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PNEUMATIC DUST CONTROL IN GRAIN ELEVATORS: GUIDELINES FOR DESIGN OPERATION AND MAINTENANCE

SUBPANEL ON PNEUMATIC DUST CONTROL

Report of the
Panel on Causes and Prevention
of Grain Elevator Explosions
of the
Committee on Evaluation of Industrial Hazards

NATIONAL MATERIALS ADVISORY BOARD
Commission on Engineering and Technical Systems
National Research Council
National Academy of Sciences

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

The report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PLEASE NOTE CAREFULLY

This handbook has been compiled as a guide for designers, installers, and owners of pneumatic dust collection systems. Most of the information contained herein is equally applicable to new and existing facilities.

It must be emphasized, however, that the traditional grain elevator has certain inherent structural features, which render the total control of layered dust virtually impossible by pneumatic means. The difficult areas are typically the interiors of working bins in the headhouse, concrete legwells, tanks and interstice bins.

In any part of the stock handling systems or storage facilities where layered dust can accumulate in significant quantities, there is always the possibility of "cling" dust being dislodged by pressure from a primary explosion or by the dropping of a leg belt. The growth of these layered dust formations will be retarded by a properly functioning dust control system, but their presence should always be anticipated, and appropriate means should be employed to remove them as necessary.

PREFACE

The National Materials Advisory Board is a unit of the Commission on Engineering and Technical Systems of the National Research Council. Its general purpose is the advancement of materials science and engineering in the national interest. It fulfills that purpose by providing advice and assistance to government agencies and private organizations on matters of materials science and technology affecting the national interest, by focusing attention on the materials aspects of problems and opportunities, and by making appropriate recommendations for the solution of such problems and the exploitation of the opportunities.

The Occupational Safety and Health Aministration (OSHA) requested that the National Research Council (NRC) of the National Academy of Sciences undertake a study of the causes and prevention of grain elevator explosions. The NRC through the National Materials Advisory Board (NMAB) appointed the Panel on the Causes and Prevention of Grain Elevator Explosions. This panel serves under the Committee on Evaluation of Industrial Hazards. The panel is composed of experts in many fields related to explosions, the grain industry, and systems analysis.

Grain-handling facilities have suffered from devastating fires and explosions for well over 100 years in this country. A common ingredient in all of these occurrences has been the accumulations of grain dust in sufficient quantities to support such fires and explosions. A variety of approaches has been used in the past to control dust accumulations. One of the most common systems used nowadays is pneumatic dust control, which is the subject matter of this manual. There is a wide variety of designs and sizes of such pneumatic systems with accompanying variations in the degree of effectiveness.

The manual addresses pneumatic dust control system design, installation, operation, and maintenance. Recommendations are made on the necessary qualifications for designers and installers of such pneumatic dust control systems and on guidelines on design, including fundamental principles and suggested specifications. Housekeeping criteria are addressed to minimize both explosive airborne concentrations and dangerous static dust accumulations of grain dust in grain elevators and grain-handling facilities. Guidelines for operation of the system and criteria for determining permissible alterations to the system are presented as well as recommendations for maintenance of the system, including training of personnel. Suggested acceptance test procedures for guidance to grain elevator operators are also given. An appendix is included in which technical terms used in the text are defined.

References to proprietary products are for illustrative purposes only and do not constitute endorsements or recommendations.

It is recognized that certain specific facets of pneumatic dust control are susceptible to further improvement. Therefore, we urge that efforts be made toward removal of explosive dust suspensions from bucket elevator legs, and for dust removal and dust emission control from truck and car dumps. Designers are requested to keep abreast of developments in this and other areas.

I would like to thank the participants in the Subpanel on Pneumatic Dust Control for their untiring efforts in preparing this manual.

Roger A. Strehlow, Chairman

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Section 1

INTRODUCTION

Grain elevators in the United States are designed and operated in such a way that at least 30 of them will suffer a dust explosion in any given year (1). Some of these explosions may cause only minor damage, but people will be injured in roughly half of the incidents, and people will be killed in about one fifth of them. What is more, elevator operators may sustain significant loss of equipment and stock. There can be no question that dust explosions in grain elevators are a serious problem in this country.

Running a grain elevator, like any business, involves certain risks. The key to success lies in managing those risks effectively. Dust fires and explosions are a large part of the total risk in operating grain elevators. Means of preventing fires and explosions, therefore, must play a correspondingly large role in the overall management and operating programs at these facilities.

All elevator operators do a certain amount of risk management. They must keep handling and processing machinery in working order to meet delivery deadlines. They must do preventive maintenance--oiling, repair, replacement, and regular inspection--to avoid costly breakdowns. These activities make good common sense. They also happen to be effective risk management. Employee training and good communications can help prevent mistakes. These activities, too, are good sense and effective risk management.

The elevator manager who recognizes and deals effectively with the risks involved in his business generally has a well-run operation and stands a better chance of showing a profit at the end of the year. Effective risk management, in other words, is effective management. The two cannot be separated.

The first step in managing the risk of dust fires and explosions in grain elevators is to recognize the problem. Many operators say they may have had a few smoldering fires in their elevators, but never an explosion. They seem to think that because they have not yet had an explosion they will never have one. Such operators are relying more on luck than on effective risk management. The only sure way to prevent dust explosions is to eliminate or control their causes.

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(1) Prevention of Dust Explosions in Grain Elevators--An Achievable Goal, U.S. Department of Agriculture, Washington, D.C., 1980.

Causes of Explosions

Grain dust explodes when three conditions occur at the same time. There must be an explosible concentration of dust suspended in air; the dust must be suspended in an enclosed space; and there must be a source of ignition, such as a spark or a hot surface.* To avoid this situation, the elevator operator must enforce sound programs of maintenance, employee training, safety, and physical security and above all he must enforce an efficient housekeeping program to keep his elevator clean.

Housekeeping programs should be based on the fact that the root of the explosion problem is dust. Dust is the material that explodes, and modern, high-speed, grain-handling methods generate large amounts of it. In many explosions the exact source of ignition has been unknown. But the one factor common to nearly all explosions in grain elevators is excess dust. Therefore, although a housekeeping program should prevent the accumulation of trash, spilled grain, discarded tools, and similiar debris, the program should be geared primarily toward dust control.

How well must dust be controlled? Many elevator operators think they need only avoid explosible concentrations of airborne dust in their facilities. That degree of cleanliness is necessary, but it is not good enough. Careful study has shown that layers of dust on floors, ceilings, walls, ledges, and equipment are also a serious hazard. Unusual currents of air, for example, can pick up layered dust, creating an explosible concentration where none existed before. More importantly, an initial explosion can violently disperse layered dust into air, leading to a series of secondary explosions. We now know that the largest part of the damage from grain-dust explosions results from devastating secondary explosions fueled by layered dust (see NMAB report 367-2).

Estimates of the amount of layered dust that is hazardous vary widely for a number of reasons. However, a layer of fine, dry dust only 1/64th of an inch thick inside an elevator can be an explosion hazard. In general terms, if accumulations of dust are visible, the elevator has a potential explosion problem. The thicker the layer of dust, the greater are both the probability of an explosion and the severity of the resulting damage.

Methods of Dust Control

The danger of dust explosions in grain elevators can be reduced or eliminated only by an effective dust-control program. Such a program has three parts: mechanical housekeeping, manual housekeeping, and various measures that minimize the creation of dust. Each of these parts is essential to the program. For example, the operator does not have a choice between mechanical and manual housekeeping--both must be used.

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* For details on explosibility parameters refer to the previous report in this series, NMAB 367-2, "Prevention of Grain Elevator and Mill Explosions."

It should be noted that "dust control" and "dust collection" have different meanings in this manual. Dust control includes all means of combating the grain-dust problem. Dust collection includes only means of collecting dust. Thus a dust-control program, as noted above, includes mechanical and manual housekeeping and measures for minimizing the generation of dust. Mechanical and manual housekeeping, in turn, include various means of collecting grain dust.

The only mechanical housekeeping system that is known to be effective is the pneumatic type. Over the past 20 years, many elevator operators have installed pneumatic dust-collection systems, primarily systems using bag (fabric) filters. However, many of these pneumatic systems do not control dust well enough to reduce either the risk of explosions or the severity of those that occur. They are inadequate even when combined with effective manual housekeeping and dust-minimization measures. Such systems generally have not done the job for several major reasons:

- There are no realistic design standards for pneumatic dust-collection systems for grain elevators.
- Systems are fabricated and installed incorrectly.
- Buyers select the lowest bid, with little regard for the contractor's expertise or reliability.
- Operators do not know how the system should be expected to perform.
- Systems are operated and maintained improperly.

This manual is designed to help correct these shortcomings. It gives detailed information on all aspects of pneumatic dust-collection systems for grain elevators. Abbreviations and definitions of terms used in dust-control work in the grain industry appear in Appendix A. Although the manual is for elevator operators, it contains guidelines for designers, installers, and contractors involved with pneumatic dust-collection systems. The manual also contains much information that should be useful to grain-elevator management.

Section 2

DUST-CONTROL TECHNIQUES AND EQUIPMENT

An efficient dust-control program in a grain elevator, as pointed out in Section 1, has three parts: mechanical housekeeping, manual housekeeping, and methods for minimizing the generation of dust. Mechanical housekeeping using pneumatic systems is the primary subject of this manual. However, the other aspects of dust-control programs deserve brief treatment at this point.

The ultimate goal of a dust-control program is perfection--no dust, either suspended in air or accumulated on surfaces inside the elevator. A sound program must be designed to approach perfection as closely as possible; at least to the point where explosible suspensions and dust layers do not exist. Guidelines aimed at peak performance in dust-control programs appear in Table 2-1.

The human element is extremely important in dust control, as in other areas of elevator operation. Well-trained and vigilant employees are vital to a successful program. Equally vital is well-organized and effective management. In this vein, one person on each shift in an elevator should be assigned the responsibility and authority for implementing the dust-control program. This individual should report directly and only to the senior manager of the elevator.

Minimizing Generation of Dust

Normal elevator operations will always produce dust, but there are ways to minimize the effect. The more the grain is handled and agitated, the more dust is produced. More efficient handling of stock, therefore, will reduce the generation of dust. Deeper layers of grain on conveyor belts are helpful. It is also helpful to avoid long free-falls and steep-angle descents of grain in spouts and to choke those spouts where these problems cannot be avoided. Besides reducing the generation and dispersal of dust, avoidance of long free-falls reduces the amount of air entrained by falling grain and carried into enclosed sections of the elevator. Reducing entrained air, in turn, reduces the load on the mechanical dust-collection system.

Manual Housekeeping

Manual housekeeping is always necessary in a grain elevator. The extent of the need depends on the effectiveness of the other parts of the dust-control program. That is, the need for manual housekeeping depends on how well the generation and dispersal of dust are controlled and on how well the mechanical system keeps dust from escaping from enclosed sections of the facility. The key to a good manual program is to anticipate the need for cleanup and schedule it accordingly. Removing dust after it has accumulated--if only to a depth at which footprints first become visible--is not good housekeeping. It is playing catch-up, and it is hazardous.

TABLE 2-1 Guidelines for Dust Control in Grain Elevators

1. Techniques for preventing or reducing the generation of dust shall be used at all possible locations.

2. Pneumatic or other mechanical dust-collection techniques shall be used at all dust-producing locations in or adjacent to a facility.

