Strontium	NA	(200–2600)
Titanium	8500	(NA)
Zinc	254	(200–450)

2.2 Types of Fly Ash Conveying Systems

The purpose of this section is to familiarize the user with the following four major types of fly ash conveying systems:

- Pressure systems
- Vacuum systems
- Combination vacuum/pressure systems
- Dense-phase systems

More detailed descriptions of each system and schematics of the system components are provided in the remainder of this section. A detailed description of component functions is provided in Section 2.3, “Introduction to Fly Ash System Components.”

With any pneumatic system—pressure, vacuum, or combination vacuum/pressure—provision must be made to store the fly ash for a predetermined period of time. The system must also provide a means for the fly ash to be removed from storage so it can be transported for sale or disposal. These systems include a storage bin and its accessories, such as fluidizing media, vent filter, vacuum/pressure relief valve, and a device for measuring the level of the bin’s contents. Unloading equipment below the bin can include a paddle/mixer unloader or a rotary unloader if the ash is to be conditioned for transport in open vehicles, or it can include a dry spout if the ash is to be kept dry and transported in a closed vehicle. A typical configuration of a fly ash storage system and its accessories is illustrated in Figure 2-1.

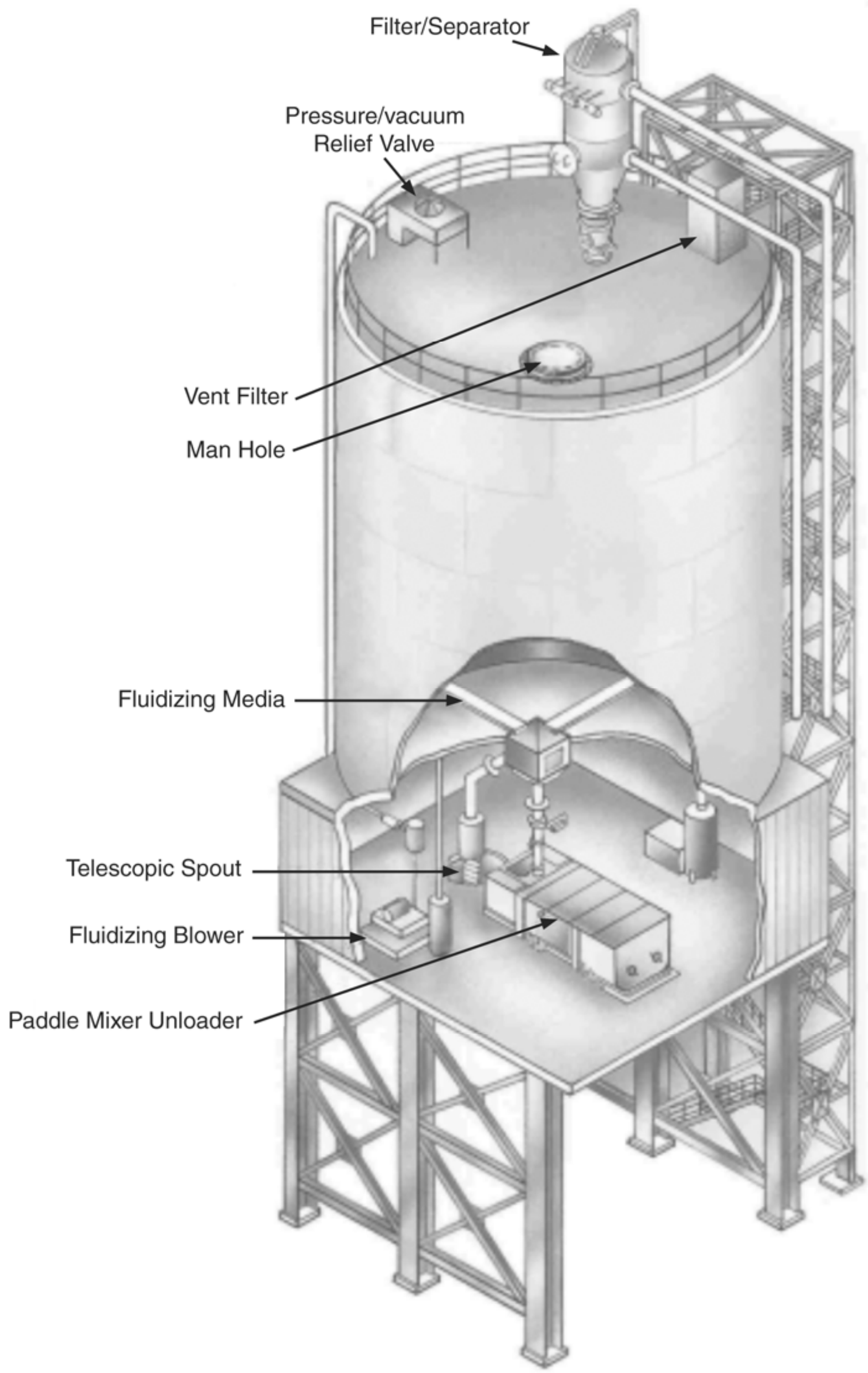


Figure 2-1
Fly Ash Storage System

Courtesy of United Conveyor Corporation

2.2.1 Overview of Pneumatic Fly Ash Conveying Systems

Pneumatic fly ash conveying systems use compressed air to transport fly ash from the storage hoppers of the fly ash collection equipment to the ash storage silo. Some types of fly ash tend to form scale inside hydraulic fly ash conveying lines. Also, all fly ash settles extremely slowly in water. These characteristics, coupled with the environmental limitations on liquid discharge, have severely restricted the use of wet-type fly ash conveying systems. An advantage of pneumatic systems is that they can be applied to both fly ash and bottom ash for stoker-fired or fluidized bed boilers, simplifying ash conveying and storage. Pneumatic systems are either vacuum, pressure, or combination vacuum/pressure types of systems.

A vacuum system pulls ash from the fly ash storage hoppers by means of mechanical, steam-powered, or water-powered exhausters, and a filtering system. Vacuum systems—depending on capacity requirements, line configuration, and plant altitude—can be designed for vacuum levels ranging from 8 to 20 in. of mercury (Hg).

Key Technical Point

Vacuum systems are generally preferable to pressure systems because in the event of a leak in the system piping joints, vacuum systems pull air into the system rather than allowing particulates to escape, thus leaving a cleaner environment. A vacuum system is recommended for capacities of less than 60 tons per hour (TPH) per system. If the conveying distance is more than 800 ft, an evaluation will need to be made to determine whether a vacuum or pressure system is more feasible.

A comparison of vacuum systems and pressure systems is shown in Table 2-4.

Table 2-4
Comparison of Pneumatic Vacuum Versus Pressure Ash Conveying Systems

Courtesy of U.S. Army Engineering and Support Center

Criteria	Vacuum Systems	Pressure Systems
When recommended	• Convey systems less than 60 TPH per system • Reasonable conveying distance	• High system capacity • Long conveying distances (greater than 1000 to 2000 ft)
Advantages	• Less maintenance at hoppers • System leaks inward for cleaner environment • Multiple collecting points • Simpler control scheme	• Relative unlimited capacity • Relative unlimited conveying distance • No separating equipment • Clean air blowers • Multiple disposal points
Disadvantages	• Requires separating equipment and process bag filtration • Blower life dependent on separating equipment reliability	• Double gates required with air lock • Air lock pressurizing and venting requires additional piping and valving • Ash leaks outward into the plant • Higher maintenance costs

A pressure system engages a positive-displacement blower, producing pressures up to 20 psig for the conveying system. System capacities in excess of 60 TPM and conveyor distances of greater than 1000 ft require higher blower pressures than vacuum systems can provide, in which case pressure systems may be used instead of vacuum systems. However, pressure systems should be avoided where possible because leaks of fine ash particulates usually occur at the piping joints.

Silo storage design is the same for a pressure system as for a vacuum system except that ash collectors are typically not required at the silo and fly ash is redeposited directly into the silo.

Key Technical Point

There are two types of pressure systems: dilute-phase systems and dense-phase systems. Dilute-phase systems usually have an ash-to-air volumetric ratio of 15:1, sometimes as high as 30:1. Dense-phase systems usually have an ash-to-air ratio of 40:1 to 50:1, sometimes as high as 80:1.

A comparison of dilute-phase and dense-phase pressure systems is shown in Table 2-5. The dilute-phase pressure system is the more widely used pressure system. Dense-phase pressure systems use a *fluidizing transporter*, a vessel in which air and ash are mixed, fluidizing the ash so that the flow characteristics resemble that of a liquid.

Table 2-5
Comparison of Pressure Dilute-Phase Versus Dense-Phase Ash Conveying Systems

Courtesy of U.S. Army Engineering and Support Center

Criteria	Dilute-Phase Systems	Dense-Phase Systems
Design criteria	Evenly loaded single conveying line Load ratio (5–22) lb of ash to lb of air 10–30 psig operating pressure 2000–3500 fpm starting velocity	Typically multiple convey lines Load ratio (20–200) lb of ash to lb of air 30–100 psig operating pressure 600–3000 fpm starting velocity
When recommended	High conveying capacity (> 30 TPH) Long conveying distances (> 1000 ft) Multiple disposal points Minimum collection points	Medium capacities (10–50 TPH) Short conveying distances (200–500 ft) Minimum disposal points Minimum collection points
Advantages	Greater capacities and distances with a single line Not affected by material changes with gravity flow Stable velocity range provides material re-entrainment Transfer stations normally not required Low initial cost air handling equipment Components subjected to lower pressure	Smaller conveying lines, bag filters, and hoppers Lower conveying velocity Normally lower horsepower Carbon steel pipe
Disadvantages	Higher air flow, larger pipe, and hoppers Often higher horsepower Components subjected to higher velocity Special pipe required (alloy pipe or ceramic lined)	Material consistency greatly affects conveying parameters, and granular material remains in airlock. Positive sealing high-differential discharge valve is critical to system performance. Transfer stations normally required. Parallel compressed air lines required to free line plugs. Multiple conveyor lines. Expensive initial cost (air compressors). Components subject to higher pressure.

2.2.2 Fly Ash Pressure Conveying Systems

Figure 2-2 illustrates a typical fly ash pressure conveying system with system components designated. The pressure conveying system is typically recommended when the conveying capacity requirements exceed the limits of a vacuum system. These systems operate at up to 40 psig (275 kPa) and can be used to convey ash up to 8000 ft (2400 m). In a pressure conveying system, multiple feeders allow the line to remain filled for long periods, resulting in high conveying efficiency. A positive-displacement or centrifugal blower furnishes conveying air, which moves ash to the storage bin under positive pressure. No separating equipment is required; however, a bin vent filter is generally used to clean the vented air.

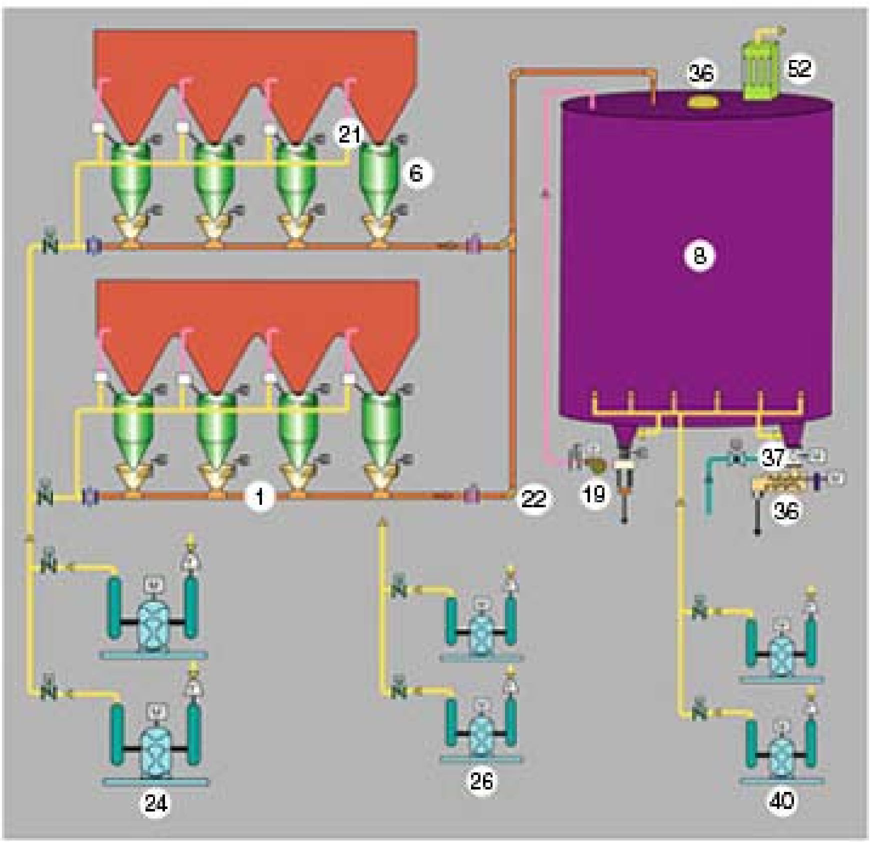
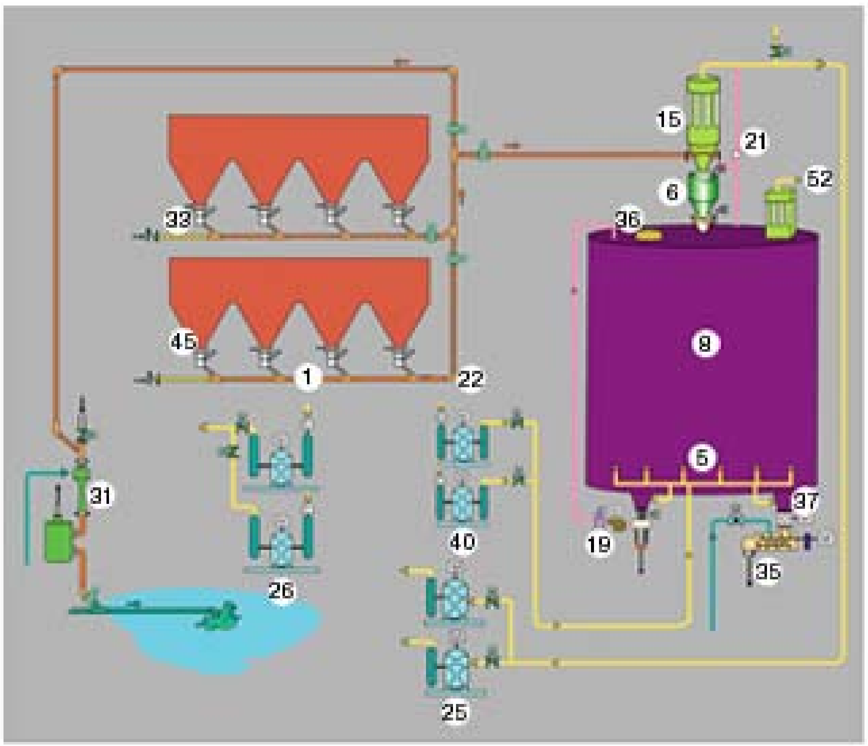


Figure 2-2
Fly Ash Pressure Conveying System

Courtesy of Allen-Sherman-Hoff

2.2.3 Fly Ash Vacuum Conveying Systems

Figure 2-3 illustrates a typical fly ash vacuum conveying system with system components designated. In a vacuum system, fly ash is transported in an air stream at negative pressures of less than 20 in. of mercury (Hg). A vacuum producer creates the conveying air flow and, at the opposite end of the system, air intakes admit conveying air to the conveyor line. Ash intakes control ash flow from the collection hoppers into the line. Separating equipment removes ash from the conveying air and deposits it in a storage bin.



Legend:
1 – Abrasion–Resistant Pipe
5 – Air Gravity Conveyor
6 – Airlock Valve
8 – Ash Storage Silo
15 – Collector and Filter
19 – Dry Dust Unloader
21 – Equalizer Valve
22 – Fitting
25 – Fly Ash Vacuum Pump
26 – Hopper Aeration Pump
31 – Hydraulic Vacuum Device
33 – Material Handling Valve
35 – Pugmill Unloader
36 – Relief Door
37 – Rotary Fedder
40 – Silo Aeration Blower
45 – Cut-Off Gate
52 - Vent Filter

Figure 2-3
Fly Ash Vacuum Conveying System

Courtesy of Allen-Sherman-Hoff

> **Key Technical Point**
>
> Advantages of the vacuum system include low headroom requirements below the collection hoppers and the ability to stop and restart automatically. Vacuum systems are intended for conveying distances up to 1500 ft (450 m).

2.2.4 Fly Ash Vacuum/Pressure Conveying Systems

Figure 2-4 shows a typical vacuum/pressure system.

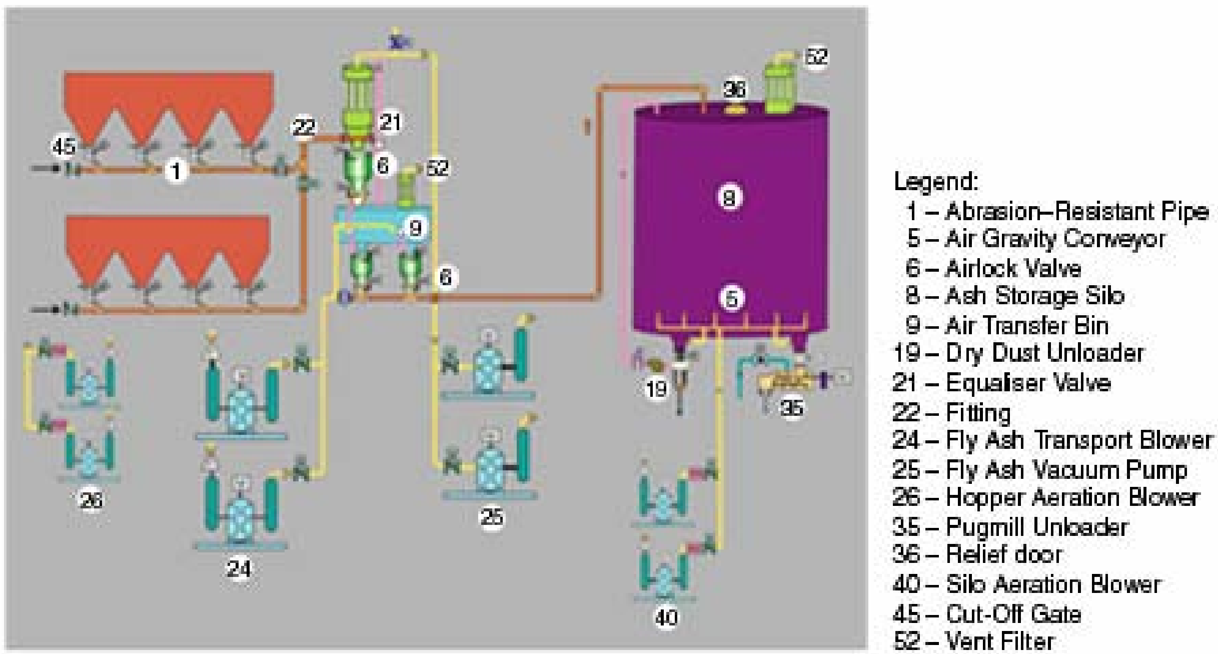


Figure 2-4
Fly Ash Vacuum/Pressure Conveying System

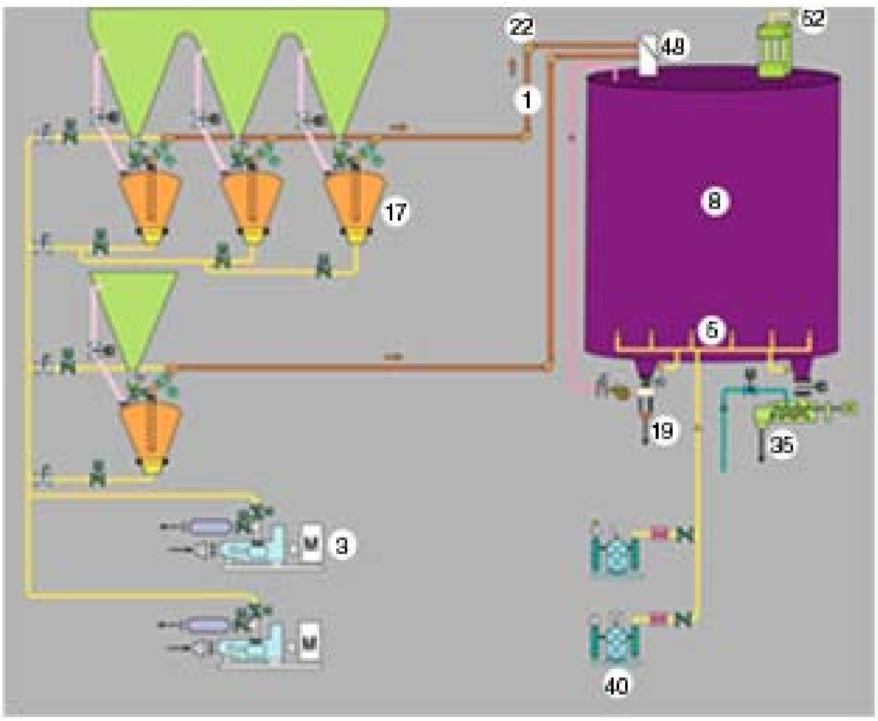
Courtesy of Allen-Sherman-Hoff

Key O&M Cost Point

In some rare cases in which distance rules out the use of a vacuum system alone, it can be more economical to combine a vacuum system with a pressure system. The vacuum system, with its simplified controls, removes ash at an optimal rate. The pressure system, reduced to one transfer point with a minimum of controls, then delivers collected ash to any terminal point at a distance of several thousand feet. The combination vacuum/pressure system provides the least complex controls of any long-distance pneumatic conveying system.

2.2.5 Dense-Phase Fly Ash Conveying Systems

Figure 2-5 illustrates a typical dense-phase fly ash conveying system with system components designated.



Legend:
- 1 – Abrasion–Resistant Pipe
- 3 – Air Compressor
- 5 – Air Gravity Conveyor
- 8 – Ash Storage Silo
- 17 – Dense–Phase Vessel
- 19 – Dry Dust Unloader
- 22 – Fitting
- 35 – Pugmill Unloader
- 40 – Silo Aeration Blower
- 48 – Target Box
- 52 – Vent Filter

Figure 2-5
Dense-Phase Fly Ash Conveying System

Courtesy of Allen-Sherman-Hoff

Key Technical Point

Like all pressure conveying systems, dense-phase conveying systems use pressurized vessels to feed ash into the conveying line. However, these systems operate at pressures up to 60 psig (415 kPa), have smaller pipelines, and require less conveying air flow than the lower-pressure systems. Therefore, dense-phase systems can be used for longer conveying distances than dilute-phase systems—up to 5200 ft (1600 m).

Also similar to the pressure conveying system, one version of the dense-phase conveying system uses multiple feeder units to feed the line; however, material flows into the conveying line before the line is pressurized. These multiple-feeder systems use a three-phase cycle, as follows:

1. Material fills the line, and the gate above the feeder closes.
2. The line is pressurized, and the material is conveyed.
3. The line is purged, and the cycle repeats.

Like the vacuum system, the multiple-feeder dense-phase system is intended primarily for short conveying distances (less than 1300 ft [400 m]), and requires little headroom below the collection hoppers.

2.3 Introduction to Fly Ash System Components

This section provides a brief tutorial regarding the components of the types of fly ash conveying systems described in Section 2.2, "Types of Fly Ash Conveying Systems," and the design features and functions associated with each of them. Table 2-6 should be used to identify various components within each type of system. A brief description of each component and its operating design parameters is provided in Table 2-7 and in the following paragraphs.

Table 2-6
Typical Components of Fly Ash Conveying Systems

Courtesy of Allen-Sherman-Hoff

Component Name	Types of Fly Ash Conveying Systems			
	Pressure Conveying Systems	Vacuum Conveying Systems	Vacuum/Pressure Conveying Systems	Dense-Phase Conveying Systems
Abrasion-resistant pipe	X	X	X	X
Air compressor				X
Air gravity conveyor		X	X	X
Airlock valve	X	X	X	
Ash storage silo	X	X	X	X
Ash transfer bin			X	
Collector and filter		X		
Dense-phase vessel				X
Dry dust unloader	X	X	X	X
Equalizer valve	X	X	X	
Fitting	X	X	X	X
Fly ash transport blower	X		X	
Fly ash vacuum pump		X	X	

Table 2-6 (cont.)
Typical Components of Fly Ash Conveying Systems

Component Name	Types of Fly Ash Conveying Systems			
	Pressure Conveying Systems	Vacuum Conveying Systems	Vacuum/Pressure Conveying Systems	Dense-Phase Conveying Systems
Hopper aeration blower	X		X	
Hydraulic vacuum device		X		
Material handling valve		X		
Pugmill unloader	X	X	X	X
Relief door	X	X	X	
Rotary feeder	X	X		
Cut-off gate		X	X	
Silo aeration blower	X	X	X	X
Vent filter	X	X	X	X

Table 2-7 provides a listing of the major system components of a typical fly ash conveying system and an overview of component design features and functions.

Table 2-7
Overview of Component Design Features and Functions

Courtesy of Allen-Sherman-Hoff and United Conveyor Corporation

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Abrasion-resistant pipe Abrasion-resistant pipe fittings	Designed specifically to withstand the abrasive wear from fly ash. Pipe sections have plain ends and are normally installed with sleeve couplings. Adapters are used to mate to standard pipe flanges. Various diameters are available in standard 18-ft lengths.
Air gravity conveyor	Normally installed in an inclined radial pattern around an outlet in the silo floor. Consist of porous stone blocks installed on top of a steel trough. Air is blown into the trough and passes uniformly through the porous stone. Aerated material becomes fluidized and flows down the inclined surface to the silo outlet.

Table 2-7 (cont.)
Overview of Component Design Features and Functions

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Airlock valve	Carbon steel storage chamber. Replaceable Ni-Hard gate and seat. Valve access door in each chamber provides ease of maintenance and inspection. Control systems designed for a variety of operator selectable parameters. Some styles provide positive sealing against a high head (25–100 ft) and are used under large storage hoppers to handle fine abrasive material. Some designs offer a fully aerated 12-in. inlet, a straight-through design with horizontal gates capable of shearing through a column of fine material. Some styles have a straight-through design and are used in applications involving oil soot, wood bark ash, or coarse granular material. Serves as a material transfer chamber with two gates that seal the inlet and outlet of the chamber. The top gate opens to let material into the transfer chamber and the bottom gate opens to discharge the material from the chamber. Both gates are operated by air cylinder actuators. The two gates are interlocked so that only one gate is permitted to open at a time. Chamber pressure is controlled by an equalizer valve.

Table 2-7 (cont.)
Overview of Component Design Features and Functions

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Ash storage silo	Typically constructed of concrete or steel that store conveyed fly ash and/or bed ash until it is unloaded for final disposal. Typically flat bottomed with discharge adapters that empty stored ash through either dry dust unloaders or pugmill unloaders. Level instrumentation, vent filter, relief door, and ash collection equipment is typically mounted on the ash storage silo roof.
Ash transfer bin	Typically constructed of steel. Temporarily stores ash collected by the vacuum portion of a vacuum/pressure fly ash system before it is conveyed through the pressure section of the same system. Not designed for long-term storage of ash and is not normally equipped with unloading equipment.
Collector and filter	Solids-laden air or gases enter the unit at the hopper or housing inlet. Air passes through the filter media, and solids are retained on the filter medial surface. Filtered air is exhausted through the clean air plenum. Cleaning cycle consists of a momentary blast of 90–100 psig compressed air momentarily taking a row of bags off-stream through pressure reversal, flexing filter bags, and releasing solids to fall toward the hopper and through a rotary valve or other discharge equipment. Cycle timer is adjusted to maintain approximately 3–4 in. water column pressure drop across the filter bags.
Dense-phase vessel	Pressure vessel in which material is thoroughly fluidized. Discharge flow characteristics resemble those of a liquid. A large aeration stone mounted near the bottom of the vessel.