3. Pneumatic dust-collection systems shall be designed and operated to capture virtually all dust emitted from the stock stream and so prevent the occurrence of explosible concentrations of airborne dust and subsequent layering of dust.

4. Manual cleanup shall be scheduled and performed so as to prevent the accumulation of settled dust at any location in quantities which, if dispersed into the air, could support propagation of an explosion at that location.

5. Manual cleanup should be applied to all surfaces in a facility as needed.

6. Vacuuming should be the preferred technique for manual cleanup inside facilities.

7. Aspiration of legs and other components of stock-handling systems shall be applied to minimize the airborne dust therein.

8. Interior parts of stock-handling systems should be designed and aspirated to minimize suspensions and formations of layers.

9. Blow-down of settled dust with compressed air is a hazardous cleanup method because it can create explosible concentrations of airborne dust. If blow-down is used for major accumulations of dust on surfaces not accessible to other cleaning techniques, all stock-handling equipment should be shut down and remain out of operation until the dust has substantially settled and been removed.

The manual-housekeeping schedule needed to control dust effectively in an elevator can be determined by experience. However, the manager can estimate his housekeeping needs by means of certain measurements.

Dust inside an elevator can be removed manually by several methods: broom and shovel, blowing down, washing down, and vacuuming. One problem with broom and shovel is that surfaces covered with hazardous but very thin layers of dust--as little as 1/64 inch thick--may look clean to a sweeper, who may thus ignore them. Blowing down with compressed air may create an explosible cloud of dust and, at best, simply redistributes most of the layered dust. Washing down with a hose is rare in this country, but also can initially create explosible clouds of dust. Vacuuming (with a cleaner approved for use in Class II, Group G locations) is the preferred method for manual cleanup. Vacuuming can collect small amounts of dust extremely well. Also, it does not disperse dust into the air, so that normal operations need not be shut down during cleanup by vacuuming.

Mechanical Housekeeping

Mechanical housekeeping systems in grain elevators have been designed traditionally to keep dust from escaping from enclosed sections of these facilities. However, mechanical systems of the pneumatic type evidently can do more than prevent emissions of dust. Recent tests in operating grain-handling facilities suggest that properly designed pneumatic systems can prevent airborne dust in enclosed spaces--such as elevator legs--from reaching concentrations high enough to explode. These very promising results have not yet been fully confirmed and further testing is under way.

Pneumatic dust collection involves only a few common-sense principles. Grain dust is heavier than air and so becomes airborne only when disturbed in some way. Once airborne, dust settles by gravity if left undisturbed. Apart from the effect of gravity, airborne dust moves only when carried by the air it is suspended in. The air, in turn, moves in response to differences in pressure. Furthermore, air moves from areas of higher pressure to areas of lower pressure. Grain dust in an enclosed space, therefore, can be controlled by controlling the air flow associated with the system.

Dust-collection systems using these principles have five basic components. exhaust fans, capture enclosures, ductwork, dust-separation devices, and storage bins. These components are described in general terms in the remainder of this section. Their application to dust-control problems is described in detail in subsequent sections of this manual.

Exhaust Fans

An exhaust fan is a centrifugal or axial device that maintains a difference between the air pressures on its intake and exhaust sides. The pressure is lower than atmospheric on the intake side of the fan and higher than atmospheric on the exhaust side. In a dust-collection system, dust is captured on the low-pressure, or intake, side of the fan and discharged on the high-pressure, or exhaust, side if the fan precedes the filter in the system. If the order is the reverse, the dust is removed by the filter, and the cleaned air is exhausted on the high-pressure side of the fan.

A fan reduces the pressure on its intake side and increases the pressure on its exhaust side. Air and entrained dust are forced through the system solely in response to the differences between these pressures and atmospheric pressure.

Ductwork

The intake ductwork in a pneumatic system connects the low-pressure side of the exhaust fan to all points in the system where the internal pressure must be lower than atmospheric.

When a pneumatic system is operating, atmospheric pressure forces air and entrained dust into the system. The intake ductwork channels the air and dust to the intake side of the fan. Here the air and dust are transported to the exhaust side of the fan, where the higher-than-atmospheric pressure forces them through the discharge duct to the filter or other dust collector.

The pressure in a duct always has two components: static pressure (SP) and velocity pressure (VP). Static pressure at any point in a duct is the pressure exerted on the wall of the duct. Velocity pressure in a duct is the pressure that a moving stream of air would exert on a flat plate at right angles to the direction of movement of the air. The sum of the two pressures is the total pressure (TP), i.e., TP = SP + VP.

If the pressure on the wall of the duct is lower inside than outside, the static pressure is said to be "negative." If the reverse is true, the static pressure is "positive." The velocity pressure, on the other hand, is always positive.

Dust-Collection Devices

Industry in general uses four basic types of devices to remove dusts and other particles from air. The four types are wet scrubbers, electrostatic precipitators, mechanical collectors or cyclones, and fabric filters. Cyclones and fabric filters are in common use in the grain industry, although the use of cyclones is declining. Following are the characteristics of the four types of devices.

Wet Scrubbers. Wet scrubbers remove particles from air by scrubbing it with water (e.g., sprays, water spinners, wetted bed collectors). The devices are effective on a wide range of particle types and sizes. As particle size decreases to the fine range, however, the energy consumption of a wet scrubber rises sharply. Also, ordinary water cannot be used in wet scrubbers mounted out-of-doors in cold climates. For these reasons and others, the devices find virtually no use in the grain industry.

Electrostatic Precipitators. The electrostatic precipitator uses high voltage to attract electrically charged particles to the collecting surfaces. Normal operation of the devices involves a certain amount of sparking, so they cannot be used with combustible and explosive grain dust. Such a device has been field-tested by a grain company, but the results are not yet available.

Mechanical Collectors. A mechanical collector or cyclone induces a spinning action in a stream of air in a cylindrical vessel with a conical bottom. Particles are thrown out of the airstream and collected. The cyclone is limited by its inability to separate fine or very light particles. Thus the use of the device in the grain industry is declining as the Environmental Protection Agency grows more concerned over the discharge of fine, inhalable particles to the atmosphere.

Fabric Filters. Fabric filters or baghouse units filter particles from air with high efficiency. Moreover, they are efficient for particles of widely varying size, including very fine and very light particles. The initial cost of a fabric filter is several times the cost of a cyclone. Also, the filters must be carefully maintained and operated to retain their design performance. Nevertheless, the air discharged from a baghouse is extremely clean, and the devices are the best available for dust collection in the grain industry.

Dust-Control Terminology

Abbreviations and definitions of terms used in dust-control work, as noted earlier, are given in Appendix A. However, explanations of three basic terms--pressure, volume flow, and velocity--are in order here.

Pressures in pneumatic dust-control systems usually are stated in inches of water. A pressure of 1 inch of water, for example, is the pressure exerted by a column of water 1 inch high, or 0.0361 pounds per square inch (psi). A pressure of 1 inch of water is also the velocity pressure exerted by air moving through a duct at approximately 4000 feet per minute (fpm). Atmospheric pressure (14.7 psi) is 407.5 inch of water.

Volume flow is the volume of air moving through a duct. Usually it is given in cubic feet per minute (cfm). In a branch duct, the volume flow is the same at all points. In a main duct, the volume is the sum of all the volume flows in the branch ducts.

Velocity is the speed of the air moving through a duct. Usually it is given in feet per minute. Velocity is equal to the volume flow divided by the cross-sectional area of the duct in square feet (sq ft). For a given volume flow, velocity may be increased by making the duct smaller and decreased by making it larger. This also introduces pressure drops in the duct.

Use of Pneumatic Systems

The practical use of pneumatic systems to collect grain dust in elevators is explained in detail in subsequent sections of this manual. The treatment starts with points of emission of dust from enclosed and open sources. It then proceeds in order through dust-collection hoods and transitions, ductwork, filter collectors, and fans. Finally, installation and acceptance of pneumatic systems, as well as training of plant personnel in the operation and maintenance of pneumatic systems are presented.

Section 3

HOODS, TRANSITIONS, AND DUCTWORK

A pneumatic dust-collection system has four main components: the hoods and other enclosures; the ductwork; the filter or other dust collector; and the exhaust fan. The system also includes transitions, the fittings that link hoods and other enclosures to the ductwork. Each component must be properly designed, fabricated, installed, and operated. If any one of them is defective in some way, the system will not work well. This section covers important aspects of dust-collection hoods, transitions, and ductwork.

Capture Velocity

Air must flow into hoods or other suction inlets fast enough to carry dust with it. This minimum capture, or pickup velocity is 200 fpm.

It has been thought that 200 fpm is the maximum permissible inlet velocity. Air at higher velocities, it was believed, would capture whole grain as well as dust. However, recent experiments have shown this belief to be incorrect (Appendix D). Minimum pickup velocities for eight grains were found to range from 900 fpm (for oats) to more than 2,200 fpm (for soybeans). There is thus no need to limit air inlet velocities to 100 or 200 fpm, which has been fairly common practice. In fact, air at velocities below 200 fpm often will not capture airborne grain dust.

A velocity of at least 200 fpm is not the only requirement at suction inlets in a pneumatic dust-collection system. Some minimum volume flow--in cubic feet per minute--is also required. For a given hood or other enclosure, the required minimum flow of aspiration air is the sum of three quantities:

1. The volume of air displaced by entering grain (1.25 cfm times the number of bushels of grain entering per minute).

2. The volume of air entrained by the entering grain.

3. The volume of air required to provide the minimum capture velocity (200 fpm times the area of the opening into the enclosure in square feet).

The required volume of aspiration air will differ at different hoods or other pickup points. Volume flows and velocities also must differ elsewhere in a pneumatic system if it is to operate properly. For example, the volume flow in a main duct is the sum of the volume flows in the branch ducts leading into it.

The total suction on a system is determined by the fan. At a given total suction, however, volume flow and velocity at various points in a system depend on its design. As noted in Section 2, decreasing the diameter of a duct increases air velocity at constant volume flow. To double velocity at constant volume flow, the cross-sectional area of the duct must be cut in half. Similarly, decreasing the inlet area of a hood increases the velocity of the entering air at constant volume flow. The movement of air can also be varied by inserting a restriction, or blast gate, in a duct.

Hood and Transition Design

Several basic points must be considered in the design and installation of dust-collection hoods. First, air moves from all directions toward hoods or other openings under suction. The pattern of movement toward a plain, circular opening is shown in cross section in Figures 3-1 and 3-2.

In these figures, the direction of air movement from points near the hood is indicated by the lines (streamlines) leading into the opening. The curved lines marked with percentages (velocity contour lines) indicate velocity relative to the velocity at the opening, or face velocity. The contour line marked 100 percent represents the face velocity. Let us say, for example, that the face velocity is 300 fpm. In that case, the velocity at any point on the contour line marked 60 percent is 180 fpm, and so on. In other words, velocity toward the hood from any direction declines sharply with increasing distance from the opening.

A hood's performance depends on the associated air movement (volume flow and velocity) and the size and shape of the opening. These characteristics are interrelated. Figures 3-1 and 3-2, as specified above, depict air movement near plain, circular openings. However, the same principles apply to other types of openings. A method of calculating airflow or velocity near hoods of various types is given in "Industrial Ventilation"[1].

We have already seen that the minimum capture velocity for grain dust is 200 fpm. On this basis, air entering a hood should have a velocity of at least 200 fpm around the perimeter of the opening. Velocity should increase to not more than 800 fpm at the entrance to the transition linking the hood to its branch duct. At higher velocities, energy losses from air friction and turbulence become excessive. For the same reason, transitions should be tapered so that velocity increases gradually to that required in the branch duct.

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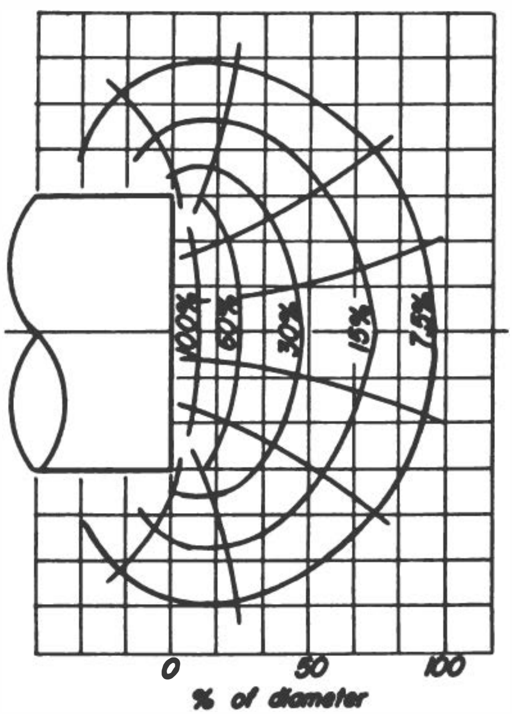
[1] Industrial Ventilation," A Manual of Recommended Practice, 16th Edition, American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation, Lansing, Michigan, 1980.



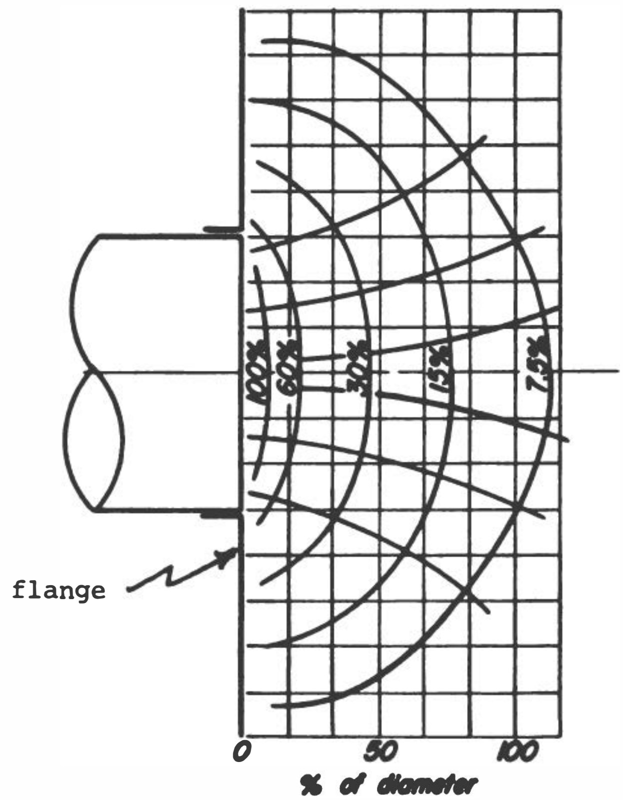


FIGURE 3-1 FIGURE 3-2
Velocity contours (expressed in percentage of opening velocity) and streamlines for circular openings. (from "Industrial Ventilation," 16th Edition, 1980)

Hood Placement

Hoods should be designed and placed so that larger pieces of airborne grain avoid capture and settle back into the grain stream while the smaller airborne dust particles are captured by the hood (Figures 3-3 and 3-4). It is extremely important, in order to maintain the recommended minimum inlet velocity of 200 fpm, that hoods have flexible side skirting in contact with the conveyor belt. The designer, when calculating air volumes, should remember that he must design for grain displacement and entrained air as well as the open area of a hood to maintain a minimum inlet velocity of 200 fpm. (See Table 3-1 and Figures 3-5, 3-6, and 3-7.) It is also recommended that the upstream and downstream ends be skirted so as not to interfere with the maximum grain stream. As a rule of thumb, the hood transition should be at least 12 inches from the grain stream. However, the proper distance and hood design will depend on a number of factors including belt speed, belt width, method of feeding the belt, idler spacing, and the physical room available. In many cases where there are a number of belt loaders loading onto a single belt in series, the installation of a continuous belt cover with suction being applied at several points along the belt is the best method of controlling the dust. (With this method or in any hood design, extreme caution should be used by the designer to avoid any internal horizontal surfaces which could collect dust.)

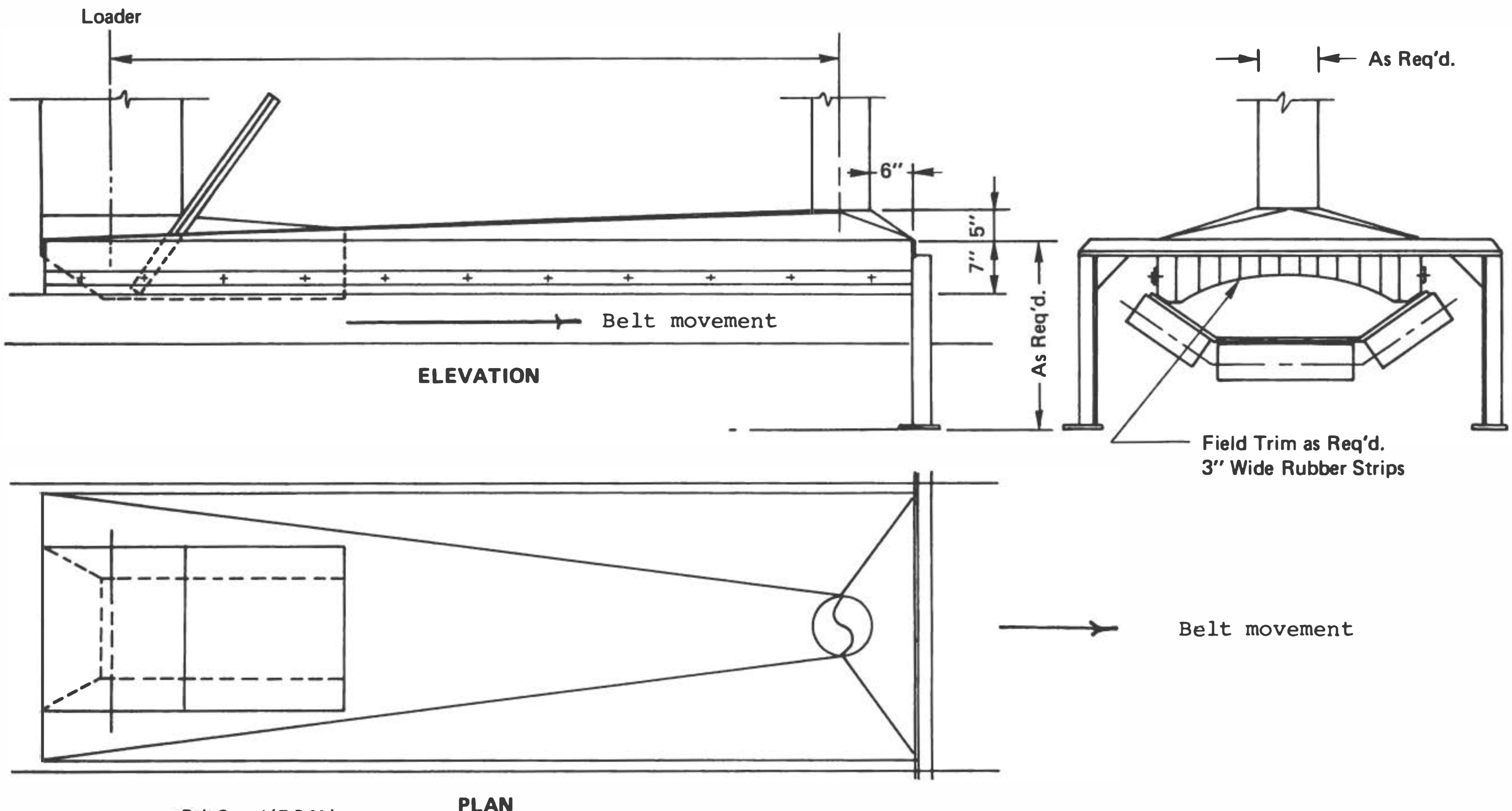
Hoods should be installed vertically, where possible. A vertical hood is entirely self-cleaning--that is, airborne particles not captured will fall from the hood by gravity. If practical, the transition should taper evenly on all four sides, with a maximum taper of 30 degrees. In some instances, hoods must be installed horizontally because of physical constraints. The bottom of a horizontal suction hood should be sloped at least 55 degrees from the horizontal.

Examples of improperly designed hoods are shown in Figure 3-8.

Ductwork Design

The ductwork in a pneumatic system connects all dust-collection points to the exhaust fan. Each combination of hood, transition, and branch duct is a simple dust-collection system in itself. Thus a complex system is really an arrangement of simple systems connected to a common main duct.

After the first step in designing a system, which is to select the proper hood or other enclosure for each dust pickup point, the volume flow and velocity at each hood determine the size of the branch duct from that hood. The main duct is then sized to handle the combined airflows from the branch ducts at a velocity high enough to transport dust.



$$X = \text{Belt Width (ft)} + \frac{\text{Belt Speed (F.P.M.)}}{100}$$

NOTE:
Hood can be supported with hangers
if layout permits.

FIGURE 3-3 Loader hood.