Table 2-7 (cont.)
Overview of Component Design Features and Functions

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Dry dust unloader	Typically designed for eliminating dust emissions and for speeding load-out operations. The spout is designed so that the product stream and dust-laden air are separately contained from the inlet to the final resting point within the container, vessel, or vehicle. Stacking inner spout cones separate the product flow from the dust-laden air stream. The spout is often kept under a slightly negative pressure by its connection to a dust collection system, which prevents the escape of generated dust into the atmosphere. Air velocity within the spout is kept relatively high at the discharge point and is reduced within the main body of the spout.
Equalizer valve	Typically an air-cylinder-actuated three-way valve. Its common port is always open to the upper chamber of the air lock valve. The other two ports are connected as indicated on the assembly drawing (depending on the type of system in which it is installed).
Fly ash transport blower Hopper aeration blower Fly ash vacuum pump Silo aeration blower Air compressor	Provides sources of compressed air to create positive pressure or vacuum in the fly ash conveying system. Blowers/compressors may be one of the following general designs: • Reciprocating • Rotary screw • Centrifugal
Hydraulic vacuum device	Designed for harsh operating conditions to transport abrasive material. Available in various sizes handling up to 1200 SCFM and vacuum levels to 22 in. of mercury (Hg): • 4 x 6 in. (ceramic lined or metal throat and flange discharge) • 6 x 8 in. (ceramic lined or metal throat and plain end discharge) • 8 x 10 in. (ceramic lined or metal throat and plain end discharge) Easy replacement or cleaning of exhauster nozzle tips by removing access covers.

Table 2-7 (cont.)
Overview of Component Design Features and Functions

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Material handling valve	Typically fitted below the outlet of the hopper, which is sealed from the transport piping system by the slide gate of the material handling valve. Two air inlet check valves are located between the hopper outlet and the slide gate. When the slide gate is opened, the air inlet check valves mix air with the material as it passes through the valve. Some valves are also equipped with a metering device which can be adjusted to regulate the material flow rate.
Pugmill unloader	A primary and secondary spray system adds water to the material to form mixture for transport. Paddle shafts rotate counter to one another in an inward direction to expose all of the ash to water. Hinged door on top of pugmill and paddle shaft bearing mounts on the exterior of the mixing chamber allows for easy access and maintenance. At the outlet, the conditioned material is discharged by gravity through a chute into vehicles for removal to the disposal.
Relief door	Designed for use on storage tanks that require large volume pressure and vacuum relief. The relief door is not a static tank appurtenance, but is an integral part of the dynamic operation of the silo.
Rotary feeder	The body of the feeder houses a rotor divided into pockets. The pockets seal against a shoe located on the inlet side of the feeder. The clearance between the rotor and shoe is adjustable. Material falls by gravity into the pockets. As the rotor rotates, the material is conveyed to the bottom of the feeder and falls from the inverted pockets. The speed and size of the rotor determines the flow rate of the material.
Cut-off gate segregating valve	The valve has almost two identical body halves, each with a raised, removable seat insert. The bodies have machined tracks in which the slide gate travels. When the valve is opened, the gate moves out of the pipeline and allows an unrestricted flow through the valve. When the valve is closed, the vacuum in the system draws the slide gate against one of the seats to make a seal. The valve is actuated by an air cylinder.

Table 2-7 (cont.)
Overview of Component Design Features and Functions

Name of Fly Ash System Component	Overview of Component Design Features and Functions
Vent filter	Solids-laden air or gases enter the unit at the hopper or housing inlet. Air passes through the filter media, and solids are retained on the filter medial surface. Filtered air is exhausted through the clean air plenum. Cleaning cycle consists of a momentary blast of 90–100 psig compressed air, momentarily taking a row of bags off stream through pressure reversal, flexing filter bags, and releasing solids to fall toward the hopper and through a rotary valve or other discharge equipment. Cycle timer is adjusted to maintain approximately 3–4 in. water column pressure drop across the filter bags.

2.3.1 Abrasion-Resistant Pipe

Most ash handling systems require pipe that is resistant to the abrasive qualities of ash when it is transported at the system's designed conveying velocity. Accessories include couplings, adapters, and expansion joints. Depending on the application, basalt-lined abrasion-resistant pipes are often used.

The standard pipe for hydraulic and pneumatic ash handling systems is made of chrome-iron alloy, a material that is able to handle most abrasive wear conditions. It is typically offered in standard lengths of 18 ft. In some cases, the alloy pipe is available in two grades that vary in hardness ranges from 280–340 Brinell to 475–550 Brinell. For easy installation and replacement or rotation of pipe, this product usually has plain ends that connect with sleeve couplings.

Another type of abrasion-resistant pipe used in fly ash conveying systems is lined with ceramic made from ultra-fine-grain high-grade alumina that has a life expectancy many times greater than the unlined steel pipe and fittings. Ceramics of this type have a hardness of 67–68 Rockwell C, and most pipe and fittings are supplied with ANSI-compatible flanges. One advantage of this product is that it weighs less than equivalent cast pipe, thereby easing the installation process.

2.3.2 Air Compressor

Air compressors are used for long-distance fly ash pressure systems and for some dense-phase systems when the required conveying pressure and flow requirements are higher than the design capabilities of rotary lobe blowers. When compressors are used to provide the conveying air flow, they are typically set up to operate along their natural operating curve.

2.3.3 Air Gravity Conveyor

In the typical storage silo application, air gravity conveyors function to maintain stored ash in a dry, fluidized state to ensure that it is free-flowing when the silo is unloaded. The conveyor sections evenly distribute dry heated air through either porous stone or treated fabric through structural channels that radiate around the silo discharge openings. The required air is supplied by silo aeration blowers operating in conjunction with air circulation heaters. Air gravity conveyors are also used in other ash handling applications.

2.3.4 Airlock Valve

Airlock valves function to continuously transfer ash from one pressure zone to another without the need to interrupt the conveying system operation. The main operational components of a typical airlock include two slide gate valves that are designed to shear through a column of ash and a transfer tank that is sized for the particular application. Airlock valves are typically used in pressure fly ash systems and in silo collector designs.

The airlock valve provides gravity transfer of fly ash or other free-flowing, granular solids from one pressure zone to another. Typical design attributes can include the following:

- Carbon steel storage chamber
- Replaceable Ni-Hard gate and seat
- Valve access door in each chamber provides ease of maintenance and inspection
- Control systems designed for a variety of operator selectable parameters
- Positive sealing against a high head (25–100 ft) and used under large storage hoppers to handle fine abrasive material
- A fully aerated 12-in. inlet, a straight-through design with horizontal gates capable of shearing through a column of fine material
- A straight-through design used in applications involving oil soot, wood bark ash, or coarse granular material

Figure 2-6 illustrates the configuration of a typical air lock valve installed on pressure, vacuum, and vacuum/pressure fly ash conveying systems.

Figure 2-6
Airlock Valve

Courtesy of Allen-Sherman-Hoff

2.3.5 Ash Storage Silo

Ash storage silos are relatively large vessels, typically constructed of concrete or steel, that store conveyed fly ash or bed ash until it is unloaded for final disposal. An ash storage silo is typically flat bottomed with discharge adapters that empty stored ash through either dry dust unloaders or pugmill unloaders that are installed on the silo unloader room floor. The silo storage section and unloader room floor are elevated above grade to allow access to ash transport vehicles below. Level instrumentation, vent filter, relief door, and ash collection equipment are typically mounted on the ash storage silo roof. Figure 2-7 illustrates the overall configuration of an ash storage silo.

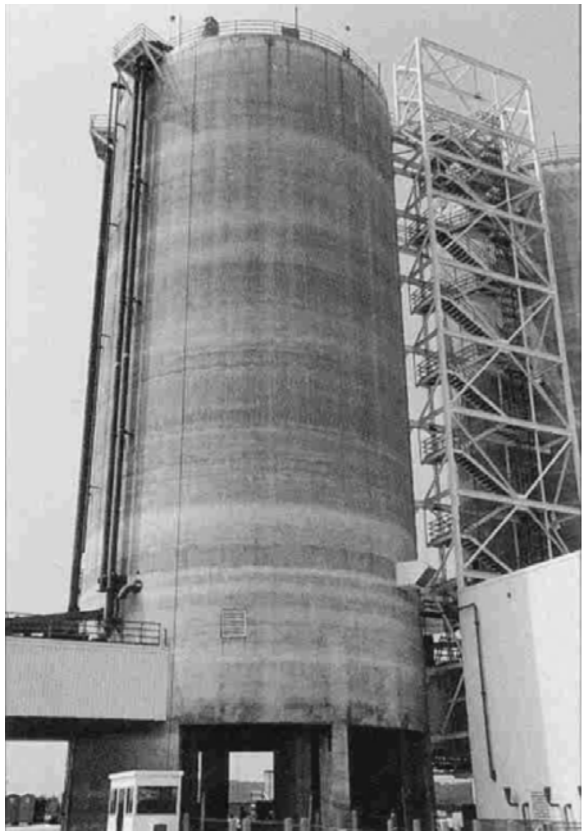


Figure 2-7
Ash Storage Silo

Courtesy of United Conveyor Corporation

2.3.6 Ash Transfer Bin

An ash transfer bin temporarily stores ash collected by the vacuum portion of a vacuum/pressure fly ash system before it is conveyed through the pressure section of the same system. The capacity of the transfer bin allows for ash conveying surges between the vacuum and pressure sections of the system. It is not designed for long-term storage of ash and is not normally equipped with unloading equipment.

2.3.7 Vacuum System Fly Ash Collector and Filter

The collector and filter arrangement of a typical vacuum fly ash system consists of a conical lower transfer section with a stone box connection and an upper bag filter section. The arrangement removes and separates the collected fly ash from the conveying air stream before it reaches the vacuum producer. Independent cyclonic collectors and bag filters are also available.

The collector provides the first stage of material separation from the conveying air of a vacuum system and transfers the material to a pressure system that discharges to remote disposal facilities. Continuous collectors often include a second gate, permitting the continuous collection of fly ash material from the conveying system without interruption during the collector emptying cycle. Collector design will vary depending on normal or high-temperature application.

2.3.8 Dense-Phase Vessel

The dense-phase vessel is the heart of a dense-phase system. It is a pressure vessel in which material is thoroughly fluidized such that the discharge flow characteristics resemble those of a liquid. A large aeration stone mounted near the bottom of the vessel admits aeration air such that the fly ash particles are completely enveloped. This allows the aerated ash to be conveyed in smaller pipes and often at a slower velocity because the ash particle friction is greatly reduced.

2.3.9 Dry Dust Unloader

A dry dust unloader incorporates a retractable motor-operated unloading spout that unloads dry material from a storage silo into a tanker-type vehicle. A cylinder-operated gate valve located above the chute is used to control the unloading rate. The dry dust unloader is locally controlled. Figure 2-8 illustrates a typical configuration for a dry dust unloader spout.

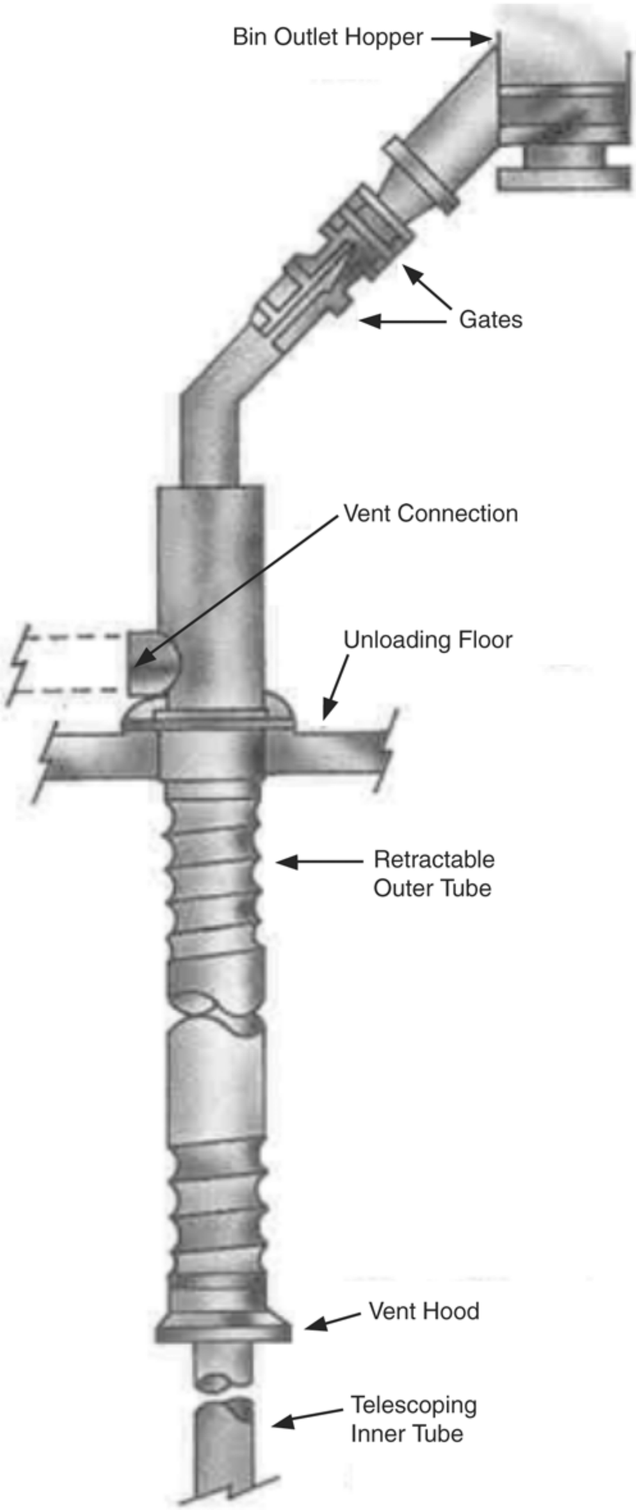


Figure 2-8
Dry Unloading Spout

Courtesy of United Conveyor Corporation

2.3.10 Equalizer Valve

The equalizer valve is a three-port valve that equalizes the pressure between two unequal pressure zones. Equalizer valves are often associated with pressure fly ash system airlocks and with vacuum system collectors. The equalizer valve pressurizes and vents an airlock so the ash can flow by gravity from a lower-pressure to a higher-pressure vessel. Thus, equalization promotes the flow of ash from one zone into the other. Figure 2-9 illustrates one style of equalizer valve (A-S-H Style II).

Figure 2-9
A-S-H Style II Equalizer Valve

Courtesy of Allen-Sherman-Hoff

Inherent to this design are the following typical attributes:

- Two access doors for on-line inspection and maintenance
- Slide gate design that ensures a secure seal
- Appropriate chamber size that reduces gas and material velocity through the valve

Figure 2-10 illustrates another style of equalizer valve (A-S-H Style III).

Figure 2-10
A-S-H Style III Equalizer Valve

Courtesy of Allen-Sherman-Hoff

Inherent to this design are the following typical attributes:

- Ni-Hard gate and seat, providing extended service life
- A gate that is dual-spring loaded, providing even seating force
- A close-coupled actuator, eliminating valve body shaft penetration seal leakage
- Flange adapters (when replacing other manufacturers' valves)

Figure 2-11 provides plan and section views of both a single-cylinder and a dual-cylinder equalizer valve.

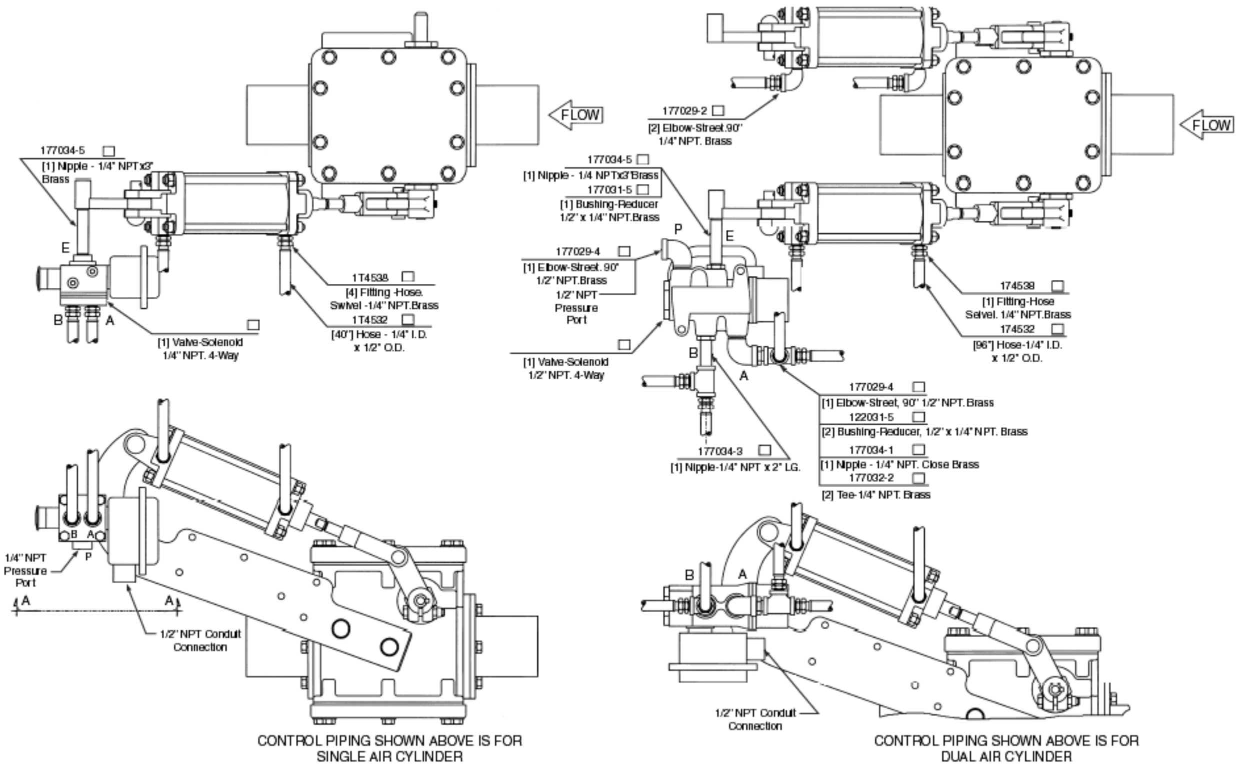


Figure 2-11
Single- and Dual-Cylinder Equalizer Valves

Courtesy of United Conveyor Corporation

2.3.11 Fittings

A fitting is a piping part required for a pipeline to change direction or diameter. Most fittings that are associated with ash handling systems are abrasion-resistant types. Typically, fittings can be categorized as being one of the three following parts: lateral, elbow, or tee. Accessories include couplings, adapters, and expansion joints. Figure 2-12 illustrates a typical integral wear-back fitting used for pipe bends and junctions in hydraulic and pneumatic pressure systems.

Figure 2-12
Integral Wear-Back Fitting

Courtesy of Allen-Sherman-Hoff

The fitting's tangent discharge-end design allows material to flow efficiently, thus minimizing coupling wear. Like the corresponding pipe, the fittings should be available in two grades, varying in hardness (400–500 Brinell range and 550 Brinell hardness). These fittings should have plain ends with sleeve couplings to allow for easy installation and replacement. Figure 2-13 illustrates a replaceable wear-back fitting.

Figure 2-13
Replaceable Wear-Back Fitting

Courtesy of Allen-Sherman-Hoff

Reversing the replaceable wear-back maximizes the fitting's wear life. These also should be available in two grades of hardness, similar to the integral fitting. Wear-back fittings should have plain ends and should be able to be removed for pipe line inspection.

Couplings connect plain-end pipe and fittings. Some designs can accommodate expansion of up to 1/4 in. (6 mm) per length of pipe and deflections of up to 3º, adding installation flexibility. The standard coupling consists of a middle ring, two followers, and a set of track-head bolt assemblies. Single couplings can accommodate fillers of up to 3 in. for 4- to 9-in. diameter pipe sizes and 5 in. for 10- to 16-in. pipe sizes. Double couplings can accommodate fillers of 3–8 in. for 4- to 9-in. diameter pipe sizes and 5–10 in. for 10- to 16-in. diameter pipe sizes.

Adapters connect abrasion-resistant pipe to flange assemblies. Standard adapters should conform with ANSI flange arrangements, but many manufacturers offer special adapters that are available for other arrangements. In general, an adapter will allow for connection of various pipe arrangements to meet specific design requirements. Figure 2-14 illustrates the general configuration and positioning of an adapter.

Figure 2-14
Typical Configuration of an Adapter

Courtesy of Allen-Sherman-Hoff

2.3.12 Fly Ash Transport Blower

Fly ash transport blowers supply the necessary air stream to convey ash in a pressure type fly ash conveying system. Most transport blowers are positive-displacement rotary-lobe type and are sized for the specific application. They are driven by electric motors in a V-belt, gearbox, or direct drive arrangement.

2.3.13 Hopper Aeration Blower

Hopper aeration blowers supply aeration air to the fly ash system precipitator or baghouse hoppers to ensure that the ash in the respective hoppers is fluidized and free flowing prior to entering the conveying air stream. The aeration air is frequently heated by an air circulation heater installed in the aeration piping downstream of the blowers. Aeration air is also often used to aerate the top gate area of certain styles of airlock valves.

2.3.14 Fly Ash Vacuum Pump

Fly ash vacuum pumps supply the necessary air stream to convey ash in a vacuum type fly ash conveying system. Most modern vacuum pumps are positive-displacement rotary-lobe type, sized for the specific application. They are driven by electric motors in a V-belt, gearbox, or direct drive arrangement.

2.3.15 Hydraulic Vacuum Device

The vacuum producer is a water-powered hydraulic vacuum device used to create the conveying air stream for fly ash vacuum conveying systems. High-pressure water is discharged through a concentric ring of nozzles into a venturi throat to create the necessary vacuum and air flow to convey the fly ash either to collectors or directly through the vacuum device to a hydraulic discharge line. Water jet exhausters create a vacuum, and the corresponding air flow conveys dry solid materials through transport pipelines.

The products should be designed for harsh operating conditions to transport abrasive material. They are typically available in various sizes handling up to 1200 SCFM and vacuum levels to 22 in. of mercury (Hg), as follows:

- 4 × 6 in. (ceramic-lined or metal throat and flange discharge)
- 6 × 8 in. (ceramic-lined or metal throat and plain end discharge)
- 8 × 10 in. (ceramic-lined or metal throat and plain end discharge)

Many designs facilitate easy replacement or cleaning of the exhauster nozzle tips by removal of the access covers. Figures 2-15 and 2-16 illustrate the configurations of a typical hydraulic vacuum device.

Figure 2-15
Hydraulic Vacuum Device Photograph

Courtesy of Allen-Sherman-Hoff

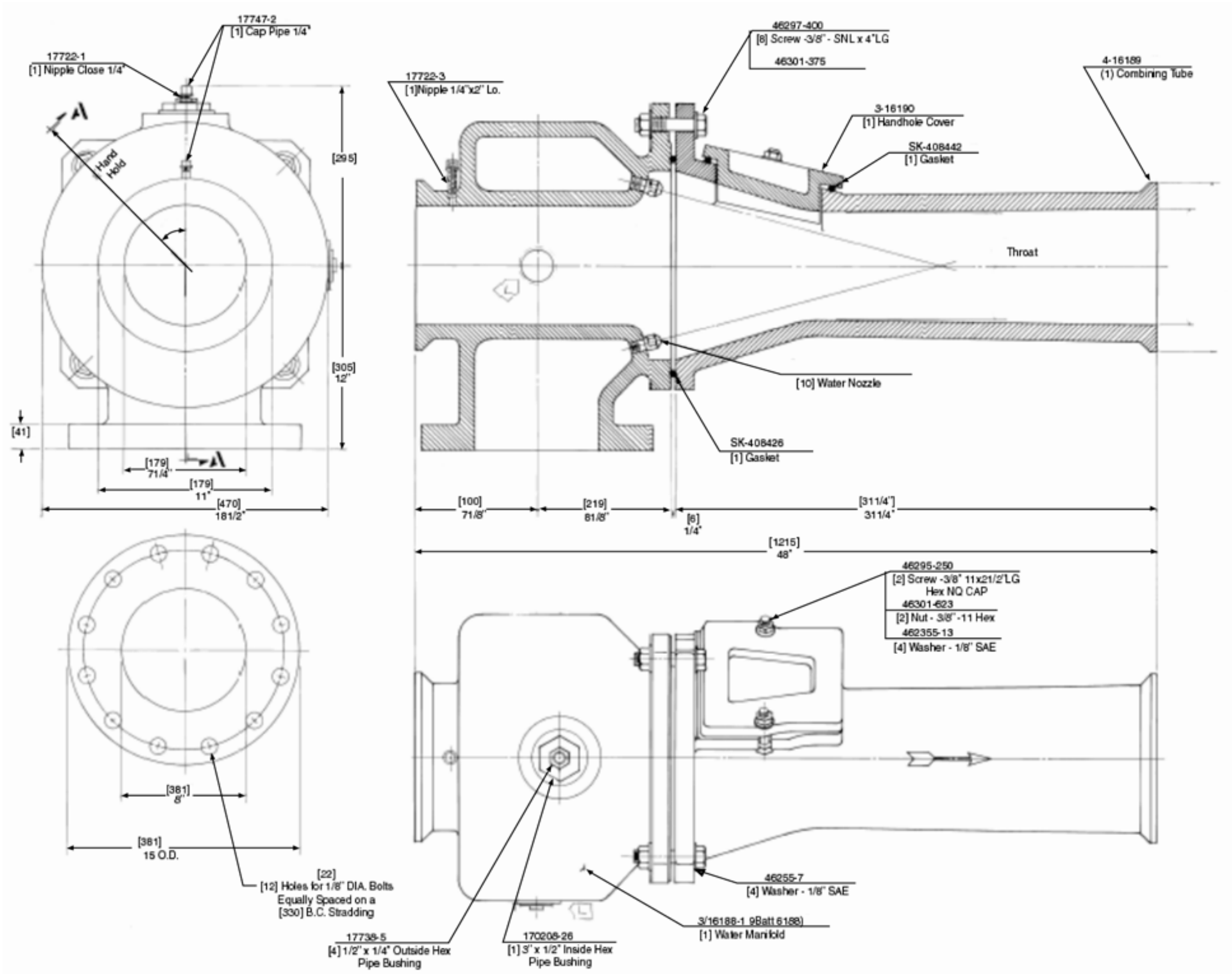


Figure 2-16
Hydraulic Vacuum Device Schematic

Courtesy of United Conveyor Corporation

2.3.16 Material Handling Valve

Material handling valves are the fly ash feed valves found at the outlet of precipitator or baghouse hoppers in a vacuum conveying system. They are typically cylinder actuated and function to control the flow of fly ash from their respective hoppers into the vacuum conveying system air stream. Only one material handling valve is opened at a time during system operation.

One system application for these valves is as a feeding device for vacuum conveying systems. In this application, the product feeds fly ash from the hopper outlet of the electrostatic precipitators, baghouses, economizers, or other ash collecting systems into a conveying line. Typical product features of these devices include the following:

- Valve inlet can be supplied either centerline or straddle centerline
- Slide gate design provides positive gate and seat seal
- Replaceable gate and seat
- Two access points provide for easy maintenance and accessibility
- Operating mechanism is an air-electric, remote-operated cylinder
- Diamonized gate and seat for increased resistance to abrasive wear (hardness of Rockwell C 60)
- Flapper style gate swings completely out of material flow path, minimizing component wear
- Pivot rotation of valve’s gate housing provides easy access for replacement of gate and seat

Another system application for these valves is at the hopper outlet of ash collecting systems. In this application, the product feeds coarse or cohesive ashes into dilute-phase vacuum conveying systems on a batch basis. Typical product features of these devices include the following:

- Design of lower valve body section allows for efficient flow of ash
- Ni-Hard gate and seat (replaceable)
- Two access points for maintenance and accessibility
- Able to handle ash at temperatures up to 750°F
- Operating mechanism ensures rapid closure of the gate

Figure 2-17 illustrates the typical configuration of an ash handling valve.