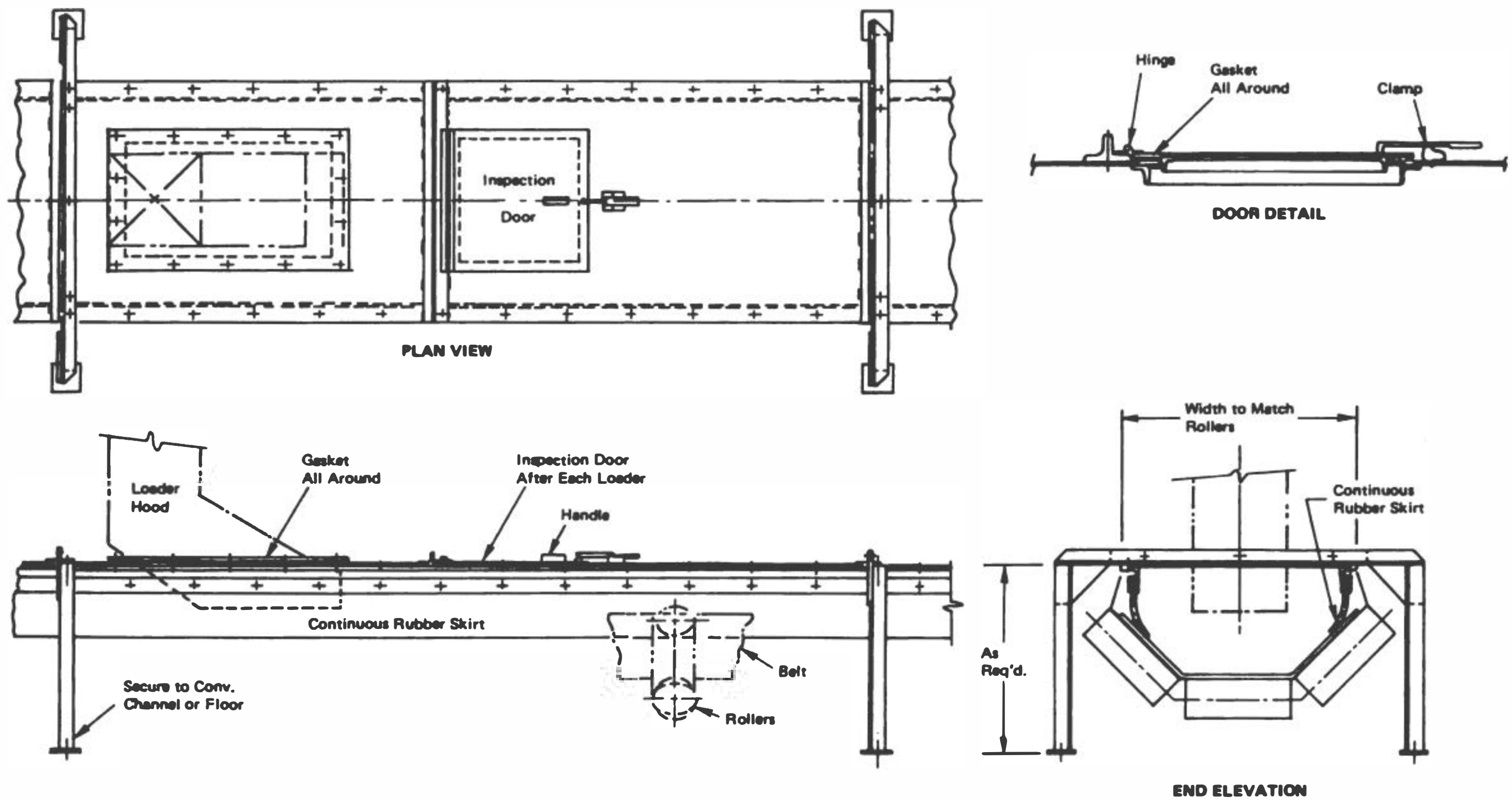


FIGURE 3-4 Continuous belt hood.

TABLE 3-1 Calculations for Design of System Shown in Figure 3-5.

Pickup Point	Pickup Location	Velocity, fpm	cfm	Duct System: Diameter, in.	Duct System: Length of Straight Run, ft	Duct System: Elbow	Duct System: Branch	Equivalent Straight Run	Static Pressure
Example 1:									
1			800	6					
2			1000	7					
3			1750	9					
	Filter to hood no. 1	3851	3550	13	20			20	0.34
	Note: This is the pickup that deter-						13 x 9 x 9	8	0.14
	mines the maximum	4074	1800	9	50			50	1.39
	static pressure						9 x 7 x 6	6	0.17
	in inches of water	4073	800	6	25			25	1.09
						(1)6" x 90°		7	0.30
				6	10			10	0.44
			3550						3.87

Summary: Total cfm = 3550 ÷ 10 A/C = 355 ft^2 cloth required
Filter selection: Model no. XYZ, bag filter with 355 ft^2 cloth
Primary cyclone used: none required

Total Static Pressure Calculation:

1. Equivalent straight run resistance = 3.87
2. Pickup hood resistance = 2.00
3. Cyclone resistance N/A
4. Filter resistance = 6.00
5. Other (filter to fan) = 0.50

Total system static pressure (in. water) = 12.37

Note: Use 12.5" to size fan.

Example 2:

Pickup Point	Pickup Location	Velocity, fpm	cfm	Diameter, in.
4 added to existing system	Note: If a pick up no. 4 is added to the system without changing the filter, fan, or duct size, the actual cfm at each pickup point is reduced to 81.6 percent of design cfm. The new cfms are as follows:			
1		3324	653	6
2		3053	816	7
3		3222	1427	9
4		3324	653	6

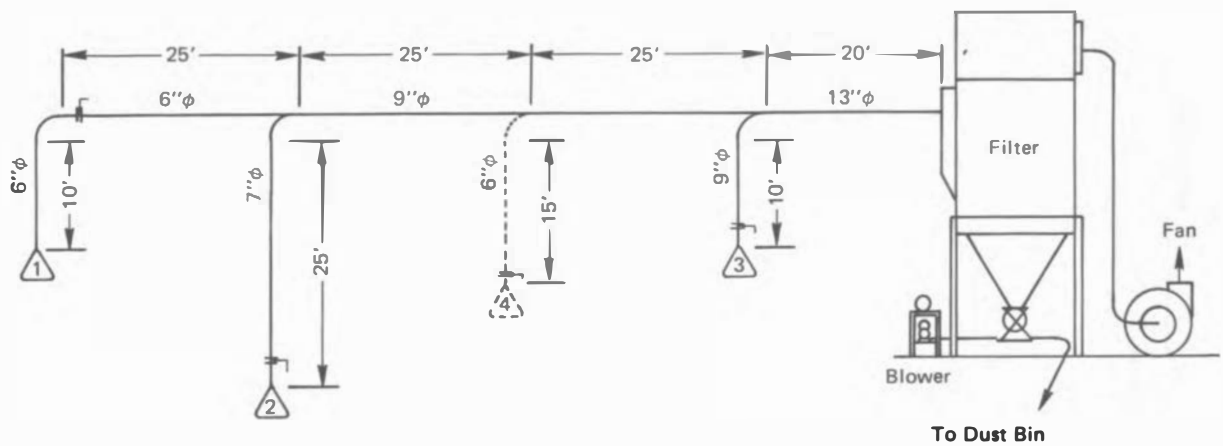
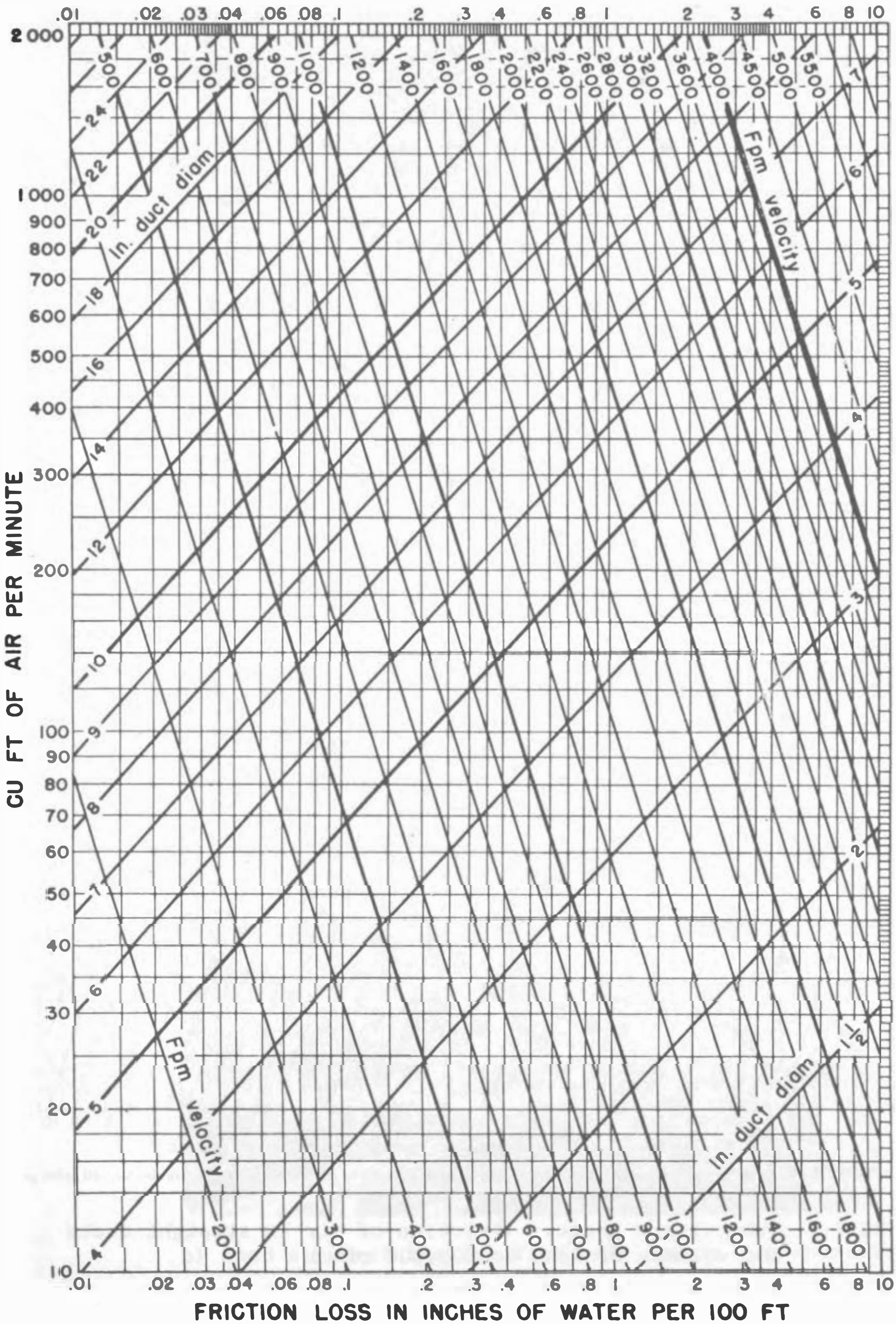


FIGURE 3-5 Typical dust-collection system.



(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.) Caution: Do not extrapolate below chart.

FIGURE 3-6 Tube sizing chart. (Friction of air in straight ducts for volumes of 10 to 2000 cfm.)