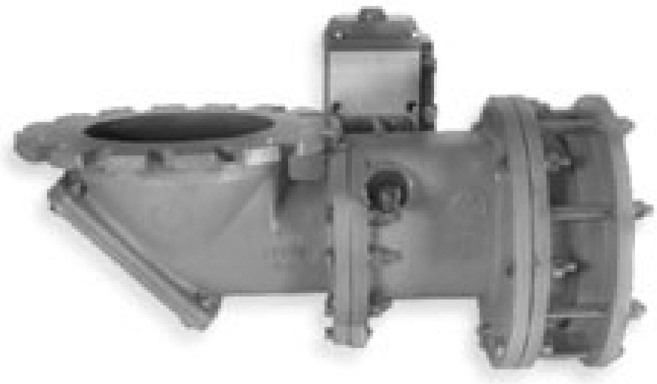


Figure 2-17
Material/Ash Handling Valve

Courtesy of Allen-Sherman-Hoff

2.3.17 Pugmill Unloader

A pugmill unloader combines material from a storage silo with water to form a moist mixture that can be transported in an open-top vehicle with minimum dust emissions. It has two counter-rotating shafts, each of which has a number of abrasion-resistant mixing paddles angled toward the pugmill discharge chute. As the shafts rotate, dry pockets of ash are mixed with water. The pugmill is driven by an electric motor that operates in conjunction with a gear reducer. The pugmill is typically supplied as part of a system that incorporates automatic controls to sequentially operate associated devices such as ash inlet valves or feeders and water supply control valves and instrumentation. Typical design attributes of the pugmill unloader can include the following:

- Primary and secondary spray systems that add water to the material to form mixture for transport
- Paddle shafts that rotate counter to one another in an inward direction to expose all of the ash to water
- Hinged door on top of the pugmill and paddle shaft bearing mounts on the exterior of the mixing chamber that allow for easy access and maintenance

Figure 2-18 illustrates the typical overall configuration of a pugmill unloader.

Figure 2-18
Pugmill Unloader

Courtesy of Allen-Sherman-Hoff

Figures 2-19 and 2-20 illustrate two types of internal mechanisms that are common in fly ash unloaders: the paddle mix style and the rotary style.

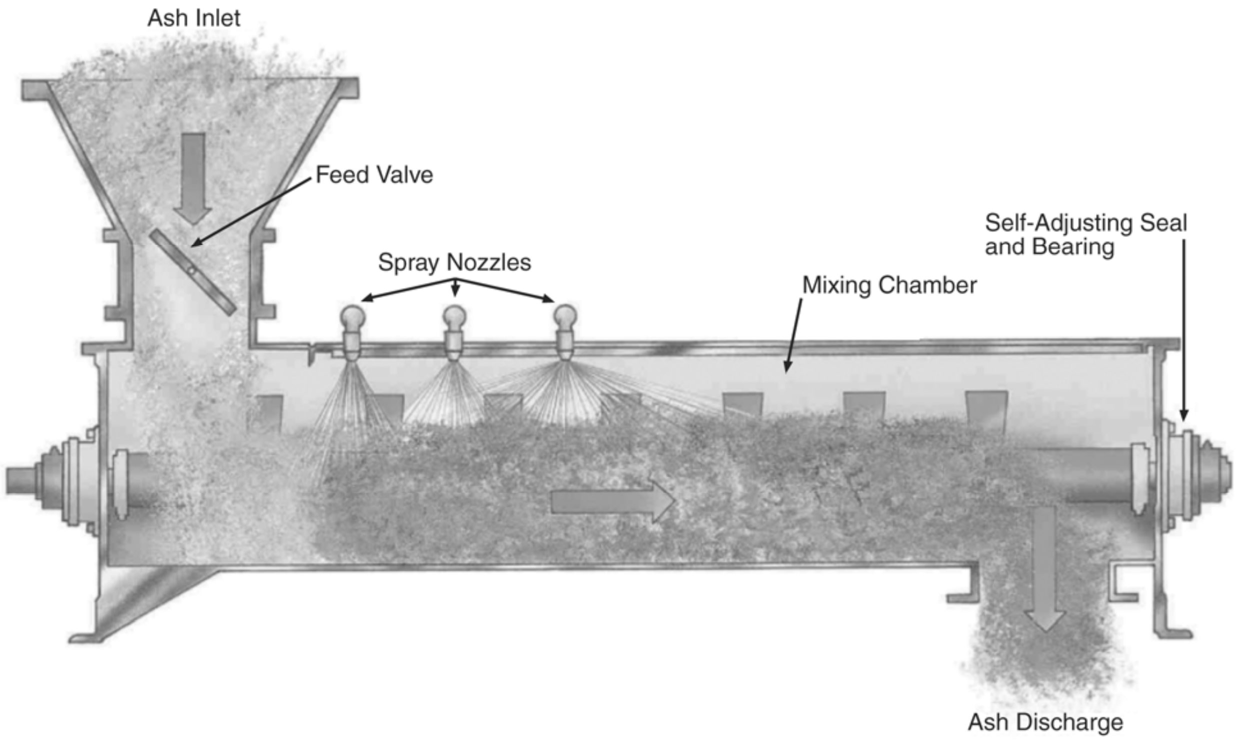


Figure 2-19
Paddle Mix Unloader

Courtesy of United Conveyor Corporation

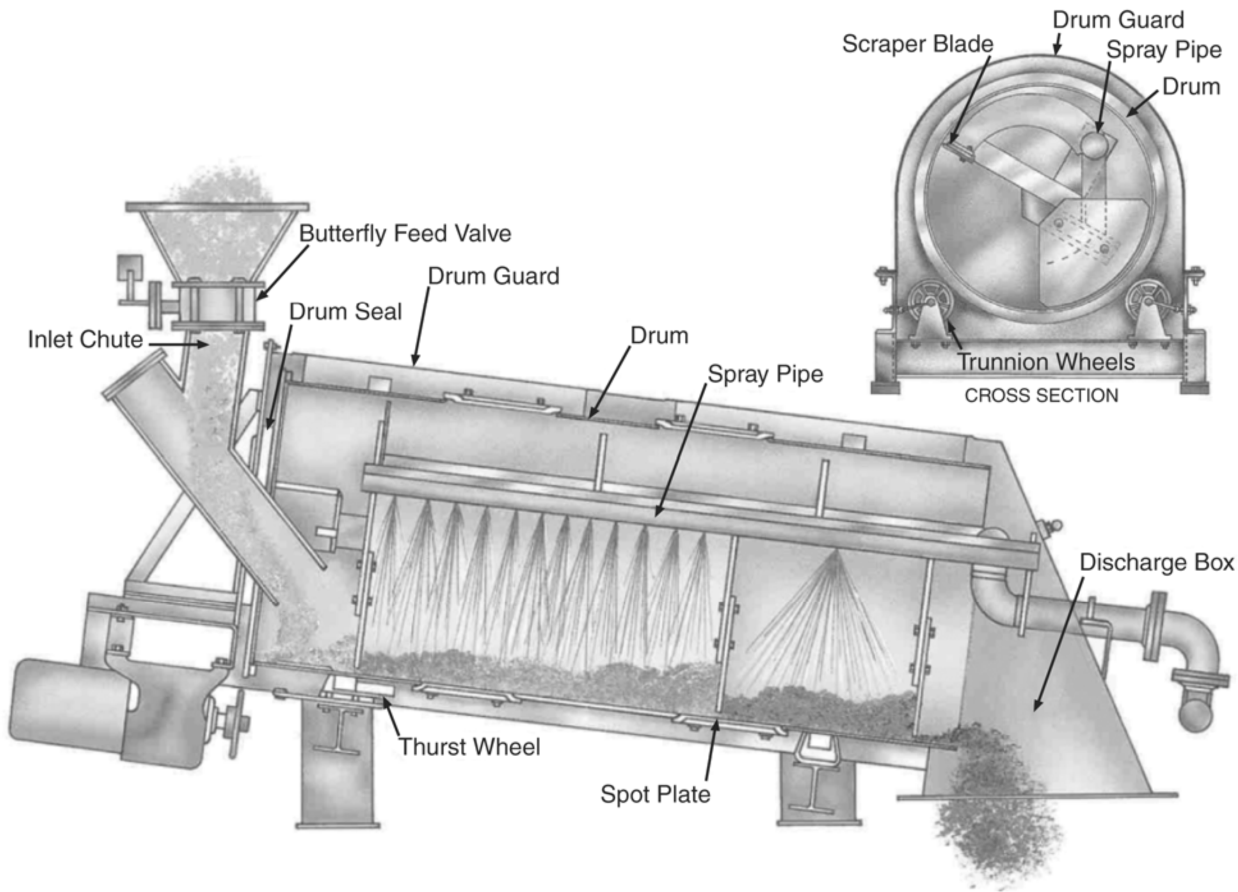


Figure 2-20
Rotary Unloader

Courtesy of United Conveyor Corporation

2.3.18 Relief Door

A vacuum/pressure relief door is a device installed on enclosed silo roofs to protect the silo from excessive positive or negative pressures that can be encountered during filling and unloading or as a result of abnormal temperature changes. It is designed to relieve a silo from overpressurization or high vacuum conditions by admitting or expelling air from silo. It is typically supplied with a hinged cover that enables accessibility into the silo (when proper precautions have been taken). Many relief doors are equipped with a replaceable diaphragm. Figure 2-21 illustrates a relief door installed on a silo rooftop.

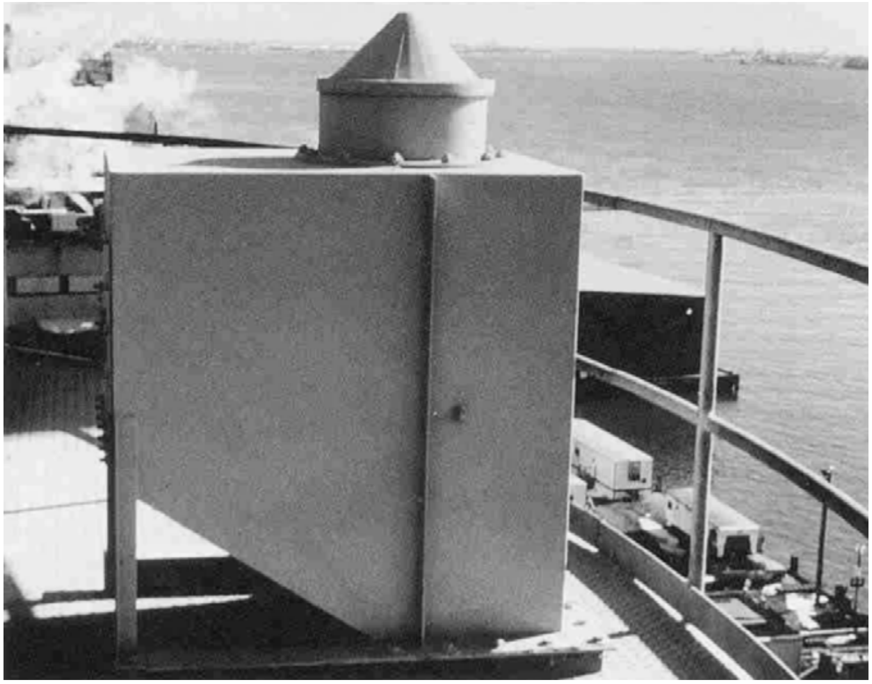


Figure 2-21
Relief Door

Courtesy of United Conveyor Corporation

2.3.19 Rotary Feeder

A rotary feeder is used to regulate the flow rates of dry, solid, free-flowing material from one chamber to another and to provide a positive shut-off when the feeder is not operating. One use is to control ash flow into a pugmill unloader, particularly when more than one type of ash is stored in the silo. It can also be used to feed material into a pneumatic conveying system. The main operational components of a rotary feeder are a shoe and multiple pocket rotors enclosed in a housing, with the rotor being chain driven by a gear motor. The size of the rotor pockets and the speed at which the rotor is driven determine the material flow rate.

The rotary feeder should be designed to provide a positive seal between rotor and shoe. Many are equipped with inspection ports that permit checking alignment and initial rotor and shoe clearances. In some designs, the rotor unit can be easily removed without removing the feeder housing from its mounting. Flanged ball bearings are often located outside the unit and include grease seals. Some include stuffing boxes with lantern and packing rings that prevent grit or gases from leaking around the shaft.

2.3.20 Silo Aeration Blower

Silo aeration blowers supply air to storage silo air gravity conveyors and discharge adapters in order to ensure that the material is fluidized and free flowing for silo unloading purposes. The aeration air is typically heated by a circulation heater installed downstream of the blowers.

2.3.21 Cut-Off Gate

The cut-off gate is a maintenance isolation gate, typically installed between a precipitator or baghouse hopper and related equipment such as a material handling valve. Its primary function is to isolate equipment requiring maintenance but still enable the system to operate. It includes a slide plate that is normally open but can be readily shifted to the closed position. Some designs permit the removal of downstream equipment after the gate has been closed without disturbing the gate itself. This feature is especially beneficial when the hopper above the gate still contains material.

2.3.22 Vent Filter

A vent filter is a bag filter mounted over an opening on an ash storage silo, which typically vents to the atmosphere. It filters out dust from displaced air exiting the silo. The bag filter is sized to simultaneously handle all potential incoming air sources. Typically, the filter bags are “jet-pulse” cleaned one row at a time by dry compressed air that is controlled by a solid-state timer. Silo vent filter bag cleaning is typically continuous. When the vent filter is equipped with additional instrumentation, bag filter cleaning can be initiated on demand based on dust loading.
Figure 2-22 illustrates a typical vent filter configuration.

Figure 2-22
Vent Filter

Courtesy of United Conveyor Corporation

3
PREVENTIVE MAINTENANCE FOR FLY ASH SYSTEM COMPONENTS

3.1 General Guidance

The following sections provide an overview of the various types of maintenance activities that can be performed on the fly ash conveying system or a particular system component.

3.1.1 Preventive Maintenance

Preventive maintenance (PM) tasks are performed based on a time or interval to avoid catastrophic equipment failure. PM performs maintenance tasks on a planned rather than reactive basis and avoids the losses associated with unplanned downtime. The penalty of PM is that some tasks are performed that are unnecessary and costly.

The following subcategories of PM are based on scheduling of the actions:

- Grace Period PM. Any PM task that is to be performed after its original due date but before the late date for that activity. Normally, this time period (due date to late date) is an additional 25% of the original schedule interval for the PM task. No engineering evaluation is required. The grace period is provided as reasonable flexibility to allow for alignment with surveillance activities and functional equipment group bundling and to better manage the use of station resources.
- Deferred PM. A PM task that exceeds its original late date with an approved engineering evaluation determining the acceptability for extension to a new due date, before the original late date is exceeded.
- Delinquent (Overdue) PM. A PM task that exceeds its late date (grace period) without an approved extension or deferral.

The distinction between predictive maintenance and periodic maintenance is presented in the following subsections.

3.1.1.1 Predictive Maintenance

Key Technical Point

Predictive maintenance tasks are performed based on equipment condition. Predictive maintenance relies on technologies to determine the current condition of the equipment so that only the required maintenance is performed before equipment failure.

Examples of predictive maintenance tasks include the following:

- Vibration analysis for all rotating equipment
- Thermography for temperature surveys on electrical equipment, leak detection, overheating, and so on
- Oil analysis (tribology) to determine the condition of the equipment and the lubricant
- Electrical testing for motor and generators

3.1.1.2 Periodic Maintenance

Key Technical Point

Periodic maintenance consists of time-based PM actions taken to maintain a piece of equipment within design operating conditions and to extend its life.

Periodic maintenance can be performed to prevent breakdown and can involve servicing such as lubrication, filter changes, cleaning, testing, adjustments, calibrations, and inspections. Periodic maintenance can also be initiated because of the results of predictive maintenance, vendor recommendation, or experience. Examples of periodic maintenance tasks include the following:

- Scheduled valve repacking because of anticipated leakage based on previous experience
- Replacement of bearings or pump realignment as indicated from vibration analysis and/or lubrication oil analysis
- Major or minor overhauls based on experience factors or vendor recommendations
- Instrument calibrations that are not part of a routine surveillance

3.1.2 Corrective Maintenance

Key Technical Point

Corrective maintenance tasks are generated as a result of equipment failure. Corrective tasks are generated when equipment is purposely operated to failure and also when equipment failure is not desired or planned. It is the most basic form of maintenance and also the most expensive. Most plants are moving away from corrective maintenance but a portion of maintenance will always be performed as a result of equipment failure.

As a rule, if the specific component requiring maintenance is substantially degraded (for example, packing or bearing degradation) or failed, the action required to repair it is classified as corrective maintenance.

To be considered corrective maintenance, the component must have failed such that it cannot meet its intended functions, or for degradation identified during PM, the component will reach this state before the next scheduled PM interval. There might be cases where corrective maintenance could include standing PM orders or procedures that are specifically invoked to correct anticipated component degradation. If the degradation does not meet these criteria, it should be considered elective maintenance.

A component should be considered failed or significantly degraded if the deficiency is similar to any of the following examples:

- It is removed from service because of actual or incipient failure.
- It exhibits significant component degradation that affects system operability. The component might be determined operable by engineering assessment, but the degradation is significant and requires immediate corrective action.
- It creates the potential for rapidly increasing component degradation.
- It releases fluids that create significant exposure or contamination concerns. Minor leaks that can be controlled and managed by simple drip catch containments would not be included here.
- It adversely affects controls or process indications that directly or indirectly impair operator ability to operate the plant or that reduce redundancy of important equipment.
- It exhibits significant component degradation identified from the conduct of predictive, periodic, or PM which, if not resolved, could result in equipment failure or significant additional damage prior to its next scheduled PM period.

Detailed guidance regarding the repair of fly ash system components is provided in Section 5, “Removal from Service and Repairs.”

3.2 Fly Ash System Component Maintenance Guidance

Table 3-1 summarizes guidance for performing PM on the components typically installed in fly ash conveying systems. The table provides a listing of the various components, the recommended PM activities (such as tests, inspections, parts replacements, and refurbishment), and the frequency at which these maintenance activities should be performed.

Table 3-1
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Abrasion-resistant pipe and fittings	Inspect pipe and fittings for cracks and holes. Inspect sleeve couplings, adapters, and expansion joints for looseness, leakage, or wear. Check for sleeve couplings that may have shifted. If so equipped, verify that all clamps and expansion joints are functioning properly. Check for defective pipe supports so the pipe is resting on every pipe support in the system.	Monthly
	Check pipe for internal wear and rotate if necessary. If so equipped, inspect fittings with replaceable wearbacks and periodically reverse them.	Annually
Air gravity conveyor	Check all air piping connections. Check that air supply isolation valves are fully open. Check air supply pressure.	Monthly
	Monitor leaks, slide wear, inlet and outlet manifolds, nozzle openings, and spillage.	Quarterly
Airlock valve	Check for smoothness and completeness of operation. Inspect gasket areas for leakage indicated by hissing sounds or material blowing out. Check all air connections. Check actuating air and aeration air pressure. Check electrical connections to the solenoid valves.	Daily
	Check equalization. Check operational sequence of the gates on the air lock valve. The top gate opens for a preset time period. When the top gates closes, the equalizer valve shifts, and the bottom gate opens for a preset time, as determined by the air lock control logic. Check that aeration at the top gate is continuous. (The air lock valve chamber should never fill closer than 8 in. to the equalizer connection.) Check gate operation and condition.	Semiannually
	Grease seal gate shaft and bushing assembly. Lubricate gate arm spring cavity of bottom gate. Coat gate shaft. Grease gate bushing housing fitting.	Quarterly After gate reassembly After shaft reassembly Weekly

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Ash storage silo	Inspect for buildup of fly ash. Check for outlet port wear (normally lined). Check for wear of aeration pads. Inspect for corrosion of steel structure or cracking of concrete cylinder. Perform level indication testing.	Annually
Ash transfer bin	Inspect for buildup of fly ash. Check for outlet port wear. Inspect for corrosion of steel structure. Perform level indication testing, if applicable.	Annually
Collector and filter	Check unit differential pressure.	Daily
	Check timer and solenoid valves for functionality. This typically is verifying uniform time intervals between blasts.	Weekly
	Lubricate fan, rotary valve, and screw conveyor. Check seals on rotary valve and screw conveyor for dust loss.	Monthly
	Inspect bags for “soft to hard” conditions and uniform tightness of clamps. On top access units, check for dust accumulation in clean air plenum. Inspect collector for excessive corrosion, pitting, and cracking.	Quarterly
Dense-phase vessel	Check for smoothness and completeness of operation. Inspect gasket areas for leakage indicated by hissing sounds or material blowing out. Check all air connections. Check actuating air and aeration air pressure. Check electrical connections to the solenoid valves.	Daily
	Check equalization. Check operational sequence of the gates on the airlock valve. The top gate opens for a preset time period. When the top gates closes, the equalizer valve shifts, and the bottom gate opens for a preset time, as determined by the airlock control logic. Check that aeration at the top gate is continuous. (The air-lock valve chamber should never fill closer than 8 in. to the equalizer connection.) Check gate operation and condition.	Semiannually

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Dense-phase vessel (cont.)	Grease seal gate shaft and bushing assembly.	Quarterly
	Lubricate gate arm spring cavity of bottom gate.	After gate reassembly
	Coat gate shaft.	After shaft reassembly
	Grease gate bushing housing fitting.	Weekly
Dry dust unloader	Visually inspect the equipment for damage or wear. Inspect all warning and caution stickers and placards for legibility or damage. Replace any that are missing or cannot be read. Test high-level/auto-raise probes. During operation, observe the equipment for abnormal behavior, malfunction, or damage. Ensure that the equipment is stored properly at the conclusion of loading operations.	Daily
	Inspect the lifting cables, outer sleeve, discharge, and main pan assembly for damage or wear. Check full-up and full-down limits for function and position. Check the function of the slack cable switch by lifting the discharge while the spout is being moved downward. Check to ensure that controls and PLCs register the limits as they are functioned.	Weekly

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Dry dust unloader (cont.)	Lubricate the shaft bearings and any external friction points with a good-quality lithium-based grease. Lubricate any optional equipment that requires lubrication. The cable sheaves contain oil-impregnated bronze bushings and do not require lubrication. However, a small amount of grease or spray lubricant may help to extend the bushing life. Inspect drive couplings, shafts and keys, lifting pulleys, and cable sheaves for wear and damage or missing parts. Inspect for fluid leakage around shaft seals and on reducers and motors. For rotary limit switches, inspect the drive chain for wear, clean off any dirt or debris, and lubricate it with a quality nondetergent oil. Measure the spout limits for accuracy and adjust the switch as necessary. Inspect all electrical connections and conduits for damage or improper installation. Clean any product or dust buildup from the entire spout assembly by sweeping or washing, as needed. Use a warm mild detergent solution for cleaning. Do not use extreme heat or pressure. Do not use any harsh chemicals or abrasives.	Monthly
	Inspect the cones and cone harness for wear, misalignment, or damage. Raise the spout to the full-up position, and disconnect the top sleeve section from the main pan. Lower the spout to the full-down position, and inspect the cones and cone harness. Raise the spout to the full-up position and re-clamp the sleeve. Inspect the inlet for wear. For air vibrators, inspect the solenoid and valve assembly for damage. Remove the exhaust mufflers and clean out any debris or dirt that may have accumulated inside. Inspect electrical conduits and connections for security or damage.	Quarterly
	Inspect all electrical equipment for moisture, corrosion, or arcing contacts. Clean any dust or debris out of all electrical enclosures. Lubricate the motor bearings with a good quality lithium-based grease. Change the gear reducer oil according the manufacturer’s instructions.	Semiannually

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Dry dust unloader (cont.)	Check all hoses, conduits, and cables for dry rot, cuts, wear, or abrasion. Inspect all hose clamps, fittings, restraints, and terminations for rust, corrosion, and wear or damage. Service the gear reducer according to the manufacturer's instructions.	Annually
Equalizer valve	Check for smoothness and completeness of operation. Check piston rod, clevis rod, linkage, crank arm, and pivot pins for scoring or wear. Check for leakage, especially from the top cover, gland packing, and loose or missing fasteners. Check air supply and electrical connections to the solenoid valve.	Weekly
	Check equalizer valve to ensure that each port seals properly. The gate should form an airtight seal with the valve seat. Observe the condition of visible seat surfaces and the backside of the gate. The gate should not show radial gouges, which would indicate leaking, or have sections missing. Minute streaks running along arcs are acceptable, provided they do not exceed 0.010 to 0.015 in. in depth. Check valve mechanism for operation, wear, and distortion. Air cylinder cushions should be adjusted to alleviate slamming at the ends of the stroke. The valve should stroke completely in one direction in approximately half a second. If there is any chattering or uneven stroking of the gate, gate and seat may be worn out and may need replacement. Check for material accumulation and/or wear in the valve body and piping ports. Check actuating air pressure and cylinder operation.	Semiannually
	Grease seal gate shaft and packing assembly.	Weekly
	Thoroughly clean valve interior and equalizing piping of material accumulation. Check and clean all moving parts.	Annually

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Air compressor Fly ash transport blower Hopper aeration blower Fly ash vacuum pump Silo aeration blower (Note 1)	Total closure valve lubrication. This task is directly focused on preventing diaphragm wear and failure from lack of lubrication. External visual inspection. External visual inspection is performed to identify the following: • Leaks of oil, cooling water, process air, or control air • Proper oil level and drip rate to the cylinders • Loose, damaged, or missing fasteners and other parts • Crushed oil or air lines • Loose mounting bolts • Worn pulleys or drive belts • Proper lubrication of couplings • Blocked or broken air filters	Monthly
	Oil analysis. Oil sampling and analysis is particularly directed at causes of bearing wear, wear on journals, and scoring of the shaft, as well as monitoring the quality and proper type of oil.	Semiannually
	Overhaul. The most important item that drives an overhaul is inspection of the degree of wear on piston rings, liners, and head valves. Overhaul can be important because it provides the only opportunity to observe some types and locations of degradation. Overhaul is the only task available to: • Observe the condition of the shaft, crosshead, and connecting rods. • Check for inadequate disk clearance in the total closure and relief valves. • Observe failed tubesheet baffles. • Pressure test or perform eddy current testing on cooler tubes. • Check alignment. • Check the torque on mounting bolts.	Annually

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Air compressor Fly ash transport blower Hopper aeration blower Fly ash vacuum pump Silo aeration blower (Note 1) (cont.)	Internal Inspection. The internal inspection is particularly focused on an inspection of the condition of the inlet and outlet head valves and check valves. This also provides an opportunity to inspect the condition of the piston rings and liner by inserting a feeler gauge into the space between them. The diaphragm of the total closure valve should be inspected to ensure that it is being properly lubricated. Functional Tests. The functional test is a start/load test conducted as part of a post-maintenance test on the equipment to verify operability and readiness for return to service. The functional test should be performed when returning powered equipment to service. The test should be performed according to startup operational procedures, and conducted under closed valve conditions with suitable instruments to determine performance.	As needed
Hydraulic vacuum device	Check operator's vacuum records for trends that may indicate decreased efficiency and possible wear or damage.	Each shift
	Check operating water pressure. Check for leaks. Check for loose or missing fasteners. Check seals, gate, and casing wear.	Weekly
	Remove access covers and check ejector head for foreign material. Check original dimension of the nozzle tip inside diameter. Check nozzle tips for excessive wear by inserting a rod or drill bit that fits, and comparing the diameter with the original dimension. Any nozzle tip exceeding the original dimension by 10% should be replaced.	Quarterly
	Disassemble component and check for wear. Check inlet liner for excessive wear. It should be replaced if the wall thickness has been reduced to half of the original thickness.	Semiannually
	Periodically clean any foreign material out of the ejector head. Remove the access covers and wash out.	Quarterly
Material handling valve	Check for smoothness and completeness of operation. Check for leakage indicated by a hissing sound, especially from the gland packing, and the end covers and its fasteners. Check for loose or missing fasteners.	Weekly

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Material handling valve (cont.)	Check and tighten packing gland. Check actuating air pressure and cylinder operation. Check air supply connections to the solenoid valve. Check electrical connections to the solenoid valve, and if so equipped, the proximity switches. Check metering device setting, if so equipped.	Monthly
	Check for material accumulation in the valve, especially on the slide gate and in the slide gate tracks. Check condition of slide gate and valve seat. Check condition of air inlet check valves. Check condition of metering device assembly, if so equipped.	Semiannually
	Thoroughly clean valve interior of material accumulation.	As needed
Pugmill unloader (Notes 2 and 3)	Check for smoothness and completeness of operation. Check for material and water leakage at shaft seals. Check for lubricant leakage at shaft seals of bearings, gear casing, and (motor) reducer. Check gear case lubricant level. Check for loose or missing fasteners. Check for loose or missing covers and guards. Lubricate bearings.	Weekly
	Inspect mixing chamber interior for foreign and caked material. Check nozzles for proper spray pattern and plugging. Inspect paddles for wear. Inspect V-belts for wear and proper tension. Inspect condition of gear case lubricant. Check electrical connections to motor and speed switch.	Monthly
	Check for foreign material jammed between paddles or shafts. Check for loose or misaligned paddles. Check for loose end shaft to paddle shaft connection. Check for binding caused by ash or sludge in the gear case. Check spur gears for wear and misalignment. Check bearings for wear and misalignment. Check drive coupling for wear or damage. Check V-belt tension. Replace spur gear lubricant.	Annually
	Lubricate drive unit.	Per manufacturer's recommendations.

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Pugmill unloader (Notes 2 and 3) (cont.)	Remove nozzles and clean thoroughly. Flush out the nozzle header. Check and clean all moving parts. Thoroughly clean the interior of the gear case when changing oil.	As needed
Relief door	Check for excessive wear on casing and gasket seals. Check for product buildup or corrosion of manway. Inspect base and cover for corrosion pitting.	Monthly
	Check for operability of vacuum spring, spring retainer, and spring retainer nut. Check all pins for a consistent fit and other parts for corrosion, looseness, and thread quality. Test each cam set, locked down on cover. Clean and remove foreign material that has coated any surface in the pressure and vacuum disk areas. Inspect spring rod guides for surface condition, straightness, and tightness into the pressure disk, vacuum disk, and cover. Check all springs to verify that they can carry the necessary load. Dimensionally inspect dome for holes or openings where moisture may enter, and concentricity to cover.	Quarterly
	Perform field dynamic test. Remove hood for access to pressure and vacuum disks. With both hands on opposite sides of pressure disk, exert force to cause pressure and vacuum disks to open. All rods and springs should move evenly. If they do not operate smoothly, recheck spring lengths, and check rod surfaces for binding.	Semiannually
Rotary feeder	Lubricate shaft bearings and roller chains.	Daily
	Check for smoothness and completeness of operation. Check for material leakage. Check for loose fasteners or covers. Plough inspection with casing, drive, limits, and sealing devices.	Weekly
	Check clearance between rotor and shoe. Check electrical connections to drive unit and limit switch.	Monthly
	Check and clean moving parts.	As needed

Table 3-1 (cont.)
Recommended Preventive Maintenance for Fly Ash System Components

Fly Ash System Component Name	Preventive Maintenance Activities	Frequency
Silo aeration blower	Performance test under closed valve with suitable instruments to determine performance. Water coolers, air receivers pressure testing, oil changes, filters, V belts, greasing.	Depending on media normally every 3, 6 months and yearly
Cut-off gate segregating valve	Check for smoothness and completeness of operation. Check for leakage indicated by a hissing sound, especially from the end cap, access covers, and loose or missing fasteners. Check for loose or missing fasteners.	Weekly
	Check valve seal. With slide gate closed and system vacuum producer on, remove pipe plug in the end cap. Excessive air flow through the hole indicates a bad seal and probably a worn slide gate and/or seal. Check actuating air pressure and cylinder operation. Check air supply and electrical connections to solenoid valve and electrical connections to proximity switches.	Monthly
	Check condition of slide gate and valve seats. Check for material accumulation, especially on the slide gate and in slide gate tracks. Check gaps for proximity switches.	Semiannually
	Thoroughly clean valve interior of material accumulation.	As needed
Vent filter	Check timer and solenoid valves for functionality. This typically is verifying uniform time intervals between blasts.	Weekly
	Lubricate fan, rotary valve, and screw conveyor. Check seals on rotary valve and screw conveyor for dust loss.	Monthly
	Inspect bags for “soft to hard” conditions and uniform tightness of clamps. On top access units, check for dust accumulation in clean air plenum.	Quarterly

Notes:
1. The size and type of blower/compressor will vary depending on the particular design of each fly ash conveying system and the application within each system. The PM guidance provided in this table is generic to most types of blowers/compressors installed in fly ash conveying systems and is based on the guidance provided in the EPRI report *Compressed Air System Maintenance Guide* (1006677). This report can be referenced for additional details, and should be used in conjunction with the PM recommendations provided by the equipment manufacturer for the actual equipment installed.
2. Additional guidance regarding the PM of couplings is provided in the EPRI report *Flexible Shaft Couplings Maintenance Guide* (1007910).
3. Additional guidance regarding the PM of gearboxes is provided in the EPRI report *Gearbox and Gear Drive Maintenance Guide* (1009831).

4
PREVENTIVE MAINTENANCE BASIS

It is the intent of this section to establish a PM Basis document for ash handling and conveyance systems.

4.1 Background

Many power plants are in the process of reducing PM costs and improving equipment performance by matching PM tasks with the functional importance of the equipment. For this to succeed, utilities require information on the most appropriate tasks and task intervals for the important equipment types, while accounting for the influences of functional importance, duty cycle, and service conditions.

An early approach to optimizing PM activities was the use of reliability-centered maintenance (RCM). RCM was developed in the 1960s by the commercial airline industry to apply reliability concepts to maintenance and the design of maintenance programs. The RCM approach to preventing equipment failure is to perform maintenance tasks that are specifically aimed at preventing component failure mechanisms from occurring. Many nuclear power plants used the RCM process to improve their PM programs.

In 1991, the Nuclear Regulatory Commission issued 10CFR50.65, “Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” also called the Maintenance Rule. In brief, the Maintenance Rule required the nuclear power plants to develop a reliability and availability monitoring program for the systems, structures, and components considered to be within the scope of the rule. The monitoring part of the rule included determining the effectiveness of the maintenance performed on the components. In addition, the Maintenance Rule required the utility to evaluate industry operating experience and to use that experience when modifying the maintenance program. When maintenance practices have been changed, the most common action is to modify the PM tasks for the components.

Initially, PM tasks were assigned based on vendor recommendations and plant experience. In modifying or optimizing the preventive maintenance tasks, one vital piece of information was missing—the time to failure for the components. Because the time to failure was not known, it was difficult to justify the PM task intervals. Also missing was the understanding of the factors that influence the progression of the degradation mechanisms for the component.

As a result of the need to comply with the Maintenance Rule and to optimize the PM tasks for more effective maintenance, the PM Basis project was proposed by EPRI. The PM Basis objectives were the following:

1. To provide a summary of industry experience that the PM tasks and task intervals were based on
2. To establish the relationship between the degradation mechanism, the progression of the mechanisms to failure, and the opportunities available to discover the failure mechanisms before component failure occurred

During the 1996–1998 timeframe, 39 PM Basis documents were developed for major components in the nuclear power plants. The components included various style valves, switchgear, motor control centers, motors, pumps, compressors, HVAC (heating, ventilation, and air conditioning) components, inverters, batteries, relays, heat exchangers, turbines, transformers, and I&C (instrumentation and control) components. The PM Basis documents can be found in the EPRI report *Preventive Maintenance Basis Volumes 1–38* (TR-106857) [18].

Currently, there are over 73 component types in an electronic PM database. The database can be accessed by logging onto and searching for "PMBD: Preventive Maintenance Basis Database, Version 5.1.1 (PMBDv5.1.1), 1010919, 2004." The product can be downloaded from www.epri.com; however, it is best to order the CD from the EPRI Orders and Conferences Center at 1-800-313-3774 (press 2).

Although fossil power plants do not have the same regulatory requirements as nuclear power plants, the establishment of the PM Basis for critical components provides valuable information for optimizing maintenance programs.

The next step in the development of this PM Basis document is an additional review with plant personnel. The PM tasks are further analyzed for criticality, condition monitoring options, and other parameters before being added to the EPRI PM database.

The information used in the development of the PM Basis was gathered from the manufacturer, industry literature, and input from utility maintenance personnel. The following is a description of the tables generated by the PM Basis document.

4.2 Failure Locations, Degradation Mechanisms, and PM Strategies

Table 4-1 contains the following fields of information:

Failure Locations. A list of the most common components.

Degradation Mechanisms. The cause of the component failing at the specified failure location.

Degradation Influence. Aspects of the environment, plant operations, maintenance, or design that cause the initiation of degradation processes or can affect how rapidly the degradation progresses.

Degradation Progression. Whether the degradation progress is present most of the time (continuous) or whether it would not normally be present but might exist or initiate in a haphazard (random) way.

Failure Timing. The relevant time period that the component would be free from failure.

Discovery Opportunity. Reasonable, cost-effective opportunities for detecting the failure mechanism.

PM Strategy. The choice of PM tasks where the discovery of the failure mechanism can occur.

Table 4-1
Failure Locations, Degradation Mechanisms, and PM Strategies for Fly Ash System Components

Failure Location	Degradation Mechanism	Degradation Influence	Degradation Progression	Failure Timing	Discovery Opportunity	PM Strategy
Abrasion-resistant piping	Leaking pipes from holes in pipe	Wear	Continuous	Continuous	Operations check, internal inspection	Operations check, internal inspection
		Foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection
Abrasion-resistant fittings	Leaking fittings	Wear	Continuous	Continuous	Operations check, internal inspection	Operations check, internal inspection
		Foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection
		Defective pipe supports	Random	Random	Operations check	Operations check
		Shifted sleeve couplings, clamps, expansion joints	Random	Random	Operations check	Operations check
Air gravity conveyor	Slides worn out	Wear	Continuous	Continuous	Operations check	Operations check
Airlock valve	Leaking gasket	Wear	Continuous	Continuous	Operations check	Operations check
Ash storage silo	Holes in silo	Wear	Continuous	Continuous	internal inspection	internal inspection
Ash transfer bin	Holes in bin	Wear	Continuous	Continuous	internal inspection	internal inspection

Table 4-1 (cont.)
Failure Locations, Degradation Mechanisms, and PM Strategies for Fly Ash System Components

Failure Location	Degradation Mechanism	Degradation Influence	Degradation Progression	Failure Timing	Discovery Opportunity	PM Strategy
Ash collector and filter	Filter breakdown	Wear	Continuous	Continuous	Check differential pressure	Operations check, calibration
	Damaged fan, rotary valve, and/or screw conveyor	Foreign material	Random	Random	Operations check	Operations check
	Damaged fan, rotary valve, and/or screw conveyor	Wear	Continuous	Continuous	Internal inspection	Internal inspection
	Collector holes	Corrosion	Continuous	Continuous	Internal inspection	Internal inspection
Dense-phase vessel	Leaking gasket	Wear	Continuous	Continuous	Operations check	Operations check
Dry dust unloader	Clogged spout assembly	Ash buildup	Continuous	Continuous	Operations check	Operations check
	Pan assembly damaged	Wear	Continuous	Continuous	Operations check	Operations check
	Cones and cone harness damaged	Wear	Continuous	Continuous	Operations check	Operations check
	Electrical connections—limit switches malfunctioning	Contamination	Random	Random	Operations check, calibration	Operations check, calibration

Table 4-1 (cont.)
Failure Locations, Degradation Mechanisms, and PM Strategies for Fly Ash System Components

Failure Location	Degradation Mechanism	Degradation Influence	Degradation Progression	Failure Timing	Discovery Opportunity	PM Strategy
Equalizer valve	Leakage	Wear	Continuous	Continuous	Operations check, calibration	Operations check, calibration
Blowers	Bearing failure	Lack of lubrication	Random	Random	Operations check	Operations check
	Bearing failure	Improper oil properties	Random	Random	Oil analysis	Oil analysis
	Bearing failure	High temperature	Continuous	Seasonal	Operations check, clean cooler	Operations check, internal inspection
	Piston ring, liners, head valve failure	Wear	Continuous	Continuous	Internal inspection	Internal inspection
	Blower not performing to specifications	Foreign material	Random	Random	Calibration	
Hydraulic vacuum device	Poor vacuum from thin nozzle tip	Wear	Continuous	Continuous	Internal inspection	Internal inspection
	Poor vacuum from damaged nozzle tips	Foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection
Material handling valve	Gate failure to open or close	Foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection

Table 4-1 (cont.)
Failure Locations, Degradation Mechanisms, and PM Strategies for Fly Ash System Components

Failure Location	Degradation Mechanism	Degradation Influence	Degradation Progression	Failure Timing	Discovery Opportunity	PM Strategy
Material handling valve (cont.)	Gate failure to open or close (cont.)	Wear	Continuous	Continuous	Internal inspection	Internal inspection
Pugmill unloader	Failure due to clogged nozzles	Foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection
	Failure due to paddles not functioning	Wear	Continuous	Continuous	Internal inspection	Internal inspection
Relief door	Failure to open	Damage from foreign material	Random	Random	Operations check, internal inspection	Operations check, internal inspection
	Leaking door	Corrosion	Continuous	Continuous	Operations check	Operations check
Rotary feeder	Feeder not moving ash	Wear on vanes and casing	Continuous	Continuous	Internal inspection	Internal inspection

4.3 PM Tasks and Their Degradation Mechanisms

Table 4-2 contains the PM tasks and intervals for the various components of a fly ash handing system. The PM tasks and the degradation mechanisms are listed from the previous table. The corresponding PM task interval is then given for each applicable PM task.

Table 4-2
PM Tasks and Their Degradation Mechanisms for Fly Ash System Components

Component	Location/ Degradation	PM Task and Interval			
		Calibration	Oil Analysis	Operations Check	Internal Inspection
		Annually	6 months	Daily	Annually
Abrasion-resistant piping	Leaking pipes from holes in pipe/wear			X	X
	Leaking pipes from holes in pipe/foreign material			X	X
Abrasion-resistant fittings	Leaking fittings/wear			X	X
	Leaking fittings/foreign material			X	X
	Leaking fittings/defective pipe supports			X	
	Leaking fittings/shifted sleeve couplings, clamps, expansion joints			X	
Air gravity conveyor	Slides worn out			X	
Airlock valve	Leaking gasket			X	
Ash storage silo	Holes in silo				X
Ash transfer bin	Holes in bin				X
Ash collector and filter	Filter breakdown	X		X	
	Damaged fan, rotary valve, and/or screw conveyor			X	
	Damaged fan, rotary valve, and/or screw conveyor				X
	Collector holes				X
Dense-phase vessel	Leaking gasket			X	

Table 4-2 (cont.)
PM Tasks and Their Degradation Mechanisms for Fly Ash System Components

Component	Location/ Degradation	PM Task and Interval			
		Calibration	Oil Analysis	Operations Check	Internal Inspection
		Annually	6 months	Daily	Annually
Dry dust unloader	Clogged spout assembly			X	
	Pan assembly damaged			X	
	Cones and cone harness damaged			X	
	Electrical connections—limit switches malfunctioning	X		X	
Equalizer valve	Leakage	X		X	
Blowers	Bearing failure			X	
	Bearing failure		X		
	Piston ring, liners, head valve failure				X
	Blower not performing to specifications	X			
Hydraulic vacuum device	Poor vacuum from thin nozzle tip				X
	Poor vacuum from damaged nozzle tips			X	X
Material handling valve	Gate failure to open or close/foreign material			X	X
	Gate failure to open or close/wear				X
Pugmill unloader	Failure due to clogged nozzles			X	X
	Failure due to paddles not functioning				X
Relief valve	Failure to open			X	X
	Leaking door			X	

Table 4-2 (cont.)
PM Tasks and Their Degradation Mechanisms for Fly Ash System Components

Component	Location/ Degradation	PM Task and Interval			
		Calibration	Oil Analysis	Operations Check	Internal Inspection
		Annually	6 months	Daily	Annually
Rotary feeder	Feeder not moving ash				X

4.4 Preventive Maintenance Template

The PM template in Table 4-3 summarizes the program of tasks and task intervals for the equipment type. Each plant should base its program on the manufacturers' recommendations and its own history of equipment performance. The PM template can serve as a beginning for development of a PM program for the equipment, and changes can be made as a result of feedback received during implementation of the program.

The PM template contains the following information:

- **Conditions**. Columns 1 through 8 list the 8 sets of conditions for the fly ash system components. Each column corresponds to the combined choices of critical or noncritical equipment, high or low duty cycle, and severe or mild service conditions. Time intervals for the performance of each task are entered at the intersections of the task rows and columns 1 through 8.

  The definitions of template application conditions are the following:

  - Critical
    - Yes. Functionally important; that is, risk significant, required for power production, safety related, or other regulatory requirement.
    - No. Functionally not important, but economically important for any of the following reasons: high frequency of resulting corrective maintenance, more expensive to replace or repair than to do preventive maintenance, high potential to cause the failure of other critical or economically important equipment.
  - Duty Cycle
    - High. Frequently cycled or partially loaded during the greater part of its operational time.
    - Low. Fully loaded during the greater part of its operation time.

- Service Condition
  - Severe. High or excessive humidity, excessively high or low temperatures, excessive temperature variations, excessive environmental conditions (such as salt, corrosive, spray, steam, or low-quality suction air), high vibration.
  - Mild. Clean area (not necessarily air conditioned), temperatures within OEM specifications, normal environmental conditions.

- **PM Tasks**. The PM tasks provide a cost-effective way to intercept the causes and mechanisms that lead to degradation and failure. The PM tasks can be used to develop a complete PM program or to improve an existing program. These tasks are intended to complement and not to replace the PM recommendations given by the manufacturer. A brief description of the PM tasks follows the PM Template.

Table 4-3
PM Template for Fly Ash System Components

Conditions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Critical: Yes	X	X	X	X				
No					X	X	X	X
Duty cycle: High	X		X		X		X	
Low		X		X		X		X
Service condition: Severe	X	X			X	X		
Mild			X	X			X	X
PM Tasks	**Frequency Interval**							
Calibration	1 Year	1 Year	1 Year	1 Year	2 Years	2 Years	2 Years	2 Years
Oil analysis	6 Months	6 Months	6 Months	6 Months	1 Year	1 Year	1 Year	1 Year
Operations check	Daily	Daily	Daily	Daily	Weekly	Weekly	Weekly	Weekly
Internal inspection	1 Year	1 Year	1 Year	1 Year	2 Years	2 Years	2 Years	2 Years

4.5 Description of Preventive Maintenance Tasks

The following is a brief description of PM tasks used in the PM Template.

- **Calibration.** Calibration of the ash handling equipment includes the setting and verification of instruments and components. Instruments include thermocouples, resistance temperature detectors (RTDs), pitot tubes, and pressure gauges. The calibration of components includes setting the clearances and tolerances for the blowers, limit switches, equalizer valves, filters, and other equipment.
- **Oil analysis.** Oil analysis is valuable predictive maintenance technology for detecting problems in equipment before failure occurs. For the ash handling equipment, oil samples should be taken and analyzed for the blowers and any other rotating equipment. Samples should be analyzed for contamination and oil properties. The results of the oil analysis can alert personnel that bearings are failing, and plans can be made to monitor the operation of the equipment, take more frequent samples, or shut the equipment down.
- **Operations check.** Operations check includes an external visual inspection of the ash handling equipment. This includes listening for noises, smelling for smoke, checking temperatures, checking pressures, looking for leaks, and so on.
- **Internal inspection.** An internal inspection of the ash handling components is performed to determine their condition and repair or replace any needed parts. Components to be inspected include blowers, feeders, valves, unloaders, collectors, piping, fittings, silos, bins, and so on. Inspections include physical measurements, ultrasonic thickness checks, nondestructive testing, general condition assessment, checking for wear areas, checking for foreign material or debris, and so on.

5
REMOVAL FROM SERVICE AND REPAIRS

5.1 General Guidance

Figure 5-1, which is taken from the EPRI report *Facilities Maintenance Guide* (1009670), illustrates a generic process for determining whether to repair or replace a system component that is no longer performing in accordance with design requirements.

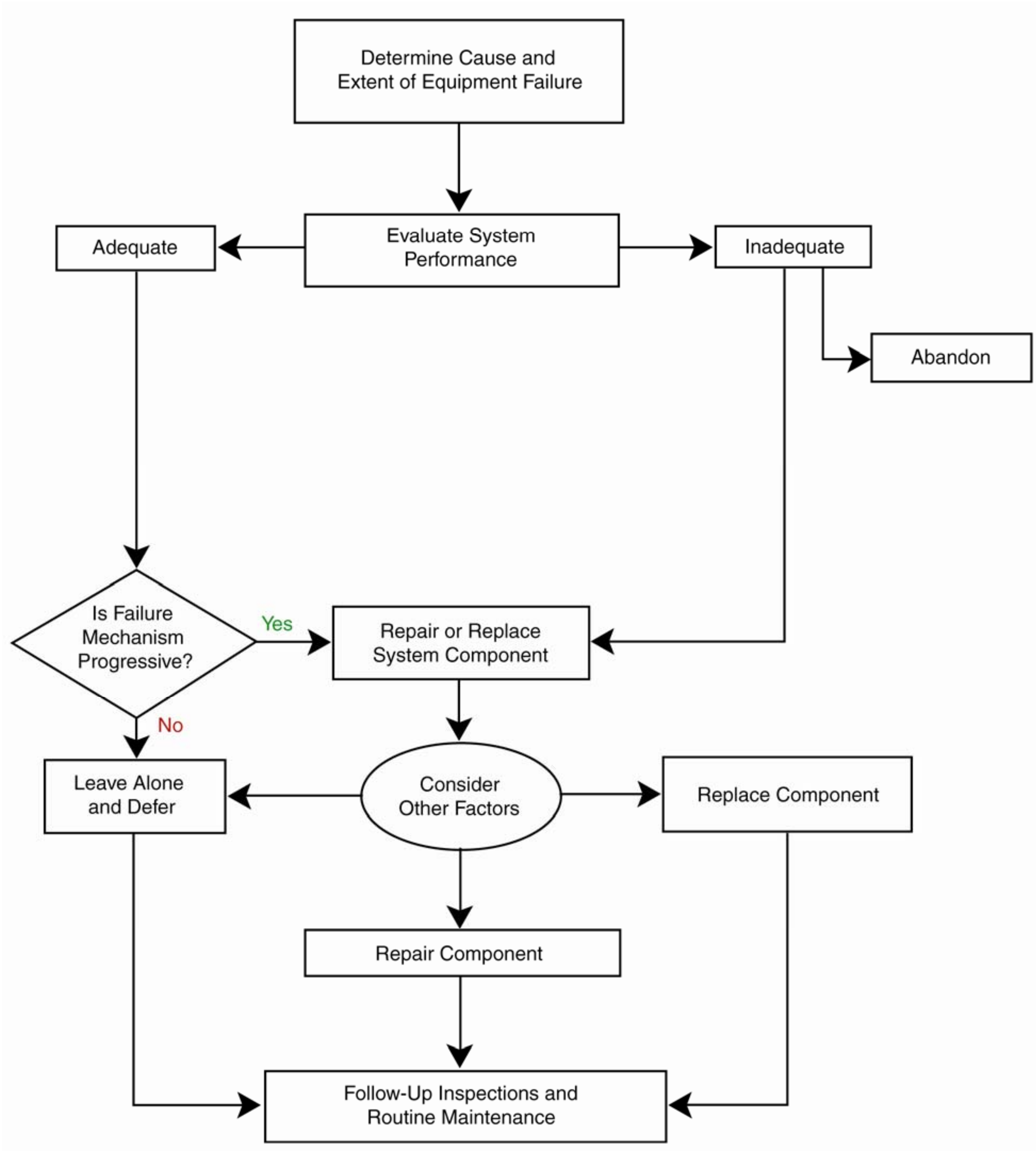


Figure 5-1
Generic Repair Versus Replace Evaluation

The question of whether to repair, replace, or defer maintenance on a system component is often a complicated one to answer. The issue is further complicated depending on whether the analysis is performed for an entire system or simply a particular component of an existing fly ash conveying system. In most cases, a thorough economic cost study is the only effective method of attaining a quantified answer.

Key O&M Cost Point

As a rule of thumb, if the repair costs 50% or less of the replacement cost, repair should be considered. If the percentage is greater, replacement is generally the best option.

This rule of thumb is generally effective if the system can be put out of service during replacement construction. Of course, options exist to either do nothing or defer the maintenance.

Figure 5-2 illustrates a number of factors that should be considered when performing a comprehensive analysis. Some of the factors are easier to quantify than others, and in some cases actual costs can be estimated. To quantify the results of the analysis, some factors can be weighted as to their relative importance in the calculation.

Because of the complexity of the analysis and the varying relevance of each factor, this report does not attempt to provide a mathematical equation for performing such a calculation. Some factors are qualitative in nature and difficult to quantify in an economic cost study.

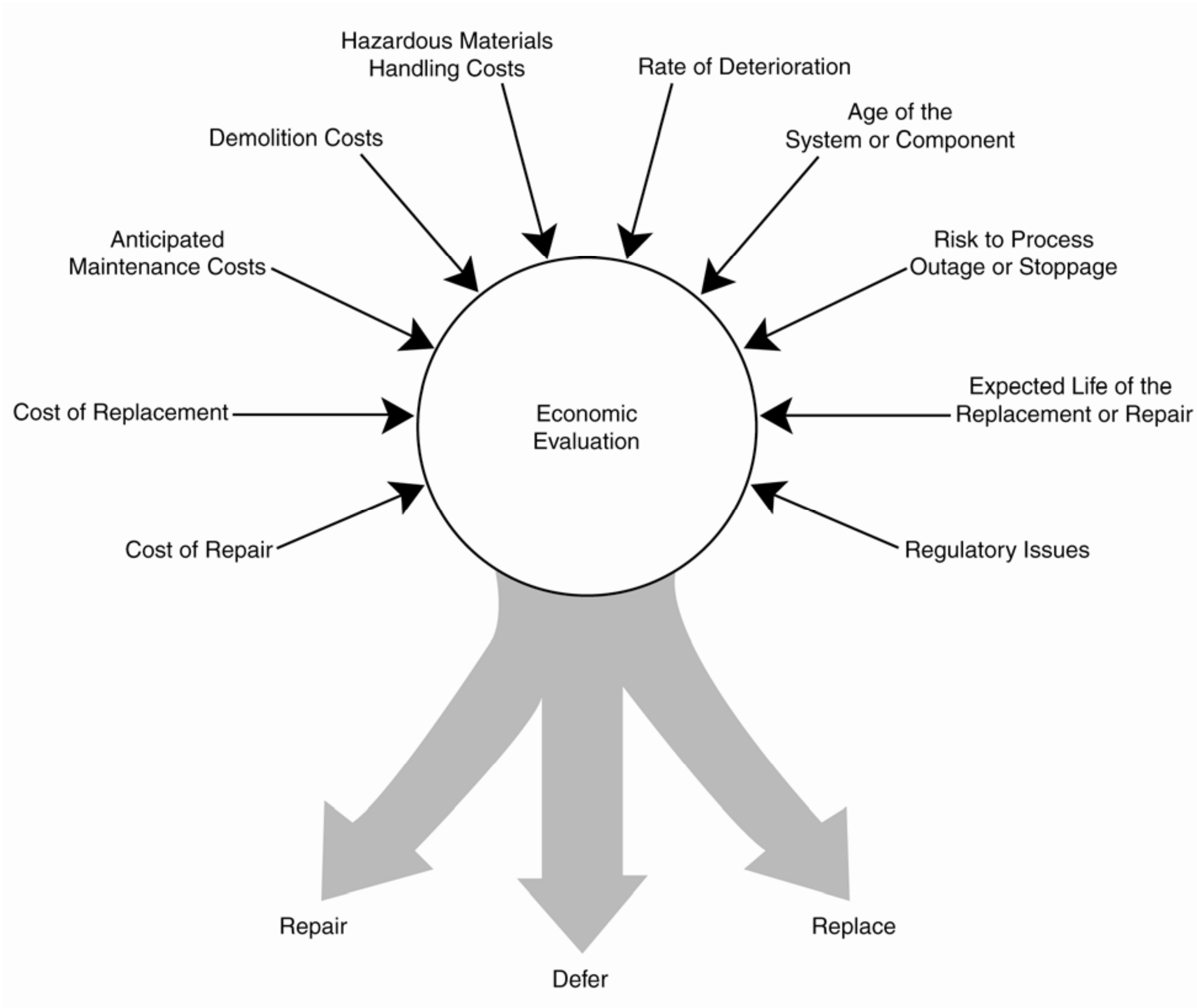


Figure 5-2
Factors Considered During the Decision-Making Process

Based on EPRI 1009670

Each factor illustrated in Figure 5-2 is described in more detail in the following subsections. This list of factors is not all-inclusive; it is provided for illustrative purposes only.