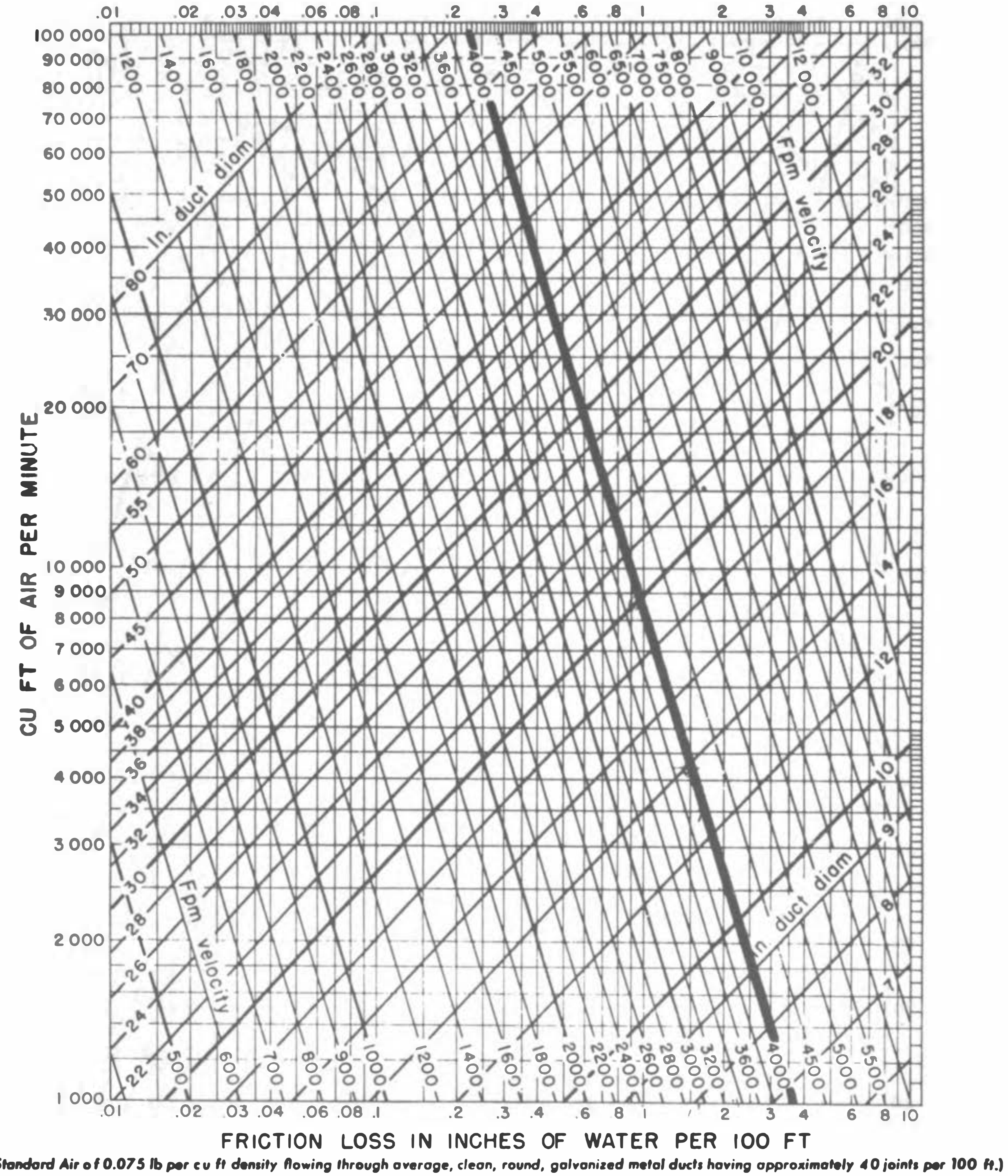
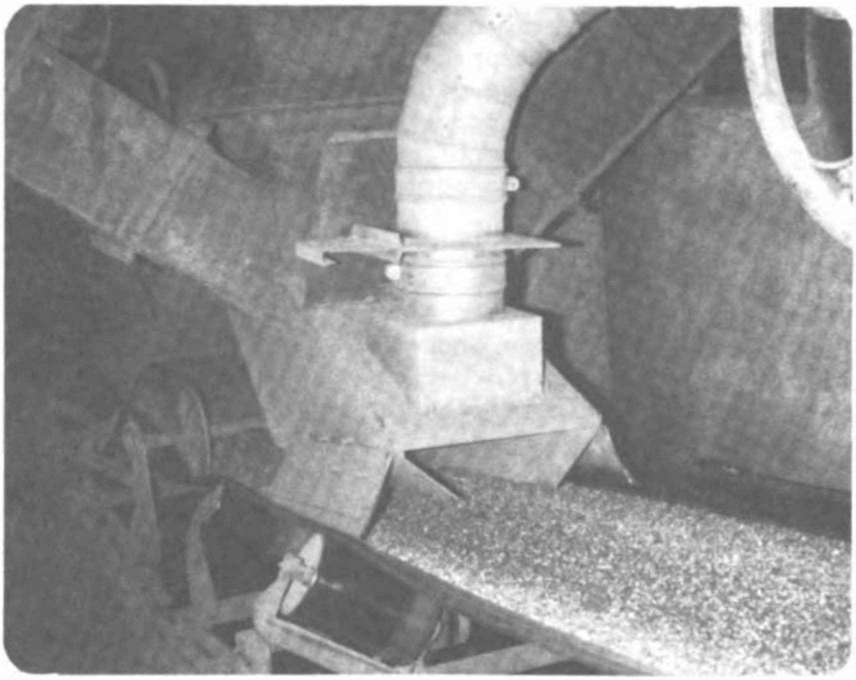
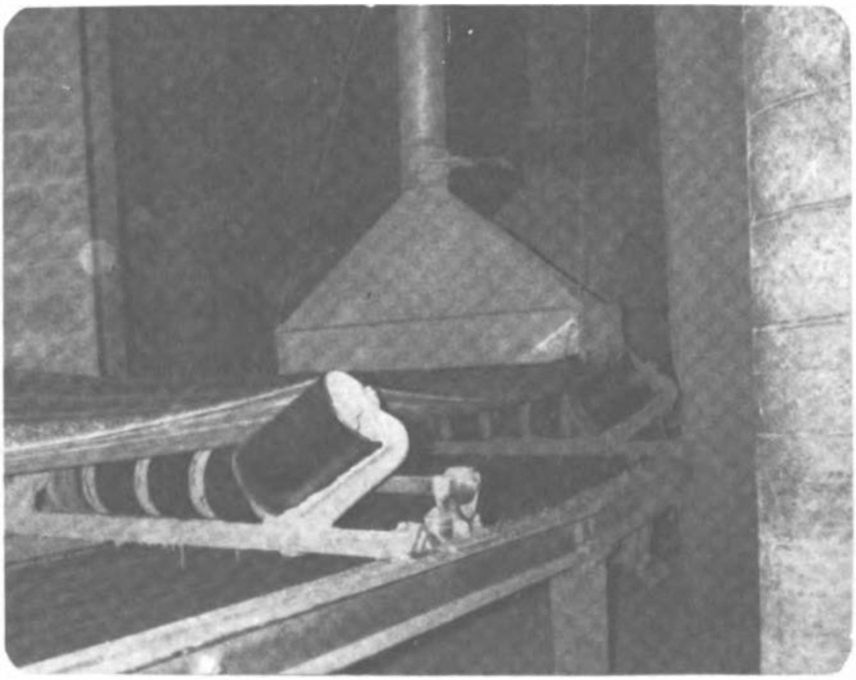


FIGURE 3-7 Tube sizing chart. (Friction of air in straight ducts for volumes of 1000 to 100,000 cfm.)



a) Emission areas not covered by suction hood.



b) Hood situated too far from belt and is not skirted.

FIGURE 3-8 Improperly designed suction hoods.

Each component of a system causes a decrease in static pressure, or pressure loss, relative to atmospheric pressure due to friction of air flowing in the duct. It is this pressure decrease, as pointed out in Section 2, that permits atmospheric pressure to force air through the system. The sum of the pressure losses in the components of a system is the static pressure of the system. This static pressure, or suction, must be provided by the exhaust fan selected for the system.

It is important to recognize that ductwork is more than a conduit for air--a good deal of solid particulate material can be transported along with the air. Proper design of hoods and other enclosures will insure that only light, flotation dust is captured during normal operation. However, during abnormal conditions, larger particles of grain can also enter the system. Therefore, ductwork should be designed to transport abnormal amounts of solids without clogging. In addition, clean-out doors should be provided in all ducts that could be carrying grain.

Duct Velocity

The single most important design specification for ductwork is the velocity. It was noted above that air must flow through a duct at least fast enough to transport the captured dust. This minimum velocity is called the transport velocity. Normally, a velocity of 4,000 fpm all the way to the fan will assure good operation without clogging problems. However, there is room for judgment through a range of 3,500 to 4,500 fpm. At some pickup points, where abnormal conditions are unlikely, transport velocities at the lower end of the range may be employed. At other pickup points, such as elevator boots, occasional surges are more likely. Ductwork from these points should be designed for velocities at the higher end of the range.

Minimizing Horsepower

In vertical runs that are self-cleaning, velocities considerably lower than 3,500 fpm may be used. Lower velocities require less pressure drop and so reduce horsepower demand.

Other ways to minimize horsepower demand may be detected by carefully examining the entire system. For example, a long run of small branch duct with low airflow will require much more pressure drop than the average branch. If the entire system is designed to provide the high suction needed by this branch, the required horsepower will be higher (often by 20 to 30 percent) than would otherwise be needed. In such cases, it might be better to install a small, separate collector close to the distant source of dust. In this way the main system would be freed from operating at unduly high suction.

Bends and Branch Entries

To maintain a uniform velocity in ductwork, generous radii should be provided at all bends and branch entries. Also, abrupt enlargement or contraction of duct diameters should be avoided. Sharp changes in the direction and diameter of ducts increase friction and turbulence, which upset flow. Turbulence and abrupt changes in direction also may cause larger particles to settle and plug the duct, regardless of the nominal air velocity. Furthermore, increases in friction and turbulence increase the horsepower demand on the system. Guidelines for design of elbows and other duct fittings appear in Figures 3-9, 3-10 and 3-11.

Balancing the System

A pneumatic system must be designed so that airflow is properly distributed among the branches. Otherwise, the system will not produce the airflow required at each hood or other pickup point. Designing for proper distribution of airflow is called balancing the system. To achieve proper airflow distribution, therefore, the static pressures in all ducts entering a junction must be the same. A system can be balanced in three basic ways: the balance method; the blast-gate method; and the plenum method.

In the balance method, each branch is designed to have the correct pressure loss up to the main duct. The designer simply calculates the duct diameter that will produce the desired pressure loss. The balance method requires more design time than the other methods. However, it avoids the need for adjustable restrictions in ducts, which can lead to improper operation. A system designed in this way has limited flexibility because changes or additions require recalculation of the entire system. Also, extra high velocity is often needed in short branches near the filter or other collector to achieve enough pressure loss to maintain balance. Unusually high velocities can lead to excessive wear by abrasion. In some cases, however, effective use of high-loss flexible hose can result in proper pressure loss without extra high velocity.

The blast-gate method achieves balanced airflow by means of an adjustable restriction, or blast gate, in each branch. This approach simplifies design calculations. However, it complicates start-up because each blast gate must be adjusted for proper flow. When each blast gate has been adjusted, it should be locked in position with a pin to prevent tampering. When blast gates are placed in horizontal runs they should be placed at the top of the duct so that they will not act as dams and knock occasional large particles from the flowing air.

The plenum method employs a low-velocity plenum, or duct, equipped with a dust-removal system. Air need not flow at transport velocity because any airborne material that settles is conveyed away. This approach is especially useful where many branches are required in a relatively compact space.

Which method should be used to balance a pneumatic system? There is no universal answer. The blast-gate method is the most popular in the grain industry, primarily because of its operational flexibility. However, each installation should be evaluated on its own merits by a competent engineer. In a few cases, the correct duct system is none at all. That is, the best choice is to use bin-vent collectors at individual locations.

Materials of Construction

Low-carbon steel is the construction material used most commonly in pneumatic dust-collection systems. The metal must withstand normal corrosion and also erosion--a high-velocity stream of grain dust can be extremely abrasive. Also, ductwork and other enclosures under suction must withstand pressure equivalent to the difference between the internal static pressure and atmospheric pressure. The metal in each duct should be of a gauge that will withstand the maximum negative pressure that can be imposed on the duct.