5.1.1 Quantifiable Factors for Economic Cost Study

Some factors are easier to quantify than others and in some cases costs can be estimated for each course of action. A brief description of the quantifiable factors and costs follows:

- **Cost of the repair.** One primary factor that should be considered is the cost of the repair. This cost is typically composed of the costs for materials, equipment, labor, and preparation needed to perform the repair. For the purposes of this report, this cost would not include follow-on maintenance costs associated with maintaining the repaired components over the life of the operating system.

- **Cost of replacement.** Another primary factor that should be considered is the cost of replacement. This can apply to either the entire system or a particular component under evaluation. Similar to repair cost estimates, replacement cost estimates should include the costs for materials, equipment, labor, and preparation needed to replace the existing component(s). Likewise, for the purposes of this report, this cost would not include follow-on maintenance costs associated with maintaining the replaced components over the life of the operating system.

- **Anticipated maintenance costs.** When making the decision to replace or repair a particular component, the manager should consider the anticipated maintenance costs associated with either action. Whether an item is replaced or repaired, there will be costs associated with maintaining it for some period of time. An estimation of projected maintenance costs should include the following components:

  – Maintenance equipment costs. Special equipment, tools, or both are often required to perform a repair or to replace a given item. The costs of using these items should be factored into the decision whether replace it or repair it.

  – Labor costs. The labor costs associated with projected or anticipated maintenance are important to consider because they can constitute a significant portion of the cost if the life expectancy of the operating system or component is high. Labor costs can be affected by the availability of maintenance personnel, whether special or unique skills are required, and whether the maintenance personnel are in-house or contracted.

- **Demolition costs.** In many cases, significant demolition costs are associated with a replacement that are not necessarily as important when performing a repair. Demolition costs should include costs associated with preparing the system or structure for the replacement, removing the components that have been replaced, and disposing of the waste.

- **Hazardous materials handling costs.** In some cases, costs associated with handling certain hazardous materials such as asbestos, lead paint, and hazardous chemicals should be factored into the overall cost of performing maintenance or repair on existing operating systems and their components. These costs can be so significant that the most economical option is to defer the maintenance or repair until the end of the service life of the facility.

5.1.2 Key Qualitative Factors in the Decision-Making Process

Several key qualitative factors that should be considered in the analysis are the following:

- **Rate of deterioration**. The rate of deterioration should be considered when evaluating the cost benefits of either repairing or replacing a system component. The rate of deterioration primarily impacts the urgency with which the item needs to be addressed. For an item that is failing at a slow rate, the system owner is afforded additional time to decide what course of action to take. In some cases, the rate of deterioration can be so slow that the best course of action is to defer any action until the component's condition becomes more severe. Items that are failing at a faster rate require that more prompt action be taken.
- **Age of the system or component.** The age of the operating system and its components should be factored into the evaluation for a number of reasons:
  - The older the system, the less likely it is that repairs will be feasible.
  - The newer the system, the less beneficial it is to replace the entire system and the more feasible it is to repair needed components.
  - Older systems can have a number of maintenance issues that need to be considered simultaneously. In that case, the repair or replacement costs of these multiple issues should be considered together rather than separately.
- **Risk to process outage or stoppage.** The risks associated with inadvertently interrupting the process(es) should be considered from two perspectives: short term and long term. In the short-term perspective, the system owner should consider which action—repair or replacement—would present the least risk to interrupting the processes. In some cases, a repair can be performed without any disruption to the processes, whereas a replacement can require that the process equipment be shut down until the replacement is complete. When this is the case, the system owner should also consider the cost of lost production necessitated by the replacement. In the long-term perspective, the system owner should consider the effectiveness of the maintenance activity, the component's susceptibility to failure, and the need for repeated repairs, all with respect to the risk imposed over time to inadvertently disrupting the fly ash system process.
- **Expected life of the replacement or repair.** Another factor that should be considered is the expected life of the replaced or repaired component. Regardless of what action is taken, the restored condition will not last forever. In time, the item will either have to be initially repaired, repeatedly repaired, or replaced again. The length of time until one of these follow-on activities is required will vary depending on the maintenance decisions taken now.
- **Regulatory issues.** Regulatory issues that might have arisen or new regulations that might have been enacted since the original construction of the system should also be considered when deciding the optimal maintenance action to take.

5.2 Repair and Replacement of Fly Ash System Components

Table 5-1 summarizes guidance regarding the repair or replacement of fly ash system components. The table lists the various components and indicates whether the component is typically repaired or replaced in its entirety. For those components that are repaired, the table provides guidance on whether the repair can usually be done on site or at the manufacturer's facility and the typical scope of repairs performed.

Table 5-1
Repair and Replacement Guidance for Fly Ash System Components

Fly Ash System Component Name	Repair or Replace?	Repair on Site?	Typical Scope of Repairs Performed on Component
Abrasion-resistant pipe and fittings	Replace	No	Rotate worn pipe segments or fittings. Replace worn pipe segments or fittings.
Air gravity conveyor	Repair	Yes	Replace porous stones.
Airlock valve	Repair or replace	Yes	Replace top and/or bottom gate seat. Adjust top gate spring tension. Adjust top gate actuator stops. Remove and replace top gate air cylinder. Remove and replace top and/or bottom gate shaft and bushing. Remove and replace top and/or bottom gate aeration subassembly.
Ash storage silo	Repair	Yes	Repair cracks or corroded areas by welding new plates to steel cylinder.
Ash transfer bin	Repair	Yes	Repair cracks or corroded areas by welding new plates to steel cylinder.
Collector and filter	Repair or replace	Yes	Replace filter bags (although with some applications can be laundered). Replace or repair solenoid valves with manufacturer's repair kit. Replace or repair diaphragm valves with manufacturer's repair kit. Repair rotary valves by replacing seals and blades. Repair screw conveyors by replacing V-belts and shaft seals. Repair fans by adjusting V-belt tension and replacing bearings.

Table 5-1 (cont.)
Repair and Replacement Guidance for Fly Ash System Components

Fly Ash System Component Name	Repair or Replace?	Repair on Site?	Typical Scope of Repairs Performed on Component
Dense-phase vessel	Repair or replace	Yes	Replace top and/or bottom gate seat. Adjust top gate spring tension. Adjust top gate actuator stops. Remove and replace top gate air cylinder. Remove and replace top and/or bottom gate shaft and bushing. Remove and replace top and/or bottom gate aeration subassembly.
Dry dust unloader	Repair or replace	Yes	Remove and replace motor. Remove and replace gear reducer. Remove and replace bearings. Remove and replace transfer sheave. Remove and replace limit switch. Replace self-sealing lower cone, cone seal, and sleeve (if applicable). Remove and replace sleeve guide. Remove and replace sleeve, cable, and cone.
Equalizer valve	Repair	Yes	Remove and replace valve gate and seat. Adjust gate travel location. Remove and replace gland packing rings. Remove and replace air cylinder.
Air compressor Fly ash transport blower Hopper aeration blower Fly ash vacuum pump Silo aeration blower	Repair or replace	Yes	Repairs or replacements of blower/compressors and their subassemblies should be in accordance with the respective vendor's recommendations. Repairs can range from simple replacements of worn parts and lubrication, to complete overhauls. Typical parts that may be replaced are listed as part of the troubleshooting solutions in Table 6-4 of this report.
Hydraulic vacuum device	Repair or replace	Yes	Remove and replace throat piece. Replace throat piece liner. Replace nozzle tips. Remove and replace inlet liner.

Table 5-1 (cont.)
Repair and Replacement Guidance for Fly Ash System Components

Fly Ash System Component Name	Repair or Replace?	Repair on Site?	Typical Scope of Repairs Performed on Component
Material handling valve	Repair or replace	Yes	Remove and replace slide gate and valve seat. Adjust air inlet check valves. Remove and replace air inlet valve extension spring. Replace gland packing rings. Remove and replace air cylinder. Install, remove, and replace metering device assembly.
Pugmill unloader	Repair	Yes	Replace worn nozzles. Replace worn paddles or align as needed. Replace or tighten V-belt. Replace bearings. Replace spur gears.
Relief door	Repair or replace	Yes	Remove and replace cam sets (cam, cam swivel nut, jaw end fitting, and pins). Remove and replace lid gasket and base seal gasket. Remove and replace bent or corroded rods.
Rotary feeder	Repair	Yes	Adjust rotor and shoe clearances. Remove and replace rotor assembly. Remove and replace shoe. Remove and replace bearing and shaft packing. Remove and replace shaft spacer sleeve. Remove and replace inner shaft sleeve. Adjust overload limits.
Cut-off gate segregating valve	Repair	Yes	Remove slide gate and replace seat insert. Remove and replace air cylinder. Remove, replace, and adjust proximity switch.

Table 5-1 (cont.)
Repair and Replacement Guidance for Fly Ash System Components

Fly Ash System Component Name	Repair or Replace?	Repair on Site?	Typical Scope of Repairs Performed on Component
Vent filter	Repair or replace	Yes	Replace filter bags (although with some applications can be laundered). Replace or repair solenoid valves with manufacturer's repair kit. Replace or repair diaphragm valves with manufacturer's repair kit. Repair rotary valves by replacing seals and blades. Repair screw conveyors by replacing V-belts and shaft seals. Repair fans by adjusting V-belt tension and replacing bearings.

6
FLY ASH SYSTEM AND COMPONENT TROUBLESHOOTING

6.1 System Troubleshooting

Figure 6-1, taken from the EPRI report *System and Equipment Troubleshooting Guideline* (1003093), illustrates the generic process for performing preliminary troubleshooting of a power plant system such as the fly ash conveying system. The figure emphasizes the need to define the problem, determine and validate system operating conditions, and subsequently determine whether the symptoms adversely affect system's or component's performance or reliability.

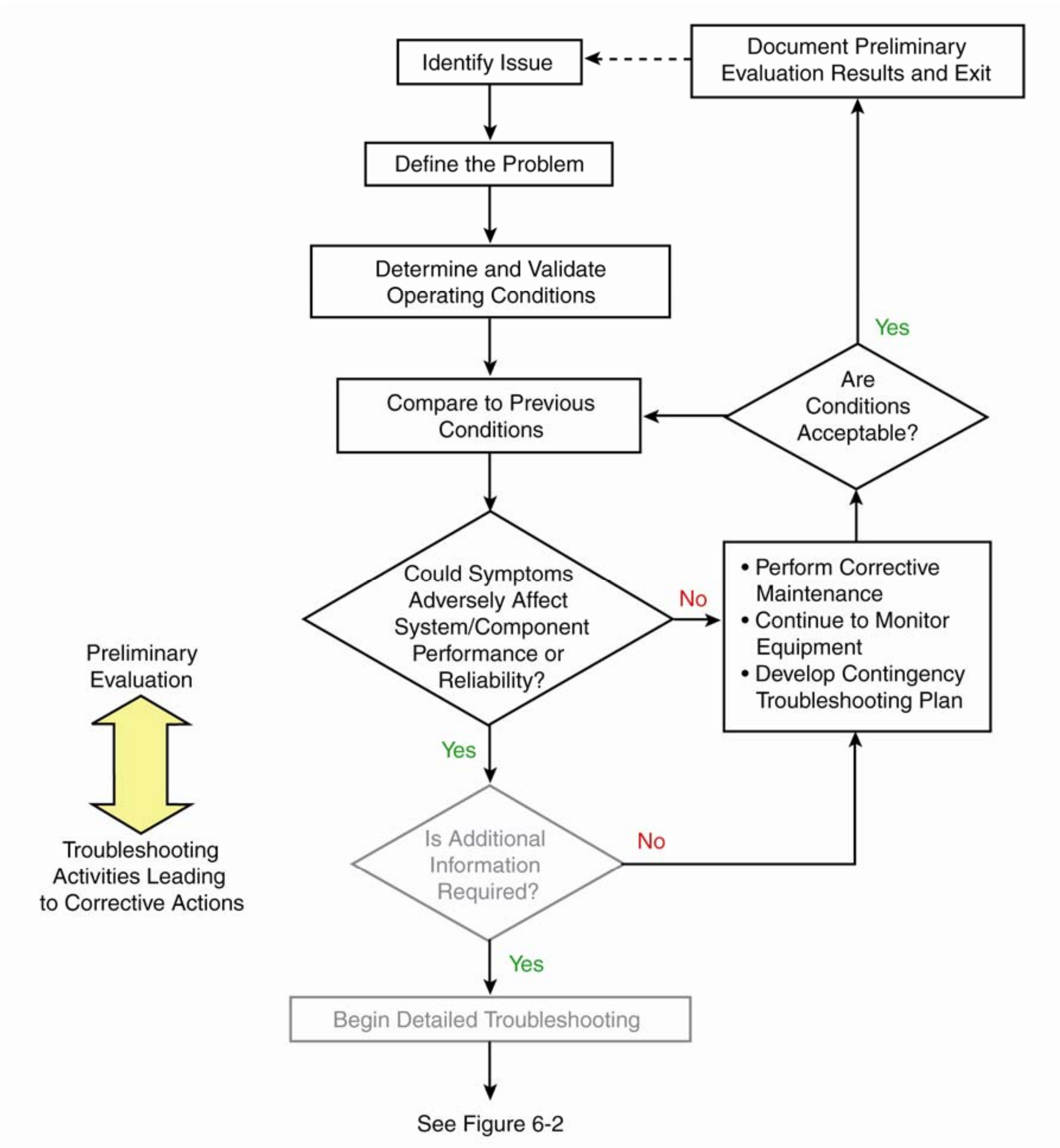


Figure 6-1
Generic Process for System Troubleshooting (Preliminary Evaluation)

Figure 6-2, taken from EPRI report 1003093, illustrates the detailed system troubleshooting process that can be undertaken to investigate the symptoms and performance problems being experienced. The figure emphasizes the need to identify failure modes, develop a troubleshooting plan (especially if the system is evaluated while on-line), identify the cause(s) of the problem, and restore system performance. Additional guidance regarding system and component troubleshooting is provided in EPRI report 1003093.

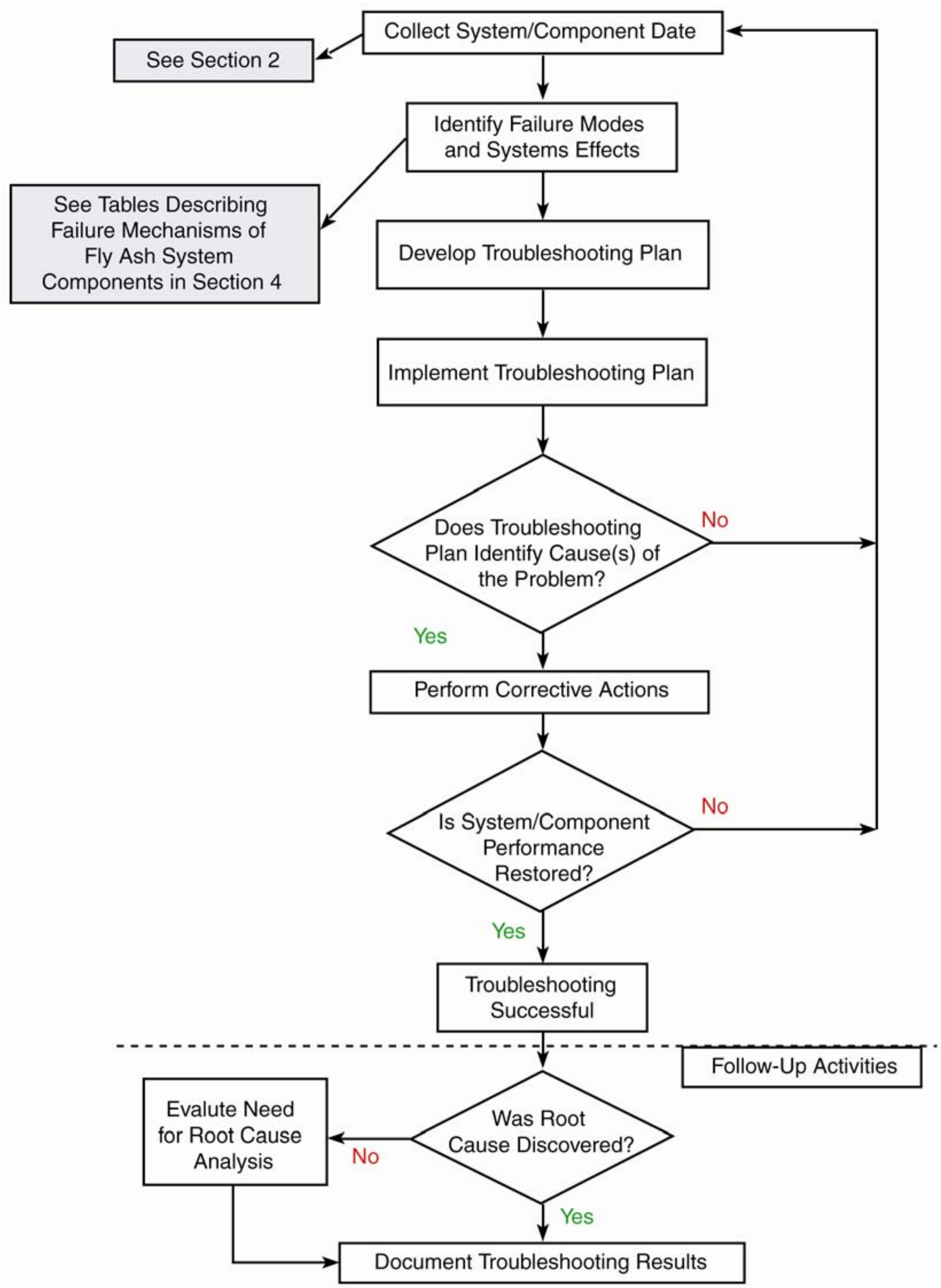


Figure 6-2
Generic Process for System Troubleshooting (Detailed System Troubleshooting)

Courtesy of EPRI 1003093

Tables 6-1 and 6-2 summarize troubleshooting guidance at a system level for the four types of system designs described in this report.

6.1.1 Pressure Conveying Systems

Table 6-1 summarizes troubleshooting guidance for fly ash pressure conveying systems. The table lists system-level failure mechanisms, potential causes of failure, and frequently used solutions to restore the system to an operational state.

Table 6-1
Recommended Troubleshooting for Pressure Conveying Fly Ash Systems

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
High level in the ESP or baghouse hoppers	Not evacuating material	Correct airlock malfunction.
Low discharge line pressure	V-belt drive failure Air lock not evacuating	Repair drive. Repair gate valves on airlock. Review for bridging in airlock.
High discharge line pressure	Faulty valve/operator in transport line Branch line plugging	Inspect and repair valve or operator. Clear transport lines.
High discharge pressure	Incorrect valve sequencing and alignment, as set by control system logic	Review timing and sequence required by manufacturer's instructions and design.
Blower failure or trip	High delta pressure, temperature, or motor current	See blower manufacturer procedures.

6.1.2 Vacuum Conveying Systems

Table 6-2 summarizes troubleshooting guidance for fly ash vacuum conveying systems. The table lists system-level failure mechanisms, potential causes of failure, and frequently used solutions to restore the system to an operational state.

Table 6-2
Recommended Troubleshooting for Vacuum Conveying Fly Ash Systems

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
High level in the ESP or baghouse hoppers	Same as pressure system	Same as pressure system.
High vacuum	Gates not opening, plugging	Repair gates. Clear plugging.
Low vacuum	Gates not closing	Repair gates.
Low vacuum	Incorrect valve sequencing, rat-holing, or broken line	Review timing and sequence required by the manufacturer's instructions and design. Clear buildup of ash if system is rat-holing; repair line or leaks.
High differential pressure trip across collector	Blinded filter bags or improper bag cleaning	Clean or replace bags; evaluate cause of bag buildup. Review cleaning cycle to determine proper timing for maximum cleaning efficiency.
Vacuum blower failure or trip	High delta pressure, temperature or motor current	See blower manufacturer procedures.

6.1.3 Vacuum/Pressure Conveying Systems

System troubleshooting for a vacuum/pressure conveying system should be similar to the guidance provided in Tables 6-1 and 6-2.

6.1.4 Dense-Phase Conveying Systems

System troubleshooting for a dense-phase conveying system should be similar to the guidance provided in Table 6-1.

6.2 Troubleshooting Components Installed in Fly Ash Conveying Systems

Table 6-3 summarizes troubleshooting guidance for the various components of a fly ash conveying system. The table lists the component type, its failure mechanisms, the causes of failure, and frequently used solutions to restore the system to an operational state.

Table 6-3
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Abrasion-resistant pipe and fittings	Decrease in system vacuum or pressure	Cracks or holes in piping. Leakage at pipe joints.	Replace cracked pipe segments. Rotate fittings and/or piping.
Air gravity conveyor	Material fails to aerate	Closed air supply isolation valve. Insufficient air supply or pressure. Leaks in air supply piping. Leaks in air gravity conveyor. Porous stones blinded.	Open air supply isolation valve. Repair leaks in air supply piping and/or air gravity conveyor. Replace porous stones.
	Porous stones blinded	Contaminated air supply. Condensation or moisture in the silo. Air supply temperature too low. Sealant smeared on stone surface during installation.	Clean/filter air supply. Adjust air supply temperature to eliminate condensation and moisture. Replace porous stones.
Airlock valve	Airlock fails to fill	Hopper above may be plugged. Top gate failure. Equalization failure. Bottom gate leakage. Aeration failure.	Unplug hopper of clogged material. Repair leakage of bottom gate. Check equalization subassemblies.
	Airlock fails to empty	Top gate leakage. Equalization failure. Foreign material in air lock. Bottom gate failure. Aeration failure.	Remove foreign material from airlock. Repair leakage of top gate. Check equalization subassemblies.
Ash storage silo	Silo leaks	Worn, corroded, or cracked cylinder.	Repair cracks or corroded areas by welding new plates to steel cylinder.
Ash transfer bin	Transfer bin leaks	Worn, corroded, or cracked cylinder.	Repair cracks or corroded areas by welding new plates to steel cylinder.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Collector and filter	Excessive pressure drop across filter bags	Inoperable differential pressure gauge.	Check the differential pressure gauge or manometer and the tubing leading to the dust collector for proper operation.
		Inadequate compressed air.	Adjust the compressed air system.
		Water or oil in compressed air.	Repair the compressed air system to ensure that air is not contaminated.
		Bags loaded with dust because:	
		Dust not discharging from the hopper	Repair dust discharge equipment or replace with higher capacity equipment, or install hopper vibrators.
		Air flow too high	Clean bags if caked; cut back on fan to prevent recurrence.
		Improper particle size and dust load	Compare dust particle size and loading with original design specification, and contact manufacturer for recommendations.
		Bags too tight	Pull bag tight around its cage and gather a small fold of material.
		Water leaks	Repair holes, cracks, or loose gaskets where water could enter.
		Condensation.	Insulate the collector and/or ductwork leading to the collector to keep surface temperatures above the dew point and prevent condensation of the filter bags.
	Extremely low pressure drop	Inoperable differential pressure gauge.	Check the differential pressure gauge or manometer and the tubing leading to the dust collector for proper operation.
		Holes in the filter bags or bags are installed incorrectly.	Repair or replace filter bags.
		Air leaks or blockage in ductwork to and from the dust collector.	Repair leaks in ducts and ensure that dampers are correctly positioned.
		Leaks in the housing.	Repair holes and cracks, and replace/tighten loose gaskets in the dust collector housing or tube sheets.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Collector and filter (cont.)	Continuous flow of dust in the clean air exhaust	Holes in the filter bags or bags are installed incorrectly. Holes in the tube sheets or loose bag cup assemblies.	Repair or replace filter bags. Repair holes and cracks; tighten bolts or bag cup assemblies (bottom bag removal only).
	Puff of dust in the clean air exhaust after each pulse (secondary dusting)	Air header pressure too high. Worn filter bags. Residual dust.	Ensure that pulsing air pressure is over 100 psig. Replace filter bags. Clean both the clean air plenum and bag/cage assemblies.
	Short filter bag life	Operating temperature too high. Incompatible material resulting in chemical degradation. Moisture content is too high. Localized abrasion. Corroded, rusted, or broken filter cages. Excessive rubbing of filter bags.	Consult the manufacturer for assistance in determining the appropriate corrective measures if bag life is inadequate.
	Inconsistent timing	Mechanical damage. Inadequate power. Blown fuse. Open or short circuit between the timer and the solenoids.	Replace damaged items, if feasible. Restore electrical power input. Replace blown fuse. Check wiring for electrical continuity.
	Pulsing failure of valves, or the same numbered valve on each header	Timer inoperative. Open or short circuit in wiring between time and solenoids.	Check timer per maintenance instructions. Check electrical continuity with ohmmeter or suitable tester, and repair as required.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Collector and filter (cont.)	Pulsing failure of valves at any location.	Plastic plug in solenoid exhaust port. Ruptured diaphragm. Pinched or plugged tubing between solenoid and diaphragm valve. Open solenoid coil. High pressure tubing connected to both sides of the solenoid valve.	Remove and discard plug. Disassemble valve, inspect diaphragm, and replace with a repair kit if needed. Inspect tubing and replace if necessary. Check continuity of solenoid coil with ohmmeter, and replace if necessary. Eliminate high pressure from discharge side of solenoid valve.
	Continuous passage of compressed air through one or more blowpipes	Tubing or fittings leaking or broken. Tubing connected into solenoid exhaust port. Solenoid armature not seating properly. Diaphragm valve air bleed hole or passage restricted.	Inspect and repair as needed. Remove tubing from compression fitting and change fitting to inlet port on valve body and reassemble. Remove particles of dirt, scale, or rust from the valve body and from around the armature. Disassemble and clear bleed hole or bleed passages in larger valves.
Dense-phase vessel	Vessel fails to fill	Hopper above may be plugged. Top gate failure. Equalization failure. Bottom gate leakage. Aeration failure.	Unplug hopper of clogged material. Repair leakage of bottom gate. Check equalization subassemblies.
	Vessel fails to empty	Top gate leakage. Equalization failure. Foreign material in airlock. Bottom gate failure. Aeration failure.	Remove foreign material from airlock. Repair leakage of top gate. Check equalization subassemblies.
Dry dust unloader	Spout does not deliver desired flow rate	Restricted material flow.	Restore material flow rate upstream of dry dust unloader.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Dry dust unloader (cont.)	Spout sleeve tends to oscillate or twist during loading	Too much negative pressure.	Install a gravity bleed damper in the ductwork between the spout and dust collector or raise the spout slightly off of the vehicle hatch to provide bleed air. On trucks or railcars with more than one hatch per compartment, open an adjacent hatch to provide necessary bleed air.
	Spout will not extend	Power source interrupted.	Ensure power source is turned on and is operating correctly. Check all electrical connections.
		Improperly adjusted limit switches.	Adjust limit switches.
		Motor overheats.	Reconfigure to preclude motor from overheating. For brake-motors, ensure that the motor brake disengages properly.
		Cables out of sheaves.	Check the lifting cables for proper tracking over the transfer sheaves. Adjust the cable retaining brackets if necessary.
		Inner spout cones and cone harness cables are jammed.	Check the sheaves and bushings for wear or damage.
		Lack of lubrication of shaft bearing, drive motor, and/or gear reducer causing seizure, wear, or damage.	Release the cones and/or cables. Check the full-up limit switch and adjust. If the switch is adjusted properly, lowering the fully-retracted position slightly (about an inch) may free the spout. Lubricate item(s) as needed.

Table 6-3 (Cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Dry dust unloader (cont.)	Spout will not retract	Power source interrupted.	Ensure that power source is turned on and is operating correctly. Check all electrical connections.
		Improperly adjusted limit switches.	Adjust limit switches.
		Motor overheats.	Reconfigure to preclude motor from overheating. For brake-motors, ensure that the motor brake disengages properly.
		Cables out of sheaves.	Check the lifting cables for proper tracking over the transfer sheaves. Adjust the cable retaining brackets if necessary. Check the sheaves and bushings for wear or damage.
		Inner spout cones and cone harness cables are jammed.	Release the cones and/or cables. Check the full-up limit switch and adjust. If the switch is adjusted properly, lowering the fully-retracted position slightly (about an inch) may free the spout.
		Lack of lubrication of shaft bearing, drive motor, and/or gear reducer causing seizure, wear, or damage.	Lubricate item(s) as needed.
	Material leakage from self-sealing discharge	Worn or damaged lower cone seal.	Replace lower cone seal.
		Worn or damaged lower sealing cone.	Replace lower sealing cone.
		Inadequate stiffness or binding of self-sealing sleeve fabric.	Install a small amount of weight equally around the self-sealing discharge ring.

Table 6-3 (Cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Dry dust unloader (cont.)	Pneumatic probe inoperable	Loss of electrical power. Blocked end of probe. Blocked air inlet in the electrical enclosure. Inadequate air output from the bubbler compressor. Inadequate air output from the flow-meter. Inoperable differential pressure gauge. Inoperable differential pressure switch. Improperly adjusted or inoperable time delay relay.	Restore electrical power. Clear blockage at end of probe. Clear blockage at the inlet of the electrical enclosure. Repair or replace bubbler compressor. Repair or replace flow-meter. Replace differential pressure gauge. Replace differential pressure switch. Adjust or replace time delay relay.
Equalizer valve	Valve will not operate	Loss of power to solenoid valve. Loss of air supply pressure. Solenoid valve stuck. Valve plugged with material.	Restore power to solenoid valve. Restore air supply pressure. Manually open solenoid valve. Clear clogged material from valve.
	Valve will not seat	Valve is not fully actuated. Material between valve gate and valve seat. Valve plugged with material. Worn valve gate and/or valve seat.	Fully actuate valve. Clean material between valve gate and seat. Clear clogged material from valve. Replace worn gate and/or seat.
Air compressor Fly ash transport blower Hopper aeration blower Fly ash vacuum pumps Silo aeration blower	See Table 6-4.		

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Hydraulic vacuum device	Excessive wear	Water supply contains uneven solids. Material being transported is highly abrasive. Misalignment of component parts. Leaks in the component.	Replace worn parts. Ensure that material composition is in accordance with design requirements.
	Decreased vacuum	Leaks in transport piping. Water supply pressure low. Leaks in the component. Nozzle tips unevenly or excessively worn. Throat liner unevenly or excessively worn. Foreign material in ejector head clogging nozzle tips.	Repair worn and leaking assemblies. Replace worn items.
Material handling valve	Valve will not open	Loss of power to solenoid valve. Loss of air supply pressure. Solenoid valve stuck. Material binding the slide gate in the tracks. Foreign material (i.e., welding rods, slag, etc.) binding the slide gate in the tracks. Worn slide gate or valve seat binding the slide gate in the tracks. Slide gate disengaged from the air cylinder operating rod.	Restore power to solenoid valve. Restore air supply pressure. Manually open solenoid valve. Clear clogged material from tracks. Remove foreign material. Replace slide gate or valve seat. Reconnect slide gate to the air cylinder operating rod.

Table 6-3 (Cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Material handling valve (cont.)	Valve will not close	Loss of power to solenoid valve. Loss of air supply pressure. Solenoid valve stuck. Material binding the slide gate in the tracks. Foreign material (i.e., welding rods, slag, etc.) binding the slide gate in the tracks. Valve plugged with material or debris. Slide gate or valve seat binding the slide gate in the tracks. Slide gate disengaged from the air cylinder operating rod.	Restore power to solenoid valve. Restore air supply pressure. Manually open solenoid valve. Clear clogged material from tracks. Remove foreign material. Clean out material or debris. Replace slide gate or valve seat. Reconnect slide gate to the air cylinder operating rod.
	Plugged transport line	Check valve at beginning of transport pipe line not operating properly. Air inlet check valve not properly adjusted. A metering device assembly is required. Metering device, if so equipped, not properly adjusted.	Repair or replace check valve at beginning of transport pipe line. Adjust air inlet check valve. Install appropriate metering device. Adjust metering device.
Pugmill unloader	Unsatisfactory mix	Erratic or improper material feed into the continuous mixer. Water supply incorrect. Nozzles or header plugged. Nozzles worn or spray pattern incorrect. Paddles worn or out of alignment. Loose V-belt causing erratic rotation of paddle shafts.	Correct flow of feed material. Adjust water supply flow. Unplug nozzles or header. Replace worn nozzles. Replace worn paddles or align as needed. Replace or tighten V-belt.

Table 6-3 (Cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Pugmill unloader (cont.)	Rough operation	Mixing drum and/or conveyor screw out of alignment. Bearings worn or out of alignment. Spur gears worn or out of alignment. Ash or sludge binding spur gears. Loose connection between end shaft and paddle shaft. Drive coupling connection loose, or coupling is worn or damaged. Loose V-belt causing erratic rotation of paddle shafts. Caked or hardened ash or foreign material causing an out-of-balance condition.	Align mixing drum and/or conveyor screw. Replace bearings. Replace spur gears. Remove binding ash or sludge. Tighten connection between end shaft and paddle shaft. Tighten connection or replace drive coupling. Tighten or replace V-belt. Remove caked or hardened ash or foreign material.
Relief door	Door does not seal	Worn, ripped, or brittle gaskets. Dome is out of round. Springs are broken or corroded. Loose fasteners.	Replace seal gaskets. Straighten or replace dome. Replace springs. Tighten fasteners.
	Door does not open and/or close	Excessive product buildup. Dome is out of round. Springs are broken or corroded. Rods are bent or corroded. Cam sets are corroded.	Clean excessive fly ash buildup. Straighten or replace dome. Replace springs. Replace rods. Replace cam set.
Rotary feeder	Material leakage	Blown gaskets. Worn packing. Loose or missing fasteners or covers.	Replace worn gaskets or packing. Tighten or replace fasteners or covers.
	Frequent jamming	Foreign or oversized material. Clearance out of adjustment.	Ensure that material composition is in accordance with design requirements. Adjust clearances.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Rotary feeder (cont.)	Decreased feed rate	Erratic or improper material flow into the integral feeder. Reduced drive unit speed. Rotor pockets clogged with material.	Ensure that material composition is in accordance with design requirements. Adjust drive unit speed. Clean rotor pockets of clogged material.
Cut-off gate segregating valve	Valve will not open	Loss of power to solenoid valve. Loss of air supply pressure. Solenoid valve stuck. Material binding the slide gate in the tracks. Slide gate distorted and binding in the tracks.	Restore power to solenoid valve. Restore air supply pressure. Manually open solenoid valve. Clear clogged material from tracks. Straighten or replace slide gate.
	Valve will not close	Loss of power to solenoid valve. Loss of air supply pressure. Solenoid valve stuck. Material binding the slide gate in the tracks. Slide gate distorted and binding in the tracks. Valve plugged with material or debris.	Restore power to solenoid valve. Restore air supply pressure. Manually open solenoid valve. Clear clogged material from tracks. Straighten or replace slide gate. Clean material or debris from plugged valve.
	Valve will not seal	Valve is not fully closed. Excessive air leakage through loose covers or fasteners. Worn slide gate or seat insert.	Manually close valve. Tighten covers and fasteners. Replace worn slide gate or seat insert.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Vent filter	Excessive pressure drop across filter bags	Inoperable differential pressure gauge.	Check the differential pressure gauge or manometer and the tubing leading to the dust collector for proper operation.
		Inadequate compressed air.	Adjust the compressed air system.
		Water or oil in compressed air.	Repair the compressed air system to ensure that air is not contaminated.
		Bags loaded with dust because:	
		Dust not discharging from the hopper	Repair dust discharge equipment or replace with higher capacity equipment, or install hopper vibrators.
		Air flow too high	Clean bags if caked; cut back on fan to prevent recurrence.
		Improper particle size and dust load	Compare dust particle size and loading with original design specification, and contact manufacturer for recommendations.
		Bags too tight	Pull bag tight around its cage and gather a small fold of material.
		Water leaks	Repair holes, cracks, or loose gaskets where water could enter.
		Condensation	Insulate the collector and/or ductwork leading to the collector to keep surface temperatures above the dew point and prevent condensation of the filter bags.
	Extremely low pressure drop	Inoperable differential pressure gauge.	Check the differential pressure gauge or manometer and the tubing leading to the dust collector for proper operation.
		Holes in the filter bags or bags are installed incorrectly.	Repair or replace filter bags.
		Leaks in the housing.	Repair holes and cracks, and replace/tighten loose gaskets in the dust collector housing or tube sheets.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Vent filter (cont.)	Continuous flow of dust in the clean air exhaust	Holes in the filter bags or bags are installed incorrectly. Holes in the tube sheets or loose bag cup assemblies.	Repair or replace filter bags. Repair holes and cracks; tighten bolts or bag cup assemblies (bottom bag removal only).
	Puff of dust in the clean air exhaust after each pulse (secondary dusting)	Air header pressure too high. Worn filter bags. Residual dust.	Ensure that pulsing air pressure is over 100 psig. Replace filter bags. Clean both the clean air plenum and bag/cage assemblies.
	Short filter bag life	Operating temperature too high. Incompatible material resulting in chemical degradation. Moisture content is too high. Localized abrasion. Corroded, rusted or broken filter cages. Excessive rubbing of filter bags.	Consult the manufacturer for assistance in determining the appropriate corrective measures if bag life is inadequate.
	Inconsistent timing	Mechanical damage. Inadequate power. Blown fuse. Open or short circuit between the timer and the solenoids.	Replace damaged items, if feasible. Restore electrical power input. Replace blown fuse. Check wiring for electrical continuity.
	Pulsing failure of valves or the same numbered valve on each header	Timer inoperative. Open or short circuit in wiring between time and solenoids.	Check timer per maintenance instructions. Check electrical continuity with ohmmeter or suitable tester, and repair as required.

Table 6-3 (cont.)
Recommended Troubleshooting for Fly Ash System Components

Fly Ash System Component Name	Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Vent filter (cont.)	Pulsing failure of valves at any location	Plastic plug in solenoid exhaust port.	Remove and discard plug.
		Ruptured diaphragm.	Disassemble valve, inspect diaphragm, and replace with a repair kit if needed.
		Pinched or plugged tubing between solenoid and diaphragm valve.	Inspect tubing and replace if necessary.
		Open solenoid coil.	Check continuity of solenoid coil with ohmmeter, and replace if necessary.
		High pressure tubing connected to both sides of the solenoid valve.	Eliminate high pressure from discharge side of solenoid valve.
	Continuous passage of compressed air through one or more blowpipes	Tubing or fittings leaking or broken.	Inspect and repair as needed.
		Tubing connected into solenoid exhaust port.	Remove tubing from compression fitting and change fitting to inlet port on valve body and reassemble.
		Solenoid armature not seating properly.	Remove particles of dirt, scale, or rust from the valve body and from around the armature.
		Diaphragm valve air bleed hole or passage restricted.	Disassemble and clear bleed hole or bleed passages in larger valves.

Table 6-4 summarizes troubleshooting guidance that is generic to most types of blowers and compressors that are installed in fly ash conveying systems. It is based on the guidance provided in the EPRI report *Compressed Air System Maintenance Guide* (1006677). This report can be referenced for additional details and should be used in conjunction with the PM recommendations provided by the equipment manufacturer for the specific equipment installed.

Table 6-4
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Courtesy of EPRI 1006677

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Low or no oil pressure	Defective gauge	Check the oil pressure gauge calibration.
	Crankcase oil level too low	Add oil to the proper level as indicated on the sight gauge. Also see the nameplate for quantity.
	Oil is too light	Check the oil specifications.
	Plugged oil strainer	Clean the oil strainer as outlined in the vendor's manual.
	Leak in oil pump suction or pressure line	Check for line leakage and tighten the fittings.
	Oil pressure relief valve out of adjustment	Adjust the oil pressure relief valve per the vendor's instructions.
	Dirt on oil pressure relief valve seat	Remove the relief valve. Clean the valve and seat. Use a magnet to remove foreign metal particles.
	Broken oil pressure relief valve spring	Replace the relief valve spring.
	Crankcase oil pump defective	Repair or replace the pump.
	Defective oil pump drive	If gear-driven, check the gear alignment and security. A direct-driven pump may require a new oiler pin and bushing.
	Improper rotation direction of the oil pump	See the vendor's manual for instructions.
	Worn crankpin or wristpin bearings	Replace the crankpin or wristpin bearings per the vendor's manual.
High oil pressure	Defective gauge	Check the oil gauge calibration.
	Relief valve improperly adjusted	Adjust as outlined under "Oil Pressure Adjustment" in the vendor's manual.
	Oil too heavy	See the oil specification in the vendor's manual.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
High oil pressure (cont.)	Plugged oil pressure line	Remove the pump discharge piping and ensure that it is cleared.
	Defective or clogged oil filter	Replace or clean the element as needed.
	Plugged oil return to sump	Remove the obstruction from the passage.
Erratic oil pressure	Crankpin bearing inserts worn or defective	Replace the crankpin bearing inserts per the vendor's manual.
Does not deliver air	Controls inoperative	Check the vendor's manual for control settings.
	Restricted suction line	Service the inlet filter. Ensure that the protective screens and removed and remove the obstruction from the inlet line.
	Unit running "unloaded"	Verify that control switch is properly set per vendor instruction for compressor loading.
	Suction and/or discharge valves missing	Replace the valves per the instructions in the vendor's manual.
Low capacity	Restricted suction line	Clear the suction line.
	Dirty air intake filter	Clean or replace the filter.
	Loose suction or discharge valve assembly	Tighten the screw(s) holding the assembly in place.
	Worn or broken valve assembly parts	Recondition valves as described in the vendor's manual.
	Suction or discharge valve improperly assembled	Re-assemble as per the vendor's manual. Check if the suction and discharge valves have been assembled for proper flow direction.
	Defective inlet valve unloaders	Service as described in the vendor's manual.
	Defective or improperly adjusted controls	Adjust or service per the instruction in the vendor's manual.
	Suction or discharge valve cages misaligned	Align the valve cap to cage as shown in the vendor's manual. Misalignment will cause valves to leak.
	Worn piston rings	Replace per the instructions in the vendor's manual.
	Leakage at piston rod packing	Tighten or replace the packing.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Low capacity (cont.)	Low compressor speed; V-belt slipping	Check speed as shown on the compressor nameplate. Tighten or replace the belts.
Low operating pressure	Defective gauge	Check the pressure gauge calibration.
	Excessive service line leakage	Check the service lines for open or leaking connections.
	Suction/discharge valve loose, worn, or defective	Service the valve assemblies per the instructions in the vendor's manual.
	System demand greater than compressor capacity	Reduce demand. Detect and repair system leaks.
	Inlet valve unloaders defective	Service the unloaders per the instructions in the vendor's manual.
	Improperly adjusted pressure control	Adjust per the instructions in the vendor's manual.
	Worn piston rings	Replace per the instructions in the vendor's manual.
	Low compressor speed; V-belt slipping	Check speed as shown on the compressor nameplate. Tighten or replace the belts.
Overheated cylinder	No cooling water	Check the cooling water supply and controls.
	Insufficient cooling water	Increase the water flow.
	Scored piston or liner	Repair or replace.
	Worn or broken valve assembly or parts	Repair or replace. Check the discharge valves first.
	Piston rod packing too tight	Loosen or replace the packing as necessary.
	Discharge pressure too high	Adjust the air pressure switch setting.
	Suction/discharge valve cage not aligned	Align the valve cap to cage per the instructions in the vendor's manual.
	Cylinder cooling jackets clogged with deposits, rust, or scale	Clean the water passages of the cylinder cooling jackets.
	Excessive carbon deposits on valve assemblies (for lubricated compressors)	Disassemble and clean. Check the lubrication rate.
	Insufficient lubrication (for lubricated compressors)	Correct the lubrication rate.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Overheated cylinder (cont.)	Broken high-pressure relief valve or check valve	Repair or replace the valves as necessary.
Water in cylinders	Cooling water temperature too low causing condensate	Cooling water inlet temperature should be above ambient air temperature. Adjust the cooling water discharge temperature to 100–120°F (38–49°C).
	Leak in head gasket	Replace the head gasket.
	Cracked cylinder head	Replace the cylinder head.
	Air discharge piping pitched toward compressor	Pitch the discharge piping away from the compressor.
	Leak in after-cooler	Check the after-cooler tube nest and repair leaks.
	Moisture separator not drained	Drain and check operation of the drain trap.
	Leak in inter-cooler	Check the inter-cooler tube nest and repair leaks.
	Condensate in the inter-cooler	Drain and check the drain trap.
Scored cylinder liner and piston	Foreign material getting into cylinder	Clean the air intake filter. Replace filter, if necessary.
	Overheated cylinder	See "Overheated Cylinder" table.
	Broken valves or valve springs	Replace as needed.
	Water in cylinder	See "Water in Cylinder" table.
	Excessively worn or broken piston rings	Replace as needed per the instruction in the vendor's manual.
	Insufficient lubrication (for lubricated compressors)	Correct the lubrication rate as specified in the vendor's manual.
Erratic or inoperative compressor control	Improper control adjustment	Adjust the controls as needed.
	Defective control components	Check the control components. Repair or replace as needed.
	Clogged, pinched, or improperly connected control piping	Clean the control air tubing to the unloaders. Replace if damaged.
	Clogged control air filter	Drain and clean the element.
	Defective inlet valve unloaders	Check the yoke, spring, and diaphragm. Replace parts as necessary.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Erratic or inoperative compressor control (cont.)	Inadequate supply of control air to unloaders and control pressure switch, respectively (air supply lines from air receiver too small)	Check the installation and control panel drawing for proper piping details. Control air must be free of surging and of ample volume while unloading.
Compressor continues to pump after unloading	Broken unloader diaphragm	Replace the inlet valve unloaders.
	Broken unloader yoke	Replace the inlet valve unloaders.
	Total closure valve fails to close	See “Total Closure Control” in the vendor’s manual.
Broken suction or discharge valve and/or valve springs	Incorrect reassembly of valves	See “Valve Assemblies” in the vendor’s manual and ensure the proper spring tension with the proper number of springs.
	Condensation and rust due to cooling water too cold	Cooling water inlet temperature should be above ambient temperature. Maintain 100–120°F (38–49°C) cooling water discharge temperature.
	Overheated cylinder	See “Overheated Cylinder” table.
	Over-lubrication (for lubricated compressors)	Clean and remove the carbon deposits from the valves. Reduce the lubrication per the instructions in the vendor’s manual.
	Insufficient lubrication (for lubricated compressors)	Increase the lubrication to the rate specified in the vendor’s manual.
Air receiver pressure too high	Defective pressure gauge	Check the pressure gauge calibration. Recalibrate or replace gauge.
	Pressure control set too high	Adjust the pressure control to a lower setting.
	Restriction in pressure-sensing line	Remove any restrictions.
	Defective unloader	Remove, inspect, and replace the valve unloaders per the vendor’s instructions.
	Defective control or unloader	Clean, repair, or replace.
Discharge air temperature too high	Overheated cylinder	See “Overheated Cylinder” in this table
	Cylinder cooling water temperature too high	Regulate the water temperature control to maintain 100–120°F (38–49°C) cooling water discharge temperature.
	Discharge pressure too high	Lower the discharge pressure.
	Insufficient cylinder lubrication (for lubricated compressors)	Correct the lubrication rate per the specification.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Compressor stops unexpectedly	A protective logic initiates the drive motor trip	Check all safety devices (oil pressure, water temperature, discharge air temperature, etc.) to determine the reason for shutdown.
	Power failure	NOTE: In the event that compressor is stopped unexpectedly or by safety devices perform “Normal Stopping” per the instruction in the vendor’s manual to avoid start-up under load. Place the selector switch in the *Off* position before resetting the circuit. For units with total closure control, se “Start-Up After Abnormal Shutdown” in the vendor’s manual.
Compressor knocks	Foreign material in cylinder	Inspect the inside of the cylinder through the valve ports.
	Incorrect head clearance	Adjust the piston head clearance per specifications.
	Loose piston on piston rod	Tighten the piston rod.
	Worn connecting rod bearings	See “Connecting Rod” in the vendor’s manual.
	Worn crosshead	See “Crosshead and Guide” in the vendor’s manual.
	Loose valve assembly or valve cage	Check the valve installation per the instructions in the vendor’s manual.
	Loose or defective main bearings	Replace the bearing if defective. Check for proper bearing fit in the bearing bore and on the crankshaft.
	Frozen piston rings	Remove and replace as necessary. Reinstall after cleaning the ring grooves to ensure free movement.
	Bent connecting rod	Check the rod for alignment. Replace if necessary. See “Connecting Rod” in the vendor’s manual.
	V-belts or sheave loose	Check the belt tension and tighten the sheave hub.
	Piping vibration	Check all piping. Provide additional support, if required.
	Loose counterweights in crankshaft	Tighten the counterweights.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Motor fails to start	Motor overload relay on motor starter tripped	Reset the overload relay after determining the cause for the overload.
	Improper wiring	Check motor circuit wiring.
	Power disconnected	Reconnect the power supply.
Motor trips after start	Low oil pressure; oil switch not holding	See "Low or no oil pressure" in this table.
	Other safety device tripped	Check all safety devices. Determine the cause for the trip before resetting.
Motor overheats	Voltage incorrect	Restore the correct voltage.
	Excitation incorrect	Restore the correct voltage.
	Dirty motor	Blow off with clean air or disassemble and clean.
	Poor lubrication	Lubricate per specifications.
	Motor overloaded	Correct the compressor operating pressure or speed. Ensure that compressor is running "free."
High inter-cooler pressure	Defective pressure gauge	Replace as necessary.
	Broken inlet or discharge valves or valve springs in the succeeding cylinder	Repair as outlined in the vendor's manual.
	Damaged head gasket in succeeding cylinder	Replace the gasket.
	Broken high-pressure check valve	Repair or replace.
	Unloader yoke holding valves open in succeeding cylinder	See "Inlet Valve Unloaders" in the vendor's manual.
Low inter-cooler pressure	Defective pressure gauge	Replace as necessary.
	Broken inlet or discharge valves or valve springs in the succeeding cylinder	Repair as outlined in the vendor's manual.
	Leak in inter-cooler	Check the inter-cooler tube bundle.
	Leaking inter-cooler drain	Check the drain and trap.
	Piston rod packing leaking	Adjust or replace as needed.
	Unloader yoke holding valves open in preceding cylinder	Reassemble the inlet valve unloaders per instruction in the vendor's manual.

Table 6-4 (cont.)
Recommended Troubleshooting for Fly Ash System Blowers and Compressors

Failure Mechanism(s)	Cause(s)	Frequently Used Solutions
Oil leaking past piston rod oil scraper rings	Scraper rings worn out	Replace the worn rings.
	Dirt between rings	Remove the rings and clean.
	Scratched or scored rod	Clean or replace the rod.
	Stretched springs	Replace the springs.
	Nicks on bottom surface of stuffing box	Refinish the surface. Maintain clearance per next item.
	Incorrect ring clearance in piston rod packing box	Proper clearance is 0.002 in. (0.05 mm) per ring or total of 0.004 in. (0.1 mm) for a two-ring set and 0.006 in. (0.15 mm) for a three-ring set. (0.0015 in. min., 0.003 in. max. per ring) (0.038 mm min., 0.076 mm max.). Rings must be able to float.

7
FLY ASH DISPOSAL AND REMOVAL FROM THE PLANT SITE

There are many methods for moving the ash away from the plant. This section covers several of these options. It was decided to cover the conveying of ash away from the plant site in a more detailed manner in a future guide.

7.1 Analysis of Fly Ash Disposal Costs and Factors

Based on information collected by the American Coal Ash Association (ACAA), multiple factors are involved in determining the cost of disposal of coal ash that cannot otherwise be used. The specific type of ash, location, transportation methods, climate and terrain, regulatory requirements, and potential for commercial use all enter into determining disposal costs.

7.1.1 Type of Material

Coal, when burned in a pulverized coal-fired boiler, produces both fly ash and bottom ash. Approximately 80% of the material produced is in the form of fly ash and 20% is in the form of bottom ash. Other boiler designs result in differing percentages of fly ash, bottom ash, and other products. Air emission control systems that create other types of coal combustion products such as flue gas desulfurization material (wet or dry) also contribute to determining the method of disposal.

7.1.2 Location

The physical location of the power plant often has a great impact on disposal. Plants located in urban areas might have no space for on-site disposal, necessitating transport to other locations for disposal. Many communities have permitted locations specifically for the disposal of ash. However, as these locations are completely filled, new land must be found for disposal. New permits often require extensive environmental reviews and regulatory hurdles. In western states and parts of the country where plants are located farther from population centers, there is often more land available for disposal. Therefore, the distance to the disposal site or the cost of land can influence disposal costs.

Fly ash can also be disposed in coal mines to replace the coal extracted from the mine. The location of the mine in relation to the plant can determine the method of transporting the ash to the mine. Conveyors, trucks, barges, and other vehicles are used to move the ash to the mine site.

7.1.3 Transportation Methods

If fly ash is collected in silos, it is often conditioned (mixed with modest amounts of water) during loading into a truck to prevent dusting and to make handling easier. In some situations, the fly ash is not mixed with water but instead loaded directly into covered trucks or pneumatic tank trucks for transport. If this material is disposed, handling at the disposal site is typically more challenging due to potential dusting issues. Heavy ash material can be conveyed hydraulically using water in pipes to deliver the material to ponds. In some cases, these ponds are only temporary holding locations from which the material is later excavated and transported to a final disposal site. At some power plants, the material is transported to its final disposal location in these water-filled pipes. At still other plants, the wet material might be stacked and allowed to dry, then transported to a final disposal site after it dries.

7.1.4 Climate and Terrain

The type of climate has a significant impact on methods of disposal. In areas where water tables are high and where rain or snowfall is significant, precautions can be required to ensure that disposed material is contained. To prevent leachates from leaving a disposal site, liners can be installed or other types of barriers can be implemented. However, in arid climates where water tables are far beneath a disposal site and annual rainfall is low, few if any barriers might be required. Therefore, the need for barriers and liners affects both the construction of disposal locations and the cost of disposal.

7.1.5 Regulatory Requirements

The Environmental Protection Agency imposes regulations for the disposal of solid and liquid waste. The discharge of water from an ash storage pond and the movement of dry ash from the plant site are regulated by both state and federal authorities.

Some states regulate the disposal of coal ash differently from other states, often because of the geography of an area. A state that regulates coal ash in a manner comparable to municipal solid waste might impose more rigorous requirements than does a state that regulates the material as an industrial waste. Again, climate and terrain come into play. Disposal in an arid state protects the environment in different ways than in an area where heavy rains, snow, or flooding can potentially impact a disposal location. Each of the requirements imposes different design requirements on a disposal facility and will affect cost commensurately.

7.1.6 Conclusion

Key O&M Cost Point

A variety of factors enter into determining disposal costs. The lowest cost occurs when a disposal site is located near the power plant and the material being disposed can be easily handled. If the material can be piped, rather than trucked, costs are usually lower. In these situations, costs can be as low as US $3–5 per ton. In other areas, when a disposal site is far away and the material must be handled several times due to its moisture content or volume, costs could range from US $20–$40 per ton.

In some areas, the costs are even higher. If new sites are required and extensive permitting processes take place, the total cost of the facility can be increased, resulting in higher disposal costs over time.

7.2 Handling Fly Ash Material

Recommended construction procedures have been developed as the result of experience gained with trial embankments and construction projects. Adjustments to these standard procedures might be necessary, depending on actual field conditions.

7.2.1 Site Preparation

The requirements for preparing a site for fly ash placement are similar to requirements for soil fill materials. The site must be cleared and grubbed. Topsoil should be retained for final cover. Special attention should be given to draining the site and to preventing seeps, pools, or springs from contacting the fly ash.

7.2.2 Delivery and Off-Site Handling

Fly ash is usually hauled from the plant site in covered dump trucks or pneumatic tanker trucks. The water content of the ash should be adjusted properly to prevent dusting. In the case of lagoon ash, reduce the water through temporary stockpiling, mixing with drier silo ash, or both, in order to prevent road spillage during transport and to allow proper placement. Because of the self-hardening properties of high-calcium ash, it should be stored dry in silos or pneumatic tanker trucks. Low-calcium ash can be stockpiled on site if the ash is kept moist and is covered to prevent dusting and erosion.

7.2.3 Spreading Fly Ash

Fly ash is usually spread and leveled with a dozer, grader, or other equipment in loose lifts that are 6–12 in. (150–300 mm) thick. The lift is then tracked with the dozer or other equipment for initial compaction.