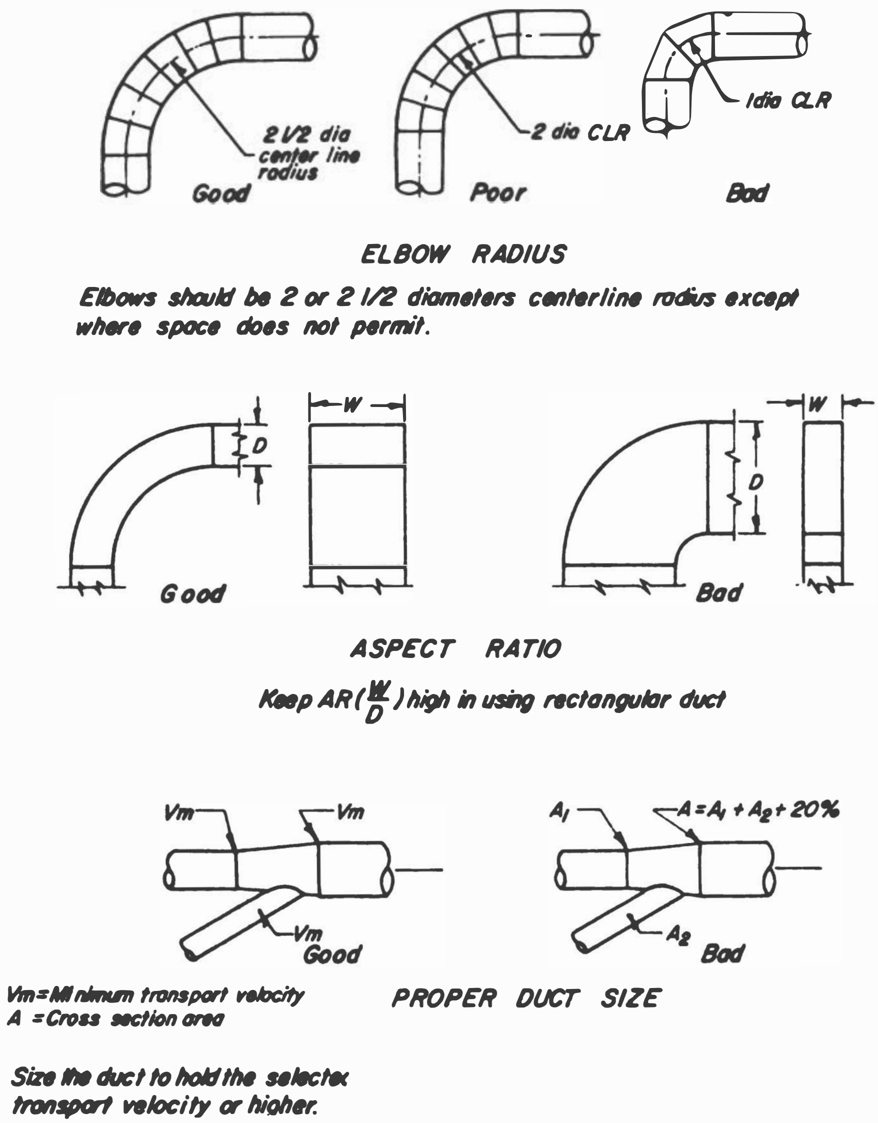


FIGURE 3-9 Principles of duct design. (from "Industrial Ventilation", 16th Edition, 1980)

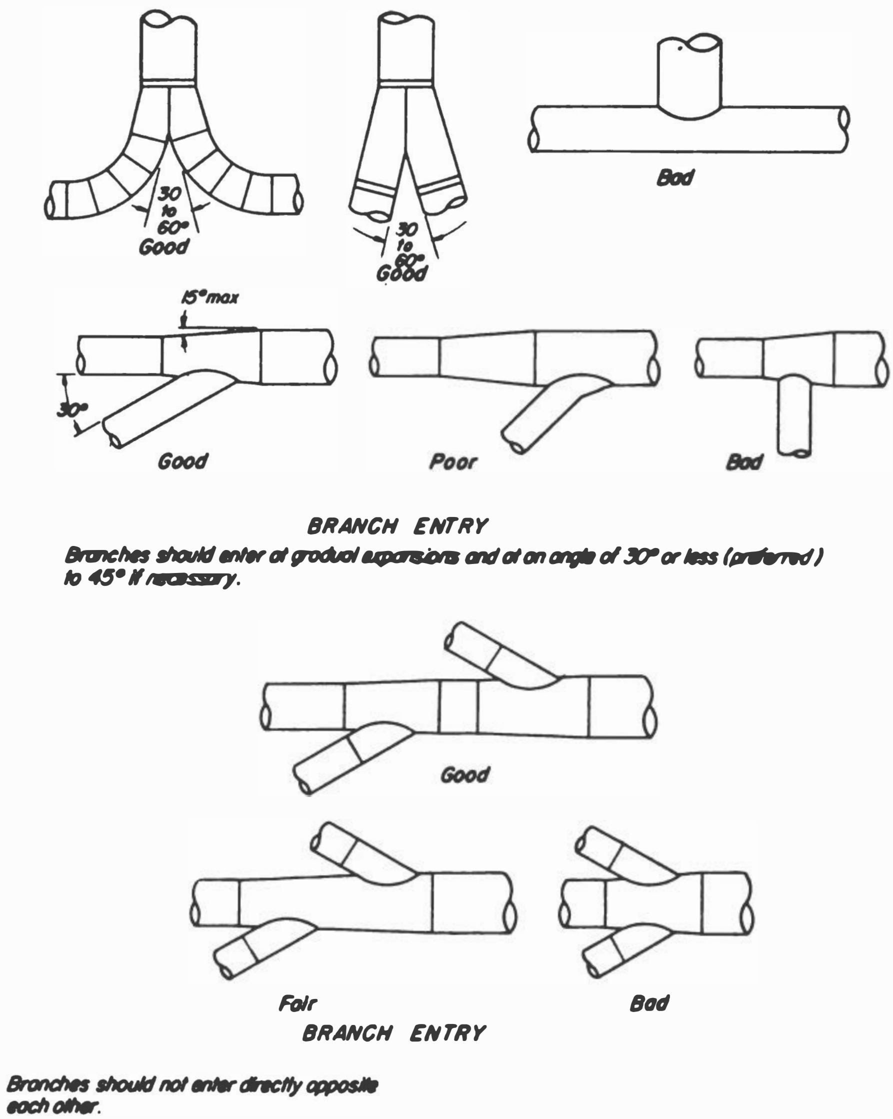


FIGURE 3-10 Principles of duct design.
(from "Industrial Ventilation", 16th Edition, 1980)

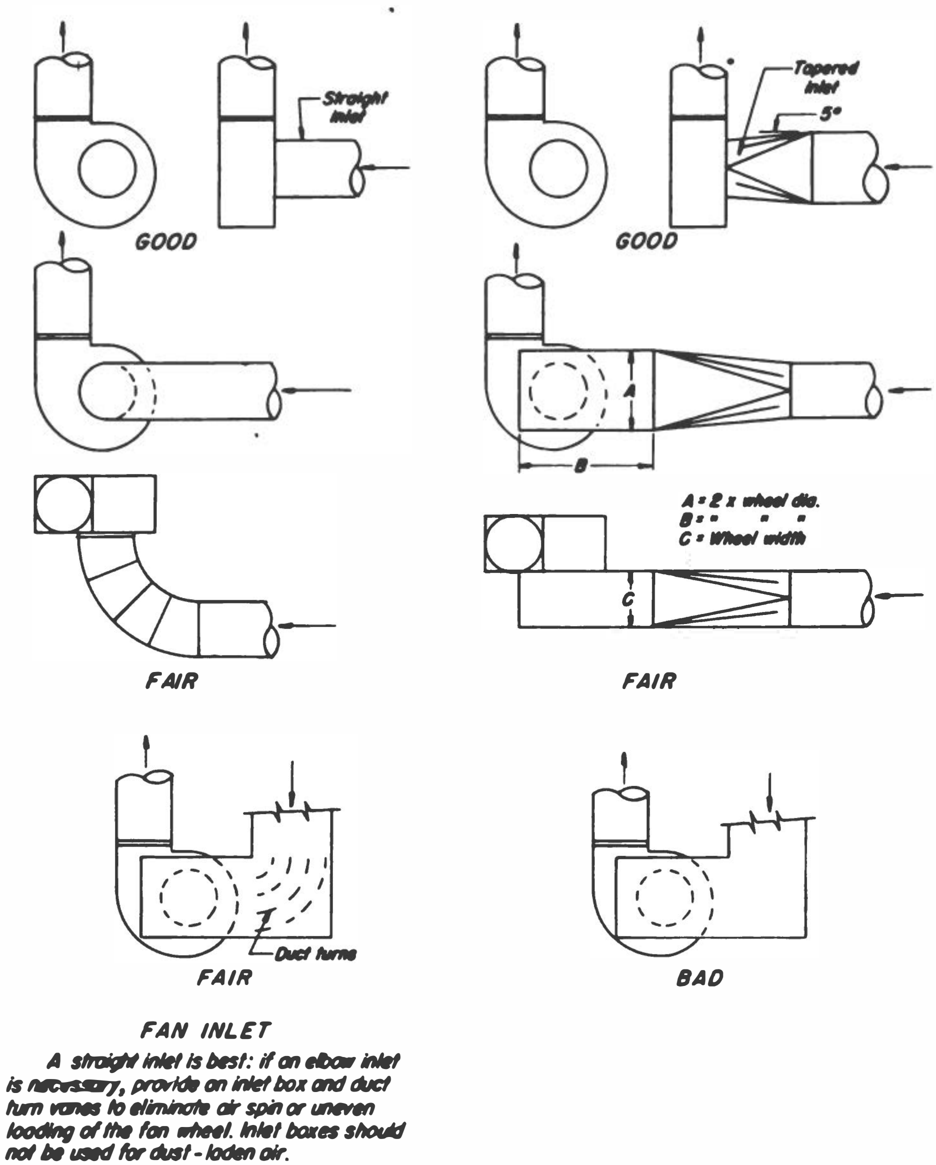


FIGURE 3-11 Principles of duct design.
(from "Industrial Ventilation", 16th Edition, 1980)

Suggested gauges for straight ducts are given in Table 3-2. It may be wise to use heavier gauges in areas where ductwork is exposed to bumping by forklifts or other materials-handling equipment. The metal in elbows and angles should be at least two gauges heavier than in straight ducts of equal diameter. The metal in hoods should be at least two gauges heavier than in straight connecting branches.

TABLE 3-2 Suggested Gauges for Ductwork Under 15"' Static Pressure[a]

Duct Diameter	Gauge
Under 8 inches	20
8-18 inches	18
18-30 inches	16
More than 30 inches	14-12

[a] See "Round, Industrial Dust Construction Standards," Sheet Metal and Air Conditioning Contractors, National Association, Inc., Vienna, VA., 1981, particularly where static pressure exceed 15".

Section 4

DUST FILTERS

A pneumatic system in a grain elevator exhausts to the atmosphere through an air-cleaning device that removes the collected dust for disposal. The most effective air-cleaning device now used in elevators is the fabric filter (sometimes called baghouse). A less effective device, the cyclone, is also used. (See Section 2 for a general comparison of these and two other devices, wet scrubbers and electrostatic precipitators.)

The great advantage of the filter is its efficiency. The device efficiently collects large particles as well as very small (submicron) and very light particles. The cyclone, on the other hand, does not collect fine or very light particles effectively. A well operated filter collects particles at an overall efficiency of more than 99 percent. Cyclones, in contrast, are 60 to 95 percent efficient.