7.2.4 Compaction Equipment for Fly Ash

Compaction should begin as soon as the material has been spread and is at the proper moisture content. The most successful compaction results have been achieved with self-propelled, pneumatic-tired rollers and self-propelled or towed vibratory rollers. Vibratory rollers operated at the resonant frequency of the fly ash will compact the ash more effectively and in fewer passes than non-vibratory rollers. Table 7-1 lists the types of compaction equipment that have been tested for use with fly ash.

Table 7-1
Types of Fly Ash Compaction Equipment

Equipment	Thickness	Passes	Comments
Vibratory smooth drum roller (1–1.5 tons [900–1330 kg])	6 in. (150 mm)	>8	May slightly overstress surface; compaction may reach only 90%
Vibratory smooth drum roller (6–10 tons [5400–9100 kg])	6–12 in. (150–300 mm)	>8	10-ton (9100-kg) roller may need as few as 3 passes at lower lift thickness; may overstress surface
Vibratory smooth drum roller (10–20 tons [9100–18,200 kg])	8–12 in. (200–300 mm)	4–6	May seriously overstress surface; ballast reduction and frequency change will reduce this problem
Pneumatic-tired drum roller (10–12 tons [9100–11,000 kg])	6–12 in. (150–300 mm)	>8	Limit tire pressure to 35 psi (250 kPa); provides good smooth surface seal
Vibratory padfoot roller (6–20 tons [5400–18,200 kg])	6–12 in. (150–300 mm)	>8	Pad height should be roughly 4 in. (100 mm) or less; pad area should be greater than 12 in^2 (7750 mm^2)
Vibrating plate tamper (large plate)	8–10 in. (200–250 mm)	2–3	Used in confined areas and where ground loading must be kept low (for example, backfills)
Sheepsfoot			Not recommended
Grid roller			Not recommended

Figure 7-1 illustrates the typical process used for spreading and compacting fly ash structural fill.

Figure 7-1
Spreading and Compaction of Fly Ash Structural Fill

Courtesy of U.S. Department of Transportation

7.2.5 Moisture Control

Control of the required range of moisture is an important consideration in the compaction procedure. Fly ash can be conditioned with water at the plant silo to achieve the desired moisture content. Care should be taken to compare the alternatives of either hauling fly ash that has been moistened to the desired water content at the plant or adding water at the disposal site. Hauling moist fly ash off-site means higher transportation costs; adding water on site can sacrifice productivity in field placement.

7.2.6 Weather Restrictions

Fly ash can often be placed during inclement weather. In the winter months, frost usually penetrates only the upper layer of the compacted ash, which can be re-compacted upon thawing. During compaction, if the water freezes too quickly, the operation should be suspended until the temperature rises. Construction can also proceed during wet weather even if the moisture content of the ash is too high. However, the equipment might bog down, and it can be difficult to achieve proper compaction.

7.2.7 Insensitivity to Moisture Variations

Because water is added to low-calcium fly ash during unloading from storage silos, fly ash can be obtained at any moisture content that is desired. Although the optimal moisture content of low-calcium fly ash is greater than that of silty soils, the compaction behavior of low-calcium fly ash is relatively insensitive to variations in moisture content when the fly ash is drier than the optimum value. High-calcium fly ash, however, self-hardens when water is added and becomes difficult to handle unless it is placed in a timely manner.

7.3 Fly Ash Disposal in Ash Ponds

Primarily, the fly ash is disposed of using either a dry or a wet disposal scheme. In dry disposal, the fly ash is transported by truck, chute, or conveyor at the site and disposed of by constructing a dry embankment (dike). Because of environmental concerns of dry fly ash escaping from either a chute or a conveyor, the most common means of dry disposal used domestically is covered truck transportation.

In wet disposal, the fly ash is transported as slurry through pipe and is disposed of in an impoundment called an ash pond. With this design, fly ash is pneumatically conveyed under negative pressure from air ejectors below the precipitator hoppers. The negative pressure is created by a water ejector in the transport line. An air separator is located downstream of the water ejector in order to remove entrapped air from the negative-pressure fly ash transport line. The downstream wet fly ash transport flow is generally combined with the bottom ash sluice system, which then is transported to a dewatering bin. The remaining fly ash sludge and bottom ash sludge is disposed in a land area.

Many power plants use wet disposal systems. When the lagoons are full, the following four basic options are available:

- Constructing new lagoons using conventional constructional material
- Hauling fly ash from the existing lagoons to another disposal site
- Raising the existing dike using conventional construction material
- Raising the dike using fly ash excavated from the lagoon (ash dike)

The option of raising the existing dike using fly ash is cost effective because any fly ash used for constructing the dike, in addition to saving the earth-filling cost, enhances the disposal capacity of the lagoon. The construction methods for an ash dike can be grouped into three broad categories:

- Upstream method
- Downstream method
- Centerline method

An important aspect of the design of ash dikes is the internal drainage system. The seepage discharge from internal surfaces must be controlled both by filters that hold particles in place but permit water to escape freely on the downstream of the dike. The internal drainage system typically consists of the construction of a rock toe (base), a 0.5-m-thick sand blanket, and a sand chimney. After completion of the final section, including earth cover, the turfing is developed from sod on the downstream slope.

7.4 Environmental Considerations of Fly Ash Disposal

The environmental aspects of ash disposal aim at minimizing air and water pollution. Directly related to these concerns is the additional environmental goal of aesthetically enhancing ash disposal facilities. The ash produced in thermal power plants can cause three environmental risks: air pollution, surface water pollution, and groundwater pollution. The pathways of pollutant movement through all these modes are schematically represented in Figure 7-2.

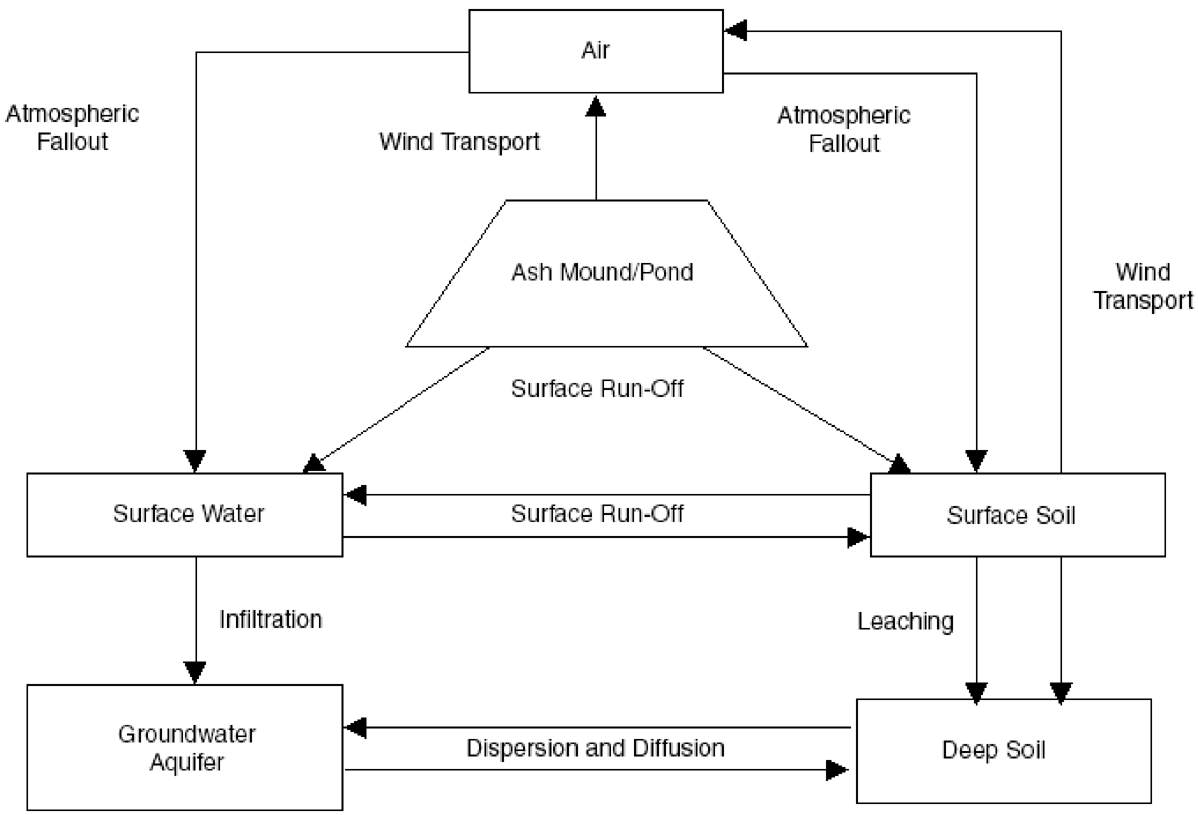


Figure 7-2
Pathways of Pollutant Movement

Air pollution is caused by direct emissions of toxic gases from the power plants as well as wind-blown ash dust from an ash mound or pond. The airborne dust can fall into the surface water system or soil and can contaminate the water or soil system. The wet system of disposal in most power plants causes discharge of particulate ash directly into the nearby surface water system. The long storage of ash in ponds under wet conditions and humid climates can cause leaching of toxic metals from ash and contaminate the underlying soil and ultimately the groundwater system. However, most of these environmental problems can be minimized by incorporating engineering measures in the design of ash ponds and by continuous monitoring of surface water and groundwater systems.

7.5 Commercial Uses for Fly Ash

Large-scale use of ash as a fill material can be applied when any of these conditions exist:

- Fly ash replaces another material and is therefore in direct competition with that material.
- Fly ash itself is used by the power generating company producing the fly ash to improve the economics of the overall disposal of surplus fly ash.
- At some additional cost, fly ash disposal is combined with the rehabilitation and reclamation of land areas desecrated by other operations.

Fills can be constructed as structural fills where the fly ash is placed in thin lifts and compacted. Structural fly ash fills are relatively incompressible and are suitable for the support of buildings and other structures. Nonstructural fly ash fill can be used for the development of parks, parking lots, playgrounds, and other similar, lightly loaded facilities. One of the most significant characteristics of fly ash in its use as a fill material is its strength. Well-compacted fly ash has strength comparable to or greater than soils normally used in earth fill operations. In addition, lignite fly ash possesses self-hardening properties, which can result in the development of shear strengths. The addition of illite or cement can induce hardening in bituminous fly ash, which might not self-harden alone. Significant increases in shear strength can be realized in relatively short periods of time, and it can be very useful in the design of embankments.

In some cases, the material disposed can potentially have future value. For example, some sites serve as stockpiles for material that can be used in future construction, such as in structural fills, highway projects, or industrial developments. Because construction is seasonal, these sites are not disposal areas but instead temporary storage facilities. Many utilities can also provide numerous examples of old disposal sites being “mined” to recover coal ash for uses that were not envisioned when the ash was originally placed.

There are a number of commercial applications for fly ash using current, established engineering technologies. Some of them are listed below:

- Building materials and bricks
- Concrete
  - Pozzolanic properties reduce need for cement
  - Spheres act like ball bearings, increasing workability
  - Fills in voids with cementitious material and acts as filler, reducing total surface area to be covered with cement
  - Retards heat of hydration, which is important for large concrete pours such as dams and the Hibernia oil platform
  - Strength increases with age
  - Enables alkali-silica reactions (provides sacrificial silica)

- Road base – substitutes for aggregate
- Structural fill – possesses high shear strength, good compaction
- Waste stabilization – solidifies into inert mass
- Soil modifier – aids in compaction, soil density, controls swell potential
- Backfill – can be poured in place, saving time

EPRI has performed numerous research projects concerning the use of coal combustion products. The following are some examples of this research:

- *Proceedings: 15th International American Coal Ash Association Symposium on Management and Use of Coal Combustion Products (CCPs): Building Partnerships for Sustainability*. EPRI, Palo Alto, CA: 2003. 1007954.
- *Guidelines for Using Ash/Organic Waste Mixtures in Horticulture and Turf Production*. EPRI, Palo Alto, CA: 2002. 1004398.
- *New Air-Entraining Admixtures for Concrete Using High Carbon Fly Ash*. EPRI, Palo Alto, CA: 2002. 1004596.
- *Development of High Volume Fly Ash Blended Cements*. EPRI, Palo Alto, CA: 2001. 1004030.
- *Development of Ternary Blends for High Performance Concrete*. EPRI, Palo Alto, CA: 2002. 1004077.

8
PERSONNEL QUALIFICATION, TRAINING, AND SAFETY ISSUES

8.1 Personnel Qualification and Training

This section provides guidance regarding typical qualifications for personnel associated with the operation and maintenance of fly ash conveying systems. Care should be taken not to interpret these as minimum requirements for qualification or certification purposes, but rather to use them as a benchmark for use within each owner's plant-specific program.

8.1.1 Fly Ash System Operators

Table 8-1 describes typical expertise and experience levels for a fly ash system operator.

Table 8-1
Typical Expertise and Experience Level – Fly Ash System Operators

Entry level with minimal or no experience as a fossil power plant system operator AND:
Completion of applicable apprenticeship program or five (5) years applicable trade experience, and a high school diploma or equivalent; OR
Two (2) years experience in fossil power plant maintenance, engineering or operations with an Associate's degree in engineering or related physical science

8.1.2 First Line Supervisors

Table 8-2 describes typical expertise and experience levels for a fly ash system supervisor.

Table 8-2
Typical Expertise and Experience Level – First Line Supervisors

Entry level with minimal or no experience in fossil power plant maintenance AND:
Five (5) to ten (10) years experience in maintenance or other plant areas and a high school diploma or GED: OR
Five (5) years experience in maintenance, engineering or fossil power plant operations with an Associate's degree in engineering or related physical science

8.1.3 Fly Ash System Maintenance Personnel

Table 8-3 describes typical expertise and experience levels for fly ash system maintenance personnel.

Table 8-3
Typical Expertise and Experience Level – First Line System Maintenance Personnel

Entry level with minimal or no experience performing fossil power plant system maintenance AND:
Completion of applicable apprenticeship program or five (5) years applicable fossil power plant maintenance experience, and a high school diploma or equivalent; OR
Two (2) years experience in fossil power plant maintenance, engineering or with an Associate's degree in engineering or related physical science

8.2 Personnel Safety Issues

8.2.1 EPRI Technical Report

The EPRI report *Fly Ash Exposure in Coal-Fired Power Plants* (TR-102576) has provided detailed guidance regarding the dangers of prolonged exposure to fly ash by plant personnel since it was published in 1993. Prior to and since the publication of the report, there has been concern over workplace exposures to coal fly ash particulate due to the presence of potentially hazardous components in the fly ash.

Key Human Performance Point

Existing data indicate the presence of potentially toxic components such as crystalline silica and arsenic in coal fly ash. Inhalation of crystalline silica and arsenic can cause respiratory tract diseases such as silicosis and lung cancer; exposure to these substances is regulated by OSHA.

Workers operating and maintaining coal-fired power plants can be exposed to coal fly ash when they work on ash collection and removal equipment, when they transport and dispose of fly ash, or whenever the interior of the boiler and flue-gas areas are inspected or repaired. Fly ash can also escape the enclosed boiler system into common work areas through leaks in the combustion chamber or fly ash handling system. Maintenance activities in areas where fly ash has accumulated present a significant opportunity for exposures to occur.

Conclusions from the EPRI report *Fly Ash Exposure in Coal-Fired Power Plants* (TR-102576) are applicable for users of the current report and should be considered when establishing safety measures for employees who might be exposed to fly ash at a fossil power plant:

> A significant number of employees at coal-fired power plants are exposed to airborne fly ash. Routine, relatively low-level exposures are encountered by workers performing inspection of the exterior regions of some boiler areas and by those who are involved in ash conveyance and collection. Routine and somewhat higher exposure is encountered by individuals operating ash loading, disposal, and transportation equipment. High but intermittent exposures are encountered by individuals performing maintenance activities associated with the interior spaces of the boiler and at other sites downstream from the combustion chamber.
>
> Information in the literature, data made available by the utility industry, and results of analyses conducted during this study confirm that coal fly ash contains constituents potentially hazardous to workers. The most notable constituents of concern include crystalline silica (quartz); trace elements such as arsenic, lead, cadmium, nickel, and chromium; and in some cases, radionuclides.
>
> Exposure studies at four coal-fired multiunit power plants revealed that in some situations airborne concentration of respirable particulate, total particulate, respirable quartz, and arsenic exceeded Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) and American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs). The most common areas in which PELs are TLVs were exceeded were interior spaces of the boiler combustion chamber and other interior areas where fly ash was present during maintenance tasks. Activities during normal plant operations, unlike maintenance tasks, rarely revealed exposures above recognized health criteria values.

The maintenance tasks associated with the highest airborne ash concentration included the following:

- Vacuum sweeping of accumulated fly ash
- Inspection and maintenance inside electrostatic precipitators and baghouses
- Installation of scaffolding in the boiler combustion chambers
- Repair or removal of boiler steam tubing

The presence and concentration of potentially hazardous fly ash constituents is highly variable between plants and in any one plant. One power plant studied, which was fired with eastern bituminous coals, had higher arsenic content in the fly ash as compared to plants fired with interior bituminous, western subbituminous, and lignite coals. The highest arsenic content was routinely detected in fly ash samples collected in the upper areas of the combustion chamber—the superheat and reheat tube sections—with lower content in the ESPs, baghouse, and ash silo areas. Quartz content values were scattered and did not indicate concentration trends at specific plant sites. Quartz levels were lower in the lignite-fired plants as compared to those fired with bituminous or subbituminous coals.

The particle size of airborne coal fly ash is generally smaller than 25 micrometers (µm), with predominant fractions smaller than 1 µm. Thus, much of the airborne particulate is in the respirable size range.

Accurate analysis of arsenic is not achieved by using inductively coupled plasma atomic emission spectroscopy (ICP-AES), a commonly used method for industrial hygiene sample analysis; however, it is accurately measurable using atomic absorption–graphite furnace (AA-GF) spectrometry methods. The National Institute of Occupational Safety and Health (NIOSH) Method 7901, which uses this latter method, yields accurate results and is the recommended sampling and analytical method for airborne arsenic determinations in work areas at coal-fired power plants.

Arsenic present on the surface of coal fly ash was detected only in the +5 valence state.

Other forms of arsenic, such as arsenic trioxide and arsine gas, were present at lower concentrations or frequently not detectable. These forms of arsenic were not detected at concentrations above the applicable PEL.

Airborne selenium concentrations, although frequently detectable at lignite-fired plants, were low and did not exceed PEL criteria values.

Polynuclear aromatic hydrocarbons were generally not detected in coal fly ash exposure areas. Whenever they were detected, the concentrations were low and no apparent trends were notable.

The highest concentration of radionuclides was detected at lignite-fired plants; on occasion measured values were above health criteria established by the Nuclear Regulatory Commission. Concentrations at plants fired with bituminous and subbituminous coals were much lower than those observed at lignite plants.

The use of respiratory protection was the most common exposure control technique observed. The use of this equipment varied considerably between the plants studied. It was most frequently observed on workers engaged in vacuum sweeping of accumulated ash and those working inside the ESPs and baghouses. Some workers in job categories associated with high airborne fly ash concentrations, such as scaffold erection crews and mechanics performing tube repairs, were rarely observed wearing protective equipment. Employee comfort appeared to be a prime consideration in the use of this equipment.

Key Human Performance Point

After shutdown of the unit, the fly ash can take a long time to cool down. Therefore, even days after shutdown, the ash can burn personnel coming into contact with it.

8.2.2 OSHA Proposals

OSHA has issued a draft proposal to drastically lower the allowable exposure limit of crystalline silica, a known human carcinogen that is present in coal fly ash to which workers can be exposed.

9
INDUSTRY RESOURCES FOR FLY ASH SYSTEM TRAINING, CONSULTING, AND REPAIR

This section provides a list of organizations capable of providing various services to utility personnel with respect to fly ash. The information presented below was compiled via searches on the Internet and World Wide Web. Users of this report should recognize that the information provided in this section was current at the time of publication but might no longer be valid. Listing these organizations does not imply any recommendation from EPRI FMAC regarding the applicability, accuracy, or competency of the organizations cited or the services they provide. Each user of this report should evaluate the current services being provided by each organization listed to determine their applicability and suitability to plant-specific needs on a case-by-case basis.

Training services. The organizations listed have capabilities to provide technical training to utility personnel in the area of fly ash chemistry, conveyance, handling, disposal, transport, or usage in other industries. The type of training offered by each institution varies and can include college-level classes, technical seminars, trade shows and exhibitions, and association technical meetings.

Consulting services. Consulting services provided by the organizations listed can include any of the following:

- Fly ash system and component design
- Fly ash system maintenance and operation
- Fly ash disposal, conveyance, and handling
- Fly ash utilization for industrial products

Repair services. The organizations listed are typically manufacturers of fly ash system components who have the capability to provide repair services either on site or at refurbishment facilities.

Table 9-1 provides a compilation of the organizations researched for inclusion in this report.

Table 9-1
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Allen-Sherman-Hoff A major supplier of ash handling equipment worldwide. www.diamondpower.com/DP/ASH/ASH/	Malvern, PA	X	X	X
American Coal Ash Association (ACAA) The American Coal Ash Association (ACAA) is a not-for profit 501(c) (6) organization that promotes the beneficial use of coal combustion products (CCPs). CCPs are produced by the burning of coal in a boiler and take the form of fly ash, bottom ash, boiler slag, flue gas desulfurization materials, and other similar materials. CCPs have a myriad of uses that allow the substitution of CCPs for natural or manufactured materials in many processes and applications. www.acaa-usa.org/	Alexandria, VA	X	X	
ASHCOR Technologies, Ltd. ASHCOR Technologies markets coal combustion products produced by ATCO Power's generating stations to the ready mix concrete and oil well cementing sectors. www.canadian-utilities.com/	Calgary, AB Canada	X	X	
AshTech, Inc. Manufacturer of integrated mechanical ash handling systems, chain conveyor systems and mixer-unloader systems. AshTech has engineered and supplied custom mechanical ash handling systems on many types of solid fueled utility and industrial power generating facilities. http://www.ashtechcorp.com	Cleveland, OH	X	X	X
Babcock and Wilcox Babcock & Wilcox supports the owners and operators of electric power plants with boiler products, boiler-related equipment and services and worldwide Engineer-Procure-Construct (EPC) capability for complete power plants. www.babcock.com/	Barbeton, OH	X	X	X
Canadian Portland Cement Association (CPCA) Users of fly ash in the development and manufacture of cement products. www.cpca.ca	Ottawa, ON Canada	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
CCP Ohio. Coal Combustion Product Pilot Extension Program. Ohio State University The statewide CCP extension program is an effort to move coal combustion product utilization technologies and processes from the research and development phases into the marketplace. http://ccpohio.eng.ohio-state.edu/ccpohio	Columbus, OH	X	X	
Center for Applied Energy Research (CAER) The Center for Applied Energy Research (CAER) is one of the University of Kentucky's multidisciplinary research centers. Its energy research provides a focal point for coal and environmental research in Kentucky. Research efforts are directed to: coal cleaning, beneficiation, utilization, and conversion process technologies. Environmental issues relating to fuel use and coal combustion by-products constitute a major effort, along with the derivation of high added-value materials and chemicals from energy resources. http://www.caer.uky.edu/	Lexington, KY	X	X	
Center for By-Products Utilization Research and development organization involved with using by-products, like fly ash, in productive applications such as cement. http://www.uwm.edu/Dept/CBU/	Milwaukee, WI	X	X	
Charah, Inc. Charah, Inc. is an ash management provider for the coal-fired electric utility industry. Charah provides a complete line of ash management services including: landfill management and operations, bottom ash processing and marketing, structural fill applications, beneficial use, ash pond management and Integrated Gasification Combined Cycle (IGCC) slag beneficiation. http://www.charah.com	Madisonville, KY		X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Coal Ash Resource Center (University of North Dakota) The Coal Ash Resources Research Consortium (CARRC) is an international consortium of industry and government representatives, scientists, and engineers working together toward a common goal: to advance coal ash utilization. Specifically, CARRC works to solve coal combustion byproduct (CCB)-related problems and promote the environmentally safe, technically sound, and economically viable utilization and disposal of these highly complex materials. http://www.eerc.und.nodak.edu/carrc/index	Grand Forks, ND	X	X	
Coal Research Center The Coal Research Center was established in 1974 to stimulate and coordinate efforts to improve the efficiency of coal mining and coal use. One of the Center's primary missions is to identify and initiate new research areas, opportunities, and programs that facilitate the development of improved coal extraction and utilization methods. These innovative technologies, which maximize energy yield while minimizing cost and environmental impact, are essential to the growth and development of clean, sustainable, domestic energy. This mission is carried out through the initiation of new programs and approaches to research, community education, faculty development and support, scholarship, and service. http://www.crc.siu.edu/	Carbondale, IL	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Columbia University - Concrete Materials Research For a number of years, research at Columbia University has been conducted to advance the state of the art in concrete technology, specifically to use recycled materials, such as waste glass, reprocessed carpet fibers, and fly ash. Covering the full spectrum of research activities from basic science to commercial production has the advantage of academia/industry feedback and its synergistic effects. Moreover, it offers all those involved, students and staff alike, fulfilling experiences. http://www.civil.columbia.edu/	New York, NY	X	X	
Combustion Byproducts Recycling Consortium (CBRC) More than 100 million tons of solid byproducts are produced by coal-burning electric utilities each year in the U.S. The mission of the Combustion Byproducts Recycling Consortium (CBRC) is to develop and demonstrate technologies to address issues related to the recycling of these byproducts.	Morgantown, WV	X	X	
DC Industrial Plant Services PVT. LTD (DCIPS) DCIPS is a premier organization of its kind in India, renders turnkey project execution services that include design, manufacture, supply, installation and commissioning followed by operation and maintenance of ash handling plants for large thermal power stations and industrial boilers. http://www.dcips.com/company.html	Kolkata, India	X	X	X
Detroit Stoker Company Detroit Handling Systems will handle bottom ash, fly ash, and pyrites from stoker fired, pulverized coal fired, fluid bed fired steam generating units, hot water generators and other types of systems where solid fuels are burned. Ash from the various collecting points is pneumatically conveyed to the ash storage silo. The ash stored in the silo is unloaded at regular periods to trucks or railroad cars for final disposal without creating a dust nuisance, and with a minimum of labor. www.detroitstoker.com	Monroe, MI	X	X	X

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Dustmaster Enviro Systems Dustmaster is the performance proven solution for treating and stabilizing both hazardous and non-hazardous waste materials. http://www.dustmaster.com	Pewaukee, WI	X	X	
Dust Control and Loading Systems, Inc. Dust Control and Loading Systems, Inc, (DCL) is a privately held company developed to provide full dust control loading systems as well as partial components to the bulk material handling industry. www.dclinc.com	Charlevoix, MI	X	X	X
F.L.Smidth Inc. The Pneumatic Transport Division of F.L.Smidth specializes in the design and manufacture of numerous materials handling systems, including those for conveying fly ash. www.fls-pt.com	Bethlehem, PA	X	X	X
Fossil Energy Research Corp. FERCO is an engineering services R&D company specializing in combustion and emissions control. Founded in 1984, the company's goal is to provide research, pilot-scale development, and full-scale evaluation to industry and government in the area of applied energy and environmental systems. www.ferco.com	Laguna Hills, CA		X	
Gardner Denver Blower Division Gardner Denver is a leading manufacturer of positive displacement and centrifugal blowers, and exhauster and vacuum pumps commonly installed in fly ash conveying systems.	Peachtree City, GA		X	X

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Headwaters Resources, Inc. Operating coast to coast, Headwaters Resources is an organization supplying materials derived from coal combustion products. Materials such as fly ash are produced principally at coal-fueled electric power plants. Fly ash use improves concrete performance, making it stronger, more durable, and more resistant to chemical attack. Fly ash use also creates significant benefits for our environment. Headwaters Resources has invested heavily in terminals and transportation equipment to provide reliable service to fly ash purchasers. And Headwaters Resources provides a comprehensive suite of services to utility and industrial generators of coal combustion products. www.flyash.com	South Jordan, UT		X	
Illinois Clean Coal Institute The Illinois Clean Coal Institute (ICCI) Coal Research and Development (R&D) Program is the technical component of the Office of Coal Development (OCD) of the Illinois Department of Commerce and Economic Opportunity (DCEO). OCD deals with developing and conducting the Illinois Coal R&D program. The function of the ICCI is to promote the development and application of new and/or improved technologies that contribute to the economic and environmentally sound use of Illinois coal. This will be accomplished using outside contractors to conduct R&D, evaluation studies and the development of concepts to assist producers and users of Illinois coal in an increasingly competitive marketplace, and to create new markets for Illinois coal. www.icci.org	Carterville, IL	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Industrial Accessories Company Industrial Accessories Company is a high-technology designer and fabricator of pneumatic conveying, dust collection, and bulk material handling equipment, to include baghouses, binvents, filter receivers, pressure blowers & vacuum blowers. OEM (original equipment manufacturer) status gives this organization the discounted buying power to provide replacement parts for all brands of equipment, such as airlocks, knife gates, fans, pipe & tubing, pulse timer boards & panels, bag filters & bag cages, level detector, gauges, hoses, silencers, & much more at very competitive prices. IAC also stocks tubesheets, clean-air plenums, and critical blower components.	Mission, KS			X
Lehigh University, Energy Research Center The Energy Research Center is a multidisciplinary research group involving professional staff, faculty, and students. As the focal point for energy-related research at Lehigh, the Center manages the University's energy research program and serves as the main energy research contact between the University, industry and government. The faculty and staff of the Center participate in many aspects of energy research, with major emphasis on research dealing with energy conversion, power generation and environmental control. The Center's projects cover the spectrum from fundamental engineering and science issues to applied research topics. http://www.lehigh.edu/~inenr/inenr.htm	Bethlehem, PA	X		
Macawber Engineering, Inc. Macawber has pioneered the use of very heavy pipeline loading for ash and other combustion waste materials from boiler plants. Generally known as dense-phase pneumatic conveying the benefits of low energy cost and very low maintenance has been proved in very many installations throughout the world. www.macawberashhandling.com	Maryville, TN	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Marsulex Environmental Technologies Marsulex Power Generation Group provides out-sourced environmental services, primarily air quality compliance, to power generators that enable them to meet environmental compliance obligations, achieve fuel flexibility and access to the savings of lower cost high-sulfur fuel as well as cost avoidance opportunities and enhanced by-product revenues. As the world's largest provider of traditional flue gas desulfurization systems - 157 units in service, 102 of them outside North America - Marsulex understands the needs of power generators. www.marsulex.com	Toronto, ON Canada	X	X	
Metso Minerals Metso Minerals is a leading global supplier of equipment, service and process solutions to industries including quarrying and aggregates production, mining and minerals processing, construction and civil engineering, and recycling and waste management. www.metsominerals.com	New York, NY		X	
Mineral Resource Technologies Mineral Resource Technologies, Inc. (MRT), a subsidiary of CEMEX, Inc. is one of the fastest growing providers of quality fly ash, bottom ash and other pozzolanic products in the US and the leading service provider to the utility industry for coal combustion products (CCP's) management services. MRT also has a complete line of patented manufactured products made primarily of fly ash. www.mrtus.com	The Woodlands, TX		X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Mintek Resources, Inc. Projects in the mining and minerals processing industries have to achieve acceptable technical, performance, and environmental risks. Mintek has developed a spectrum of skills, services, products, and technologies to meet those demands. Our scope of industry support has a history of technological innovation. Carbon-in-pulp gold processing, uranium recovery, gold refineries, DC arc furnaces, plant control systems, and bio-leaching are a firm part of the Mintek pedigree. Our environmental technologies are specially engineered to extract maximum value from dusts, slags and wastes. To add value to metals and alloys we increasingly make use of the science of nanotechnology. http://www.mintek.co.za	Dayton, OH; State College, PA; and Vincennes, IN		X	
National Conveyors Company, Inc. National Conveyors Company, Inc. is an internationally respected engineering and manufacturing firm specializing in the design and supply of bulk materials processing systems for the metal working and power industries. National Conveyors systems are in use worldwide. The company is also frequently retained as a consultant to evaluate complex materials handling issues. www.NationalConveyors.com	East Granby, CT	X	X	X

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
N-Viro International Corporation N-Viro International is a publicly traded company providing waste management technologies and support services and an industry leader in the development of bio-mineral (organic and alkaline materials) treatment technology. Today, over 100 governmental agencies and private companies use N-Viro technologies to manufacture over 1 million tons of product annually. N-Viro technology combines multiple waste/resources within the community, creating value-added commercial products for sale and distribution in lieu of destruction and disposal. N-Viro International will provide licenses to its technologies to all public and private entities. www.nviro.com	Toledo, OH	X	X	
Ohio Coal Development Office The Ohio Coal Development Office (OCDO), within the Ohio Air Quality Development Authority (OAQDA), co-funds the development and implementation of technologies that can use Ohio's vast reserves of high sulfur coal in an economical, environmentally sound manner. This is important as numerous energy forecasts project coal to fuel at least half of the nation's electric power production through 2015 and probably beyond. http://www.ohioairquality.org/	Columbus, OH		X	
Pennsylvania State University, Materials Research Institute MRI coordinates, supports, and performs materials research. MRI provides a focal point for access to Penn State materials research facilities and fosters the creation of formal and informal interdisciplinary groups as well as materials centers that address complex problems in health, the environment, energy, and national security. http://www.mri.psu.edu/	State College, PA	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Pittsburgh Mineral & Environmental Technology (PMET), Inc. Pittsburgh Mineral & Environmental Technology, Inc. (PMET) is a full-service technology development and service company specializing in metals and minerals processing, coal ash utilization, waste stream management, and precision analysis. We develop and commercialize technologies dedicated to waste minimization, waste treatment, and the conversion of industrial wastes to safe, usable, and profitable products. PMET's unique combination of state-of-the-art integrated materials analysis capabilities, process development skills, and pilot plant design and operation capabilities provides full-service solutions to a wide range of materials processing and environmental problems. PMET has assisted mining, minerals, chemical, and metals companies and electric power generators worldwide in improving the efficiency, effectiveness and safety of their operations; reducing waste; and converting formally landfilled wastes into profitable commercial products. PMET's integrated analytical and process development services are performed for clients on a contract basis and are also employed by PMET to develop proprietary technologies currently being commercialized or available for commercialization. http://www.pmet-inc.com/	New Brighton, PA	X	X	
ReUse Technology, Inc. ReUse Technology is a manufacturing organization specializing is the development of agricultural and ash-based construction products.	Kennesaw, GA		X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Sargent & Lundy, LLC Sargent & Lundy provides technical engineering and consulting services to the fossil power industry. Sargent & Lundy is supporting clients across the U.S. and globally with expert air quality engineering, consultancy, and retrofit implementation. Their expertise is state-of-the-art in solving the technical, economical, and regulatory challenges facing owners and operators of fossil-fired power generating facilities. www.sargentlundy.com	Chicago, IL	X	X	
Separation Technologies, Inc. STI has been marketing and processing fly ash since July of 1995. STI's separation technology is the first and only commercial electrostatic based, high volume, fine particle separation process in the world. We have created the first truly differentiated fly ash brand "ProAsh®". An adjacent technology for removing ammonia from fly ash has also been developed. STI devotes significant resources to R&D and technical and economic analysis, to allow it to anticipate and respond to customer needs with new technical and business solutions, and to provide clients with a better understanding of strategic options for their coal combustion products. www.stiash.com	Needham, MA		X	
Solvera Controls Solvera Controls is a leading provider of design, installation, and services for auxiliary control systems in the utilities and heavy industrial markets. Solvera Controls is focused on being the leader in the integration of particulate delivery, conversion, cleaning, and collection and disposal systems. http://www.stockequipment.com/	Solon, OH	X	X	X

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Sphere Services, Inc. Sphere Services is a user of fly ash and other fossil fuel combustion by-products, and a manufacturer of cenospheres. A cenosphere is a lightweight, inert, hollow sphere comprised largely of silica and alumina and filled with air and/or gases. Cenospheres are a naturally occurring by-product of the burning process at coal-fired power plants, and they have most of the same properties as manufactured hollow-sphered products. www.sphereservices.com	Clinton, TN		X	
Stock Equipment Company Stock Equipment specializes in the design and manufacture of coal feeders, mass flowhoppers, and downspouts; coal and other bulk material handling valves; conical nonsegregating coal distributors; feeder and weighing systems for a wide variety of bulk materials. http://www.stockequipment.com/	Chagrin Falls, OH	X	X	X
The Center for Energy Systems Research, Tennessee Technical University The former Center for Electric Power, has changed its name to reflect an expanded research focus while still performing a service to the electric power industry. When considered broadly, energy systems research can direct researchers into many new fields. For example, new composite materials could be more energy efficient to use and to produce. The new moniker easily encompasses the broad spectrum of projects that center researchers are studying from bridge design, to robotics, to construction materials, fluid flow modeling, and of course power plant efficiency. http://www.cesr.tntech.edu	Cookeville, TN	X	X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
The International Center for Aggregates Research (ICAR) ICAR The International Center for Aggregates Research (ICAR) was established by the Aggregates Foundation for Technology, Research and Education (AFTRE). The National Stone Association and National Aggregates Association (NAA), representing the aggregates industry, established AFTRE to promote research, education and technology transfer related to aggregates. http://www.icar.utexas.edu/	Austin, TX	X	X	
The SEFA Group For over a quarter of a century, The SEFA Group has excelled in our mission of maximizing the utilization of coal combustion products for our Utility Partners. Through creative solutions tailored to each utility's situation, The SEFA Group continues to execute proven strategies that make things happen. www.sefagroup.com	West Columbia, SC		X	
Trans-Ash, Inc. Trans-Ash is committed to being the leader in total ash management by challenging conventional methods with superior service to create added value for our customers. www.transash.com	Cincinnati, OH		X	
Tribo Flow Separations, LLC (TFS) TFS provides solutions for purifying dry, fine-sized powders and for measuring the foam capacities of powders and liquids. Using its gas transport, triboelectric purification (TEP™) technology and automated foam index technique (AFIT™), TFS also offers consulting and services, focused and collaborative R&D, and equipment sales. http://www.triboflow.com	Lexington, KY		X	

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
United Conveyor Corporation United Conveyor Corporation (UCC) has devoted its efforts exclusively to the design, supply, construction, and maintenance of ash handling and other abrasive material handling systems. UCC designs custom-engineered systems to meet the specific requirements of an individual power plant or utility installation, or other industrial application. www.unitedconveyor.com	Waukegan, IL	X	X	X
Universal Aggregates LLC Universal Aggregates LLC was formed in January 2000 as a joint venture between CONSOL Energy, Inc. and SynAggs Inc. to commercialize a patented technology developed by CONSOL Energy that converts coal combustion by-products (fly ash, bottom ash, fluidized-bed combustion (FBC), and FGD material) from power plants into a lightweight construction aggregate. www.universalaggregates.com	Bridgeville, PA		X	
W. L. Gore & Associates, Inc. Gore pioneered the use of GORE-TEX® ePTFE membrane for air filtration applications. This single advancement revolutionized filtration theory and practice alike. No longer does filtration efficiency depend on a flow-inhibiting, primary dust cake within the intricacies of the filter media. From startup, GORE-TEX® membrane filtration products provide optimum performance in the form of low pressure drop, near zero emissions, and consistent flow rates. This, coupled with Gore's extensive application knowledge and support team, lets us provide a totally integrated solution for your air filtration needs. For over 30 years W. L. Gore & Associates, Inc. has been providing technically advanced system solutions to meet the needs of a variety of industries. www.gore.com	Newark, DE	X	X	X

Table 9-1 (cont.)
Industry Resources for Fly Ash System Training, Consulting, and Repair

Organization	Location	Training	Consulting	Repair
Western Region Ash Group The Western Region Ash Group is an informal association of producers, users, regulators, researchers and others interested in coal combustion products (CCPs). These materials include fly ash, bottom ash, and flue gas desulfurization residues. Members are involved in reuse of CCPs including researching new applications or making others aware of the many uses of these versatile products. www.wrashg.org/	Littleton, CO	X	X	

10
REFERENCES

10.1 Regulations and Regulatory Guidance

1. Occupational Safety & Health Administration (OSHA) 29 CFR 1910.1000 Table Z-3, Mineral Dusts.
2. Occupational Safety & Health Administration (OSHA) 29 CFR 1910.1000 Table Z-1, Limits for Air Contaminants.
3. Occupational Safety & Health Administration (OSHA) 29 CFR 1915.1000, Air Contaminants.
4. Occupational Safety & Health Administration (OSHA) 29 CFR 1926.55 Appendix A, Gases, Vapors, Fumes, Dusts, and Mists.

10.2 Industry Guidance

1. *Unified Facilities Criteria (UFC) — Design: Central Steam Boiler Plants, Chapter 6: Ash Handling.* U.S. Army Engineering and Support Center, Huntsville, AL: 2003. UFC 3-430-02FA.

10.3 EPRI Technical Reports

1. *Bottom Ash System Maintenance Guide.* EPRI, Palo Alto, CA: 2000. 1000617.
2. *Compressed Air System Maintenance Guide.* EPRI, Palo Alto, CA: 2002. 1006677.
3. *Electrostatic Precipitator Maintenance Guide, Volume 1 of a Two-Volume Set (E213676).* EPRI, Palo Alto, CA: 2003. 1007436.
4. *Electrostatic Precipitator Maintenance Guide, Volume 2 of a Two-Volume Set (E213676).* EPRI, Palo Alto, CA: 2003. 1007690.
5. *Flexible Shaft Couplings Maintenance Guide*. EPRI, Palo Alto, CA: 2003. 1007910.
6. *Fly Ash Exposure in Coal-Fired Power Plants.* EPRI, Palo Alto, CA: 1993. TR-102576.
7. *Gearbox and Gear Drive Maintenance Guide*. EPRI, Palo Alto, CA: 2004. 1009831.
8. *Guideline for System Monitoring by System Engineers*. EPRI, Palo Alto, CA: 1996. TR-107668.
9. *In-Plant Ash Handling Reference Manual.* EPRI, Palo Alto, CA: 1987. CS-4880.
10. *Metrics for Assessing Maintenance Effectiveness*. EPRI, Palo Alto, CA: 2003. 1007604.

11. *Sootblowing Application and Maintenance Guide.* EPRI, Palo Alto, CA: 2001. 1004005.
12. *System and Equipment Troubleshooting Guideline.* EPRI, Palo Alto, CA: 2002. 1003093.
13. *Proceedings: 15th International American Coal Ash Association Symposium on Management and Use of Coal Combustion Products (CCPs): Building Partnerships for Sustainability*. EPRI, Palo Alto, CA: 2003. 1007954.
14. *Guidelines for Using Ash/Organic Waste Mixtures in Horticulture and Turf Production*. EPRI, Palo Alto, CA: 2002. 1004398.
15. *New Air-Entraining Admixtures for Concrete Using High Carbon Fly Ash*. EPRI, Palo Alto, CA: 2002. 1004596.
16. *Development of High Volume Fly Ash Blended Cements*. EPRI, Palo Alto, CA: 2001. 1004030.
17. *Development of Ternary Blends for High Performance Concrete*. EPRI, Palo Alto, CA: 2002. 1004077.
18. *Preventive Maintenance Basis, Volumes 1*-38. EPRI, Palo Alto, CA: 1998. TR-106857.

10.4 Utility Procedures and Maintenance Instructions

1. *Ash Conditioning Plant System Description,* Eskom, Johannesburg, South Africa: 1991.
2. *Ash Removal System Description,* Eskom, Johannesburg, South Africa: 2001.
3. *Ash Stacker System Description*, Eskom, Johannesburg, South Africa: 2001.
4. *Pressurized Fly Ash Systems, System Description A77-1104*, Entergy, Gulf States Utilities, West Lake, LA: 2005.

10.5 Manufacturers' Literature

1. *Fly Ash Conveying System Operating Description,* Nantong Cellulose Fibers Co., LTD., Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
2. *How to Maintain and Service Fabric Filter Dust Collectors, Fabric Filter Pulse-Jet Dust Collectors – Series 45 & 60,* Industrial Accessories Company, Mission, Kansas: 2003.
3. *Installation, Operations & Maintenance Instructions – Model 4024/19 &5024 Utility Mixer/Unloader*, Form No. 91122, United Conveyor Corporation, Revision 10/01.
4. *Installation, Operations & Maintenance Instructions – Walk-In Plenum Filter/Separator*, Form No. 91062, United Conveyor Corporation, Revision 12/03.
5. *Maintenance and Operations Instructions: EV/OV Standard Duty Loading Spout, Model EV20-10,* Dust Control and Loading Systems, Inc., Charlevoix, Michigan: 2004.
6. *Maintenance Instructions: 3" Equalizer Valve (w/ larger housing), MI-B22B-B,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
7. *Maintenance Instructions: Air Gravity Conveyor, MI-C665-1a,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.

8. *Maintenance Instructions: Air Lock Valve, 35 Cu. Ft., Style III/Style IV, MI-V215-7b,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
9. *Maintenance Instructions: Air Lock Valve, Style IV, 25 Cu. Ft., MI-V215-7c,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
10. *Maintenance Instructions: Ashcolite® Piping, MI-P360-1a,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
11. *Maintenance Instructions: ASHvac™ Segregating Valve, MI-V201,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
12. *Maintenance Instructions: Hydrovactor® with Lined Throat, MI-H550-1,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
13. *Maintenance Instructions: Pugmill Unloader, MI-M220-4V,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
14. *Maintenance Instructions: Rotary Feeder (Non-reversing), MI-F150-1Va,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
15. *Maintenance Instructions: Type E Materials Handling Valve, MI-V217-3,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.
16. *Operations and Maintenance Manual: #1700 Pressure/Vacuum Device, Model 1700-03-2431*, Clay & Bailey Manufacturing Company, Kansas City, MO: 2005.
17. *Parts List, Operating and Service Manual: Gardner Denver CycloBlower® Blower/Vacuum Pumps, 7CDL-P Series, 37-1-614, Version 01,* Gardner Denver Blower Division, Peachtree City, GA: 2003
18. *Pressure Fly Ash System Operating Description, Guangdong Zhuhai Power Station, FA-1,* Allen-Sherman-Hoff, Inc., Malvern, PA: 2005.

10.6 Conference Proceedings

1. Hemmings, Berry, Cornelius, Sheetz, “Speciation in Size and Density Fractionated Fly Ash. Characterization of a Low-Calcium, High-Iron Fly Ash,” Materials Research Society Symposia Proceedings, *Fly Ash and Coal Conversion By-Products: Characterization, Utilization and Disposal*, Vol. 86, 1987.

2. Berry, Hemmings, Cornelius, “Speciation in Size and Density Fractionated Fly Ash. The Influence of HCL Leaching on the Glassy constituents of a High-Ca Fly Ash,” Materials Research Society Symposia Proceedings, *Fly Ash and Coal Conversion By-Products: Characterization, Utilization and Disposal*, Vol.113, 1988.

A
FLY ASH MATERIAL SAFETY DATA SHEET

This appendix is a Material Safety Data Sheet (MSDS) for fly ash material.

Product. Fly ash

Hazardous Nature. This product is potentially classified as hazardous depending on jurisdiction and use.

Product Identification. Pozzolan, Fly Ash, Class F Fly Ash, Class C Fly Ash

Use. Supplementary cementious material for concrete and concrete products. Also used in soil stabilization and as a fine filler in asphalt and other products.

Hazardous Chemical Code. Not applicable

Poisons Schedule. Not scheduled

Dangerous Goods Class. Not applicable

Physical Description and Properties

- Appearance. Fine powder, light to dark grey or shades of brown or buff in color.
- Boiling/melting point. Melting point > 1400ºC.
- Vapor pressure. Not applicable
- Percent volatiles. Not applicable
- Specific gravity. 2.05 to 2.8
- Flash point. Not applicable
- Flammability limits. Not applicable
- Auto ignition temp. Not applicable
- Solubility in water. Essentially insoluble. Some Class C fly ashes can have soluble sodium sulfate (1–8%).
- Respirable fraction. Approximately 20–40% of particles are less than 7 microns in diameter (that is, in the respirable range)
- Other properties. Not applicable

Ingredients

Ingredients:

- Silica-Crystalline, as Quartz, 1–5%
- Mullite, 1–5%

> **Note**: Fly ash is a byproduct of coal combustion. The material is composed primarily of complex aluminosilicate glass, mullite, hematite, magnetite-spinel, and quartz. The proportion of quartz (crystalline silica) in the fly ash varies depending on the quartz content of the coal. Class C fly ash can have 1–7% free CaO and calcium sulfate as well as calcium aluminosilicate glass.

Health Hazard Information

Short-Term Exposure

- Swallowed. Unlikely under normal conditions of use. Swallowing fly ash can cause abdominal discomfort.
- Eyes. Irritating to eyes causing watering and redness.
- Skin. Irritating to skin; can cause irritant or contact dermatitis from mechanical abrasion or alkaline composition (Class C fly ash).
- Inhaled. Irritating to the nose, throat, and respiratory tract, causing coughing and sneezing.

Long-Term Exposure

- Swallowed. Not applicable
- Eyes. Not applicable
- Skin. Not applicable
- Inhaled. Repeated inhalation of dust containing crystalline silica can cause bronchitis, silicosis (scarring of the lung), and lung cancer. It can also increase the risk of scleroderma (a disease affecting the connective tissue of the skin, joints, blood vessels, and internal organs). Studies have shown that smoking increases the risk of bronchitis, silicosis, and lung cancer in persons exposed to crystalline silica. It is recommended that all storage and work areas should be smoke-free zones. Inhalation of high levels of fly ash dust can result in severe inflammation of the small airways of the lung and asthma-like symptoms.

First Aid

- Swallowed. Give plenty of water to drink. If any acute gastrointestinal distress occurs, seek medical attention.
- Eyes. Flush thoroughly with flowing water for 15 minutes. If symptoms or irritation persist, seek medical attention.

- Skin. Wash thoroughly with mild soap and water. Some Class C fly ashes are quite hydraulic and alkaline; contact with wet skin can result in burns.
- Inhaled. Remove to fresh air away from dusty area. If symptoms persist, seek medical attention.

Exposure Limits

- Silica-Crystalline, as Quartz: 0.2 mg/m^3 time-weighted average (TWA) as respirable dust.
- Dust (not otherwise specified): 10 mg/m^3 TWA as inspirable dust. However, where a state, territory, or local authority prescribes a lower exposure standard, the lower standard applies.
- Recommendations. Keep exposure to dust as low as practicable. Respirable crystalline silica levels should be kept below 0.1 mg/m^3 TWA and respirable dust below 5 mg/m^3 TWA.

Engineering Controls

Avoid generating dust. When handling fly ash, use local mechanical ventilation or extraction in areas where dust could escape into the work environment. For bulk deliveries, closed pumping systems are recommended. For handling of individual bags, follow instructions below if no local exhaust ventilation is available. Work areas should be cleaned regularly by wet sweeping or vacuuming. If generating dust cannot be avoided, follow personal protection recommendations below.

Personal Protection

- Skin. Wear loose comfortable clothing. Wash work clothes regularly. Apply barrier cream to hands or wear cotton or light-duty leather gloves or equivalent.
- Eyes. Safety spectacles with side shields or safety goggles should be worn if dust is likely to be generated.
- Respiratory. None required if engineering and handling controls are adequate. If dust is generated, wear a suitable particulate respirator. Use only respirators that bear the standards mark and are fitted correctly. Note that persons with facial hair will have difficulty in obtaining a satisfactory face seal.
- Ventilation. Refer to Engineering Controls.
- Flammability. Nonflammable.

Storage and Transport

- Keep in a dry place. When handled pneumatically, use standard dust filters on vehicles and silos.
- Spills and disposal. Follow safety requirements under “Precautions for Use” and wet sweep or vacuum dust with industrial vacuum cleaner. A fine water spray should be used to suppress dust when sweeping. Collect in containers and dispose of as trade waste in accordance with local authority guidelines. Keep out of storm water and sewer drains.
- Fire/explosion hazard. Not flammable. Does not decompose on heating.

B
LISTING OF KEY INFORMATION

B.1 Key O&M Cost Points

Key O&M Cost Point

Emphasizes information that will result in overall reduced costs and/or increase in revenue through additional or restored energy production.

Referenced Section	Page Number	Key Point
2.2.4	2-12	In some rare cases in which distance rules out the use of a vacuum system alone, it can be more economical to combine a vacuum system with a pressure system. The vacuum system, with its simplified controls, removes ash at an optimal rate. The pressure system, reduced to one transfer point with a minimum of controls, then delivers collected ash to any terminal point at a distance of several thousand feet. The combination vacuum/pressure system provides the least complex controls of any long-distance pneumatic conveying system.
5.1	5-3	As a rule of thumb, if the repair costs 50% or less of the replacement cost, repair should be considered. If the percentage is greater, replacement is generally the best option.
7.1.6	7-3	A variety of factors enter into determining disposal costs. The lowest cost occurs when a disposal site is located near the power plant and the material being disposed can be easily handled. If the material can be piped, rather than trucked, costs are usually lower. In these situations, costs can be as low as US $3–5 per ton. In other areas, when a disposal site is far away and the material must be handled several times due to its moisture content or volume, costs could range from US $20–$40 per ton.

B.2 Key Technical Points

Key Technical Point

Targets information that will lead to improved equipment reliability.

Referenced Section	Page Number	Key Point
2.2.1	2-7	Vacuum systems are generally preferable to pressure systems because in the event of a leak in the system piping joints, vacuum systems pull air into the system rather than allowing particulates to escape, thus leaving a cleaner environment. A vacuum system is recommended for capacities of less than 60 tons per hour (TPH) per system. If the conveying distance is more than 800 ft, an evaluation will need to be made to determine whether a vacuum or pressure system is more feasible.
2.2.1	2-8	There are two types of pressure systems: dilute-phase systems and dense-phase systems. Dilute-phase systems usually have an ash-to-air volumetric ratio of 15:1, sometimes as high as 30:1. Dense-phase systems usually have an ash-to-air ratio of 40:1 to 50:1, sometimes as high as 80:1.
2.2.3	2-11	Advantages of the vacuum system include low headroom requirements below the collection hoppers and the ability to stop and restart automatically. Vacuum systems are intended for conveying distances up to 1500 ft (450 m).
2.2.5	2-13	Like all pressure conveying systems, dense-phase conveying systems use pressurized vessels to feed ash into the conveying line. However, these systems operate at pressures up to 60 psig (415 kPa), have smaller pipelines, and require less conveying air flow than the lower-pressure systems. Therefore, dense-phase systems can be used for longer conveying distances than dilute-phase systems—up to 5200 ft (1600 m).
3.1.1.1	3-2	Predictive maintenance tasks are performed based on equipment condition. Predictive maintenance relies on technologies to determine the current condition of the equipment so that only the required maintenance is performed before equipment failure.
3.1.1.2	3-2	Periodic maintenance consists of time-based PM actions taken to maintain a piece of equipment within design operating conditions and to extend its life.
3.1.2	3-2	Corrective maintenance tasks are generated as a result of equipment failure. Corrective tasks are generated when equipment is purposely operated to failure and also when equipment failure is not desired or planned. It is the most basic form of maintenance and also the most expensive. Most plants are moving away from corrective maintenance but a portion of maintenance will always be performed as a result of equipment failure.

B.3 Key Human Performance Points

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent personal injury, equipment damage, and/or improve the efficiency and effectiveness of the task.

Referenced Section	Page Number	Key Point
8.2.1	8-3	Existing data indicate the presence of potentially toxic components such as crystalline silica and arsenic in coal fly ash. Inhalation of crystalline silica and arsenic can cause respiratory tract diseases such as silicosis and lung cancer; exposure to these substances is regulated by OSHA.
8.2.1	8-5	After shutdown of the unit, the fly ash can take a long time to cool down. Therefore, even days after shutdown, the ash can burn personnel coming into contact with it.

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ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Electric Power Research Institute (EPRI)

Objectifs

- Identifier les pratiques en matière de maintenance préventive et corrective des composants de systèmes de transport des cendres
- Aider le personnel d'entretien à l'identification et à la définition des problèmes d'entretien des systèmes de transport de cendre

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- 灰の取り扱いシステムの保全問題の特定と解決のためプラント保全の職員を助けること

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Objetivos

- Para determinar las prácticas de mantenimiento preventivo y correctivo para los componentes del sistema de manejo de ceniza
- Para asistir al personal de mantenimiento de la planta en la identificación y la resolución de los problemas del mantenimiento del sistema de manejo de la ceniza

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ELECTRIC POWER RESEARCH INSTITUTE

3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 USA

800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com