Particles small enough to be inhaled tend to pass through a cyclone uncollected. Because such particles have become an environmental concern, the use of cyclones in the grain industry has been declining. However, the devices are often used in series with filters. This dual arrangement is covered at the end of this section; otherwise the section is devoted to fabric filtration.

Fabric-Filtration Practice

A typical filter is shown in Figure 4-1. The fabric is in the form of stockings (tubes or rocks) in the figure, but other designs employ fabric leafs (envelopes). As the filter operates, a mat of dust builds up on the dirty side of the fabric. It is this mat that filters dust from the entering air. Resistance to airflow increases as the mat builds up, so the accumulated dust must be removed periodically. It may be removed by shaking or vibrating the fabric or by use of air in reverse flow, reverse jet, or reverse pulse. The dust dislodged falls into the lower chamber, or hopper, and is discharged through the air lock. At intervals, all bags or stockings must be removed from the filter and cleaned thoroughly.

Air-to-Cloth Ratio

An important factor in the performance of a filter is the air-to-cloth ratio--the cubic feet per minute of air being filtered per square foot of fabric in the filter. The best air-to-cloth ratio for a filter depends on factors such as the dust being handled, the design of the filter, and the filtration fabric, or medium.

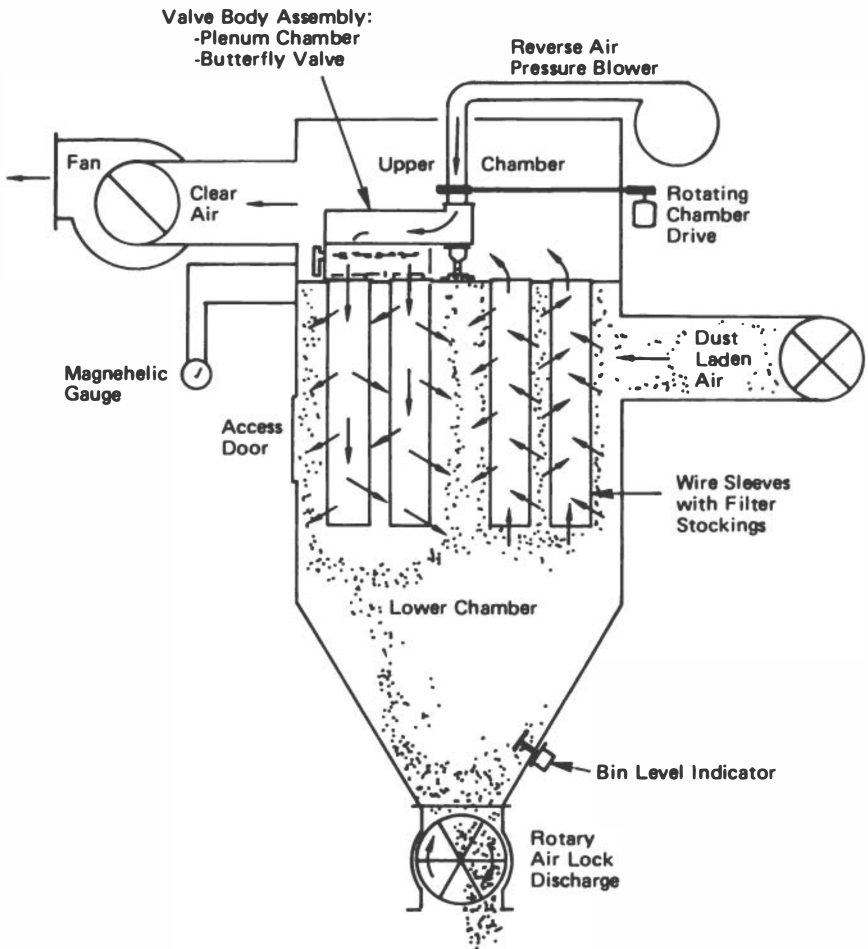


FIGURE 4-1 Typical fabric filter.

Filter performance and optimum air-to-cloth ratio also vary with humidity and the salt content of the air. However, humidity and salt content are high enough to be significant only in a coastal area reaching from Texas to Maryland (Figure 4-2). This coastal belt extends 50 to 100 miles inland.

Filters are generally classified as high-ratio or low-ratio. High-ratio filters use felt media with continuous cleaning, such as reverse-pulse or reverse-flow cleaning. Air-to-cloth ratios in high-ratio filters should not exceed 9 to 1 in the coastal belt described above. Elsewhere in the United States, they should not exceed 11 to 1. Low-ratio filters use woven media cleaned by shaking, gentle reverse flow, or intermittent methods. Air-to-cloth ratios in low-ratio filters should not exceed 2.5 to 1 in the coastal band (see Figure 4-2). They should not exceed 3 to 1 elsewhere in the United States. (See also last paragraph of this Section, under Cyclone-Filter Facilities.)

Air-to-cloth ratios higher than recommended here can be used, and the filter can be made correspondingly smaller. However, higher ratios increase maintenance and operational problems and shorten bag life. They also increase pressure loss across the filter and so increase energy costs. Furthermore, ratios higher than recommended above sometimes give less effective dust control. Lower air-to-cloth ratios tend to minimize maintenance, increase bag life, reduce pressure loss and energy costs, and give generally more trouble-free operation.

Caution should be used with air-to-cloth ratios in elevators handling any product other than whole grain. More conservative (lower) ratios should be considered for products such as malt, beet pulp, oil seeds, and low-density powders.

Filter Collector Location

Selection of a location for a filter at a grain elevator should be guided by the distinct hazard involved. The filter will contain a large amount of grain dust that can support either a fire or an explosion. Therefore, it is highly advisable that filter collectors be located so as to present the minimum exposure to elevator personnel.

A bag filter collects the smallest and driest particles of dust in the elevator. This dust makes excellent fuel. Only an ignition source is needed to set it on fire. Because the fire would occur in the confined space of the filter collectors, airborne dust in that space could explode. Explosible concentrations of dust may easily be dispersed into the air by pulse-cleaning or by an explosion propagating into the filter. An explosion in a filter produces a fireball of significant size, although we have no way as yet to predict its exact size. Venting may considerably reduce damage to a filter in the event of an explosion. However, venting also will markedly increase the size of the fireball but venting must be done in such a way to minimize danger to personnel.

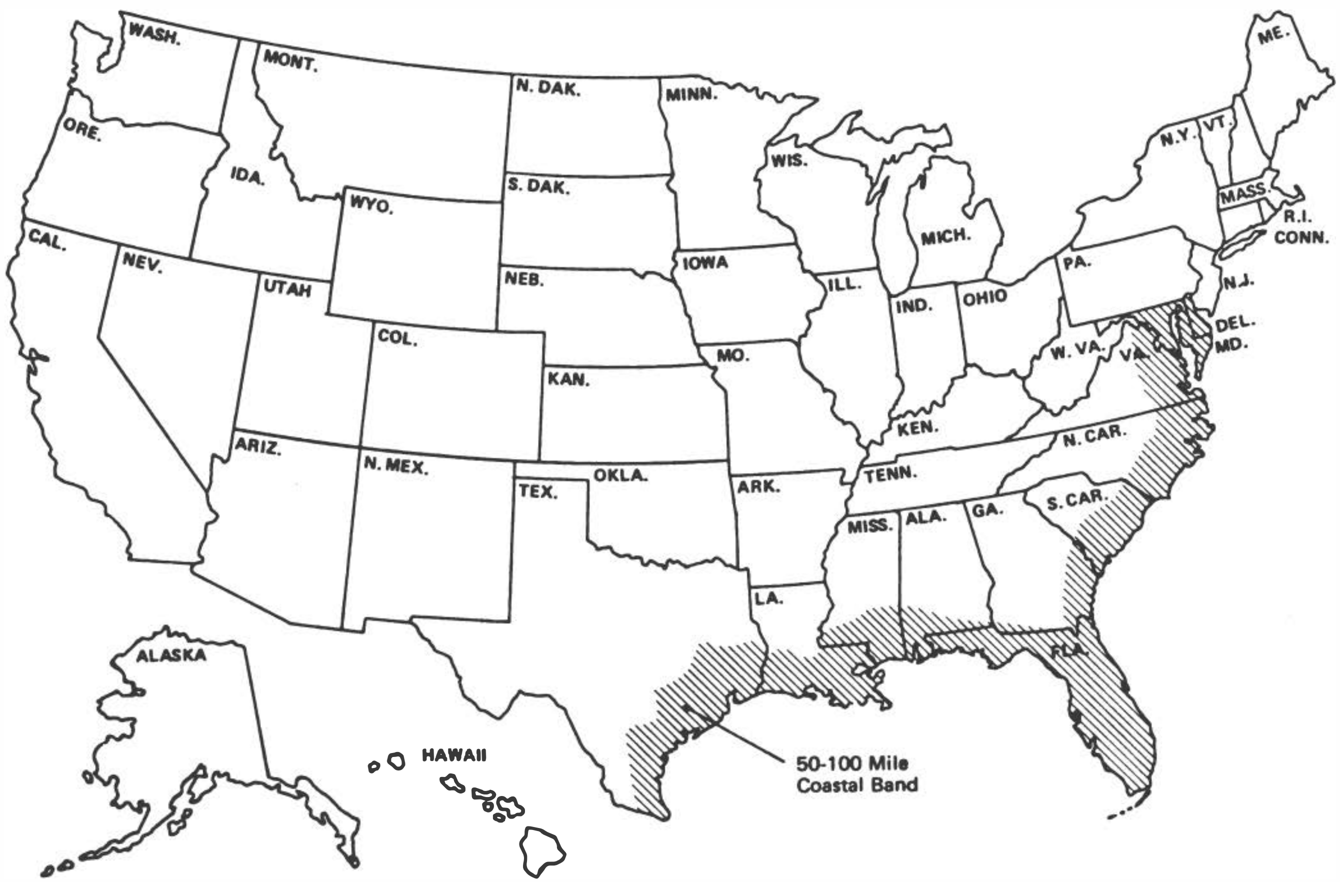


FIGURE 4-2 Coastal band of high humidity.

A filter should be situated for ease of maintenance, as well as in the interest of safety. If the unit is installed off the ground, maintenance can be eased by use of catwalks and ladders. Instruments for checking the performance of the filter should be in the elevator's control room where they can be monitored continually. A baghouse should also be located so that it can conveniently feed the dust-storage facility, whether by gravity or mechanically or pneumatically. A final consideration is noise from the exhaust fan. However, if the filter is located remotely because of the explosion hazard, noise should not be a problem.

Filter Materials and Construction

Materials and type of construction for a bag filter should be selected on three general grounds: ease of assembly and installation; service life; and maintenance requirements. The optimum materials and construction may vary for particular installations. With any filter, however, attention should be paid to the following points:

1. Magnehelic gauge or manometer.
2. Gauge of housing.
3. Type of service platform and access ladder.
4. Adequate liners at wear points.
5. Life and class rating of bearings and gear reducers.
6. Wind-loading, dead-loading, and seismic requirements of structural legs.
7. Type and construction of air lock--machined housing, close tolerance; nonmachined housing, flex tip.
8. Rating of motor--Totally enclosed, fan cooled, Class II, Group G.
9. Explosion vents and vent ratio. Housing should have high enough pressure rating to withstand rupture pressure of vents.
10. High-temperature limit switch.
11. Negative pressure rating of filter housing.

Selection of Filter Media

The selection of filter media should be based on:

1. Type of filter.
2. Type of dust being handled.
3. Temperature of air being handled.
4. Unusual characteristics of air and its contents: acidic, alkaline, moisture, etc.

Filter media can be made of a variety of materials. Those available include cotton, wool, polyester, acrylic, nylon, Nomex, and polypropylene. Wool is used rarely because it is costly and does not retain its size and shape well in service. Acrylic fiber, like wool, is costly and is used only in special applications in the starch industry. Nylon is used occasionally in acidic conditions, but has no advantages in the grain industry. Nomex, a heat-resistant fiber, would be used only where process air was hotter than 250°F. Cotton, polyester, and polypropylene are the most widely used filter materials in the grain industry. Of these three, polyester is the most common.

Filter media are made in woven form or as felts. Woven media are relatively lightweight and are used primarily in shaker and reverse-flow filters. The material can be cotton, polyester, or polypropylene. Felt media, the more common form, are used basically in reverse-jet and pulse-jet filters. They are made by needling or shrinking a loose, continuous blanket of fibers into a dense felt.

Polyester is by far the most common fiber in felts. Normal weight for polyester felt is 12 to 19 ounces per square yard. The fiber is relatively inexpensive and holds its size and shape well in service. Polyester also can be laundered or dry-cleaned and so can be renewed indefinitely.

Polyester felt can be made with a slick surface (eggshell finish) on one or both sides. This type of surface provides better dust release and has been found beneficial in high-humidity areas like the Gulf Coast. A smooth finish also can be produced by singeing the fibers at the surface of the felt with a direct flame. This type of finish also improves dust release in humid areas.

Polypropylene felt is favored by some over polyester because it gives better dust release. The two fibers are basically interchangeable, however. Their costs are similar, as are their retention of size and shape in service.

A few new types of filter media are said to offer ultrahigh efficiencies for submicron particles. One of these media is a felt-back membrane with extremely small pores. Another is an arrangement of pleated paper. These media, along with the so-called absolute filters, would be considered for cleaning air to be returned to the inside of the building. Returning air to a building is a questionable practice, however, especially if the dust involved is flammable, explosive, or toxic.

A word of caution is in order on the selection of filter media for specific installations. Generally, the medium recommended by the manufacturer of the filter will be the most suitable. Woven fabrics usually will blind (dust will plug the pores) or otherwise work inefficiently on a reverse-jet filter and should not be considered for such facilities. Also, lightweight felts (8 to 10 ounces per square yard) should be avoided.

Disposal of Collected Dust

Grain dust discharged from a filter remains a serious fire and explosion hazard. The collected dust should always be disposed of with these hazards in mind. The following practices are recommended.

Transporting Dust

Collected dust may be conveyed to storage mechanically over a short distance with one or no change in direction. Long, complicated screw or drag conveyors require their own dust-collection systems, which only add to the problem.

Dust is best moved longer distances pneumatically. Metallic, electrically conductive pipe should be used. Long-sweep elbows and other features in accord with good engineering practice should be employed. Nonconductive plastic pipe should be avoided because of the risk that static electricity will create hot spots, which are a potential ignition source. A pneumatic transport system must supply enough air to fluidize the dust and transport it to storage.

Dust Storage

Dust should be stored in a noncombustible tank not housed in a building. The tank should be located so as to minimize the length of charging and discharging conveyors. The hopper should have a minimum angle of 60 degrees, and one side of the discharge opening should be flush with the side wall. If the dust is to be stored for a considerable time, the bottom of the tank may require some sort of mechanical agitation for loadout to preclude bridging or other condition problems. The tank should only be large enough to hold 10 days' production of dust or 150 percent of the capacity of the vehicle being loaded, whichever is greater.

Returning Dust to Grain Stream

Where a long, complicated dust-transport system would be required, it may be desirable instead to return the collected dust to the grain stream. However, the dust should not be recirculated through the grain-handling and dust-collection systems. Such recirculation can be avoided by the following restrictions:

1. Dust should not be returned to bucket elevators.
2. Dust should always be returned to the grain downstream from the point where it was first collected.
3. Dust should not be returned to spaces around machinery where it would again be drawn into the dust-collection system.
4. Dust returned to conveyors or spouts must be returned so that it is beneath the grain stream.

Disposal Alternatives

Alternative methods of dust disposal are slurrying in water and agglomerization or pelletization. Particularly at elevators associated with processing plants, water containing slurried dust can be employed in the process. Grain dust can be agglomerated or pelletized to yield a product that can be handled safely. The pelletizing process has inherent fire problems and must be separated from the grain-handling operation by a fire wall. Magnets should be installed ahead of the pellet mill to scavenge tramp metal. Fire monitors also must be installed.

Cyclone-Filter Facilities

Cyclones are commonly used in series with bag filters in grain elevators. The exhaust fan must have additional horsepower to handle the pressure drops across both cyclone and filter. The advantage is that cyclones tend to collect a higher percentage of larger particles, which can be returned to the grain stream. The smaller particles tend to pass through the cyclone to the filter, where they are collected for disposal in some other way. However, dust collected by the cyclone may still contain a good deal of fine, dry material. Therefore, this dust should be returned to the grain with the same precautions that apply to dust from the filter.

Use of a cyclone ahead of a bag filter does not as a rule affect the optimum air-to-cloth ratio of the filter. The dust loading on the filter is lower with the cyclone than without it. On the other hand, the filter is less efficient. The reason is that the larger particles captured by the cyclone would otherwise contribute to the collection efficiency of the mat of dust that builds up on the filter fabric. These factors--lower dust loading and lower efficiency--tend to balance each other. Thus, although adding a cyclone reduces the dust loading on the filter, it does not permit the air-to-cloth ratio to be increased.

Section 5

EXHAUST FANS

The exhaust fan on a pneumatic dust-collection system creates the differences in pressure that cause air to move through the system. In practical terms, the fan must meet the system's requirements for airflow and static pressure. These and other criteria for selecting fans are covered in this section.

The main classifications of fans are axial flow and centrifugal. Types of fans in each classification are shown in Figures 5-1 and 5-2. The performance curves of axial-flow fans make them generally too inflexible for dust-collection systems in grain elevators. However, they are sometimes used as in-line pressure boosters. The most common exhaust fan in grain elevators is the centrifugal type with straight or radial blades (see Figure 5-2).

Selecting a Fan

To select the proper exhaust fan for a dust-collection system, the designer must have the following information:

1. Airflow required by the system (cubic feet per minute).
2. Static pressure (pressure drop) across the system.
3. The kind of material that will pass through the fan (abrasive, corrosive, etc.).
4. The flammability or explosivity of the material.
5. Whether direct drive or belt drive is best.
6. Limitations on space.
7. The permissible level of noise.
8. The operating temperature.

Points 4, 5, and 8 call for brief discussion.

If the material to be handled is explosive or flammable--and grain dust is both--the exhaust fan should be nonsparking. Also, a fan motor that is to operate in the air stream should be approved for Class II, Group G. The installation should meet the standards of the National Board of Fire Underwriters, the National Fire Protection Association, and state and local ordinances.

Direct-drive exhaust fans make a more compact assembly than belt-driven fans. Direct drive also insures constant speed by avoiding the slippage that can occur when belt drives are not maintained properly. Direct drive limits the speed of the fan to the speed of the motor (excepting direct-current motors), whereas belt drive permits fan speed to be changed quickly. However, belt drives can be sources of ignition if they fail and so should not be used inside elevators.

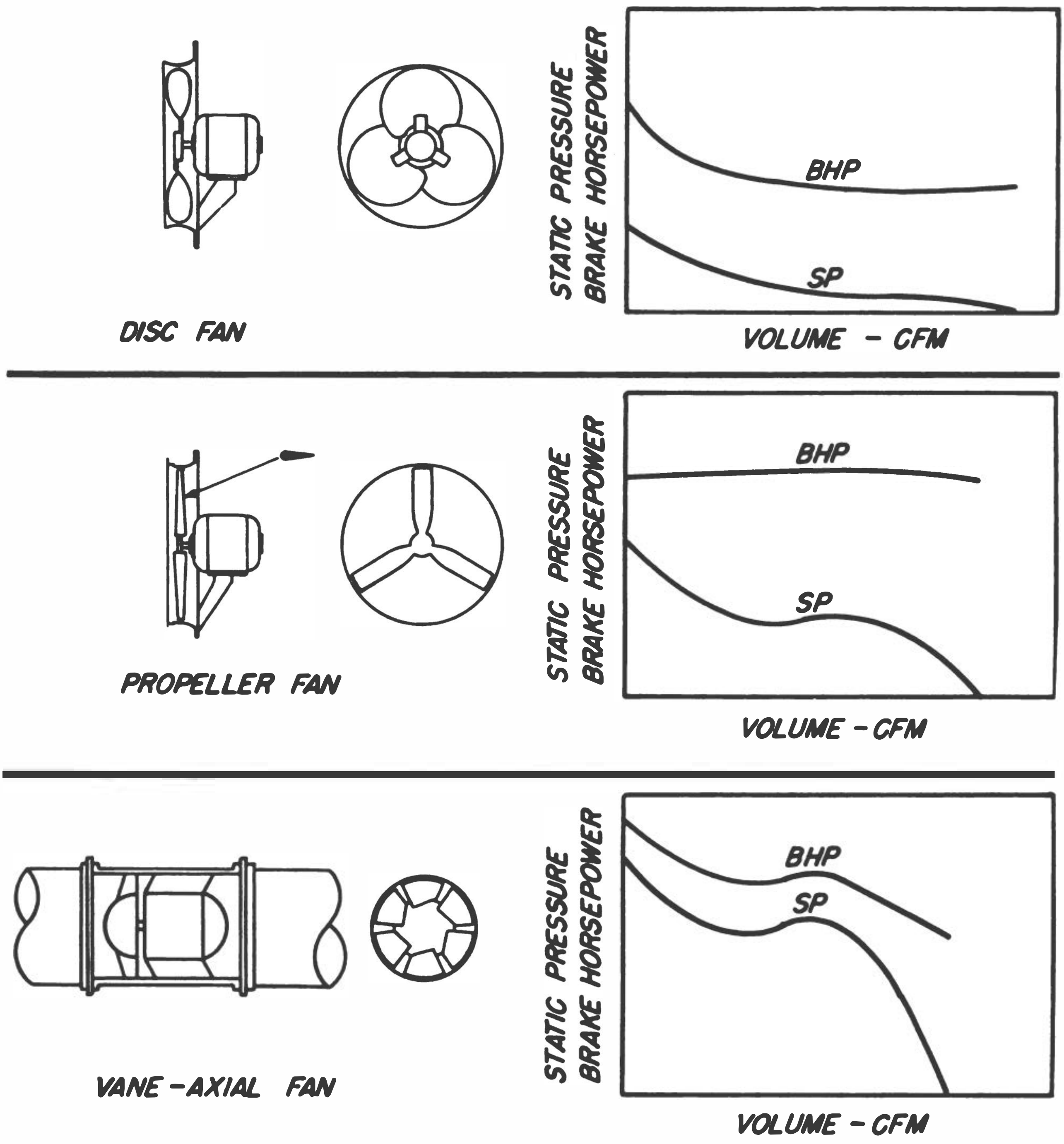


FIGURE 5-1 Axial flow fans.
(from "Industrial Ventilation", 16th Edition, 1980)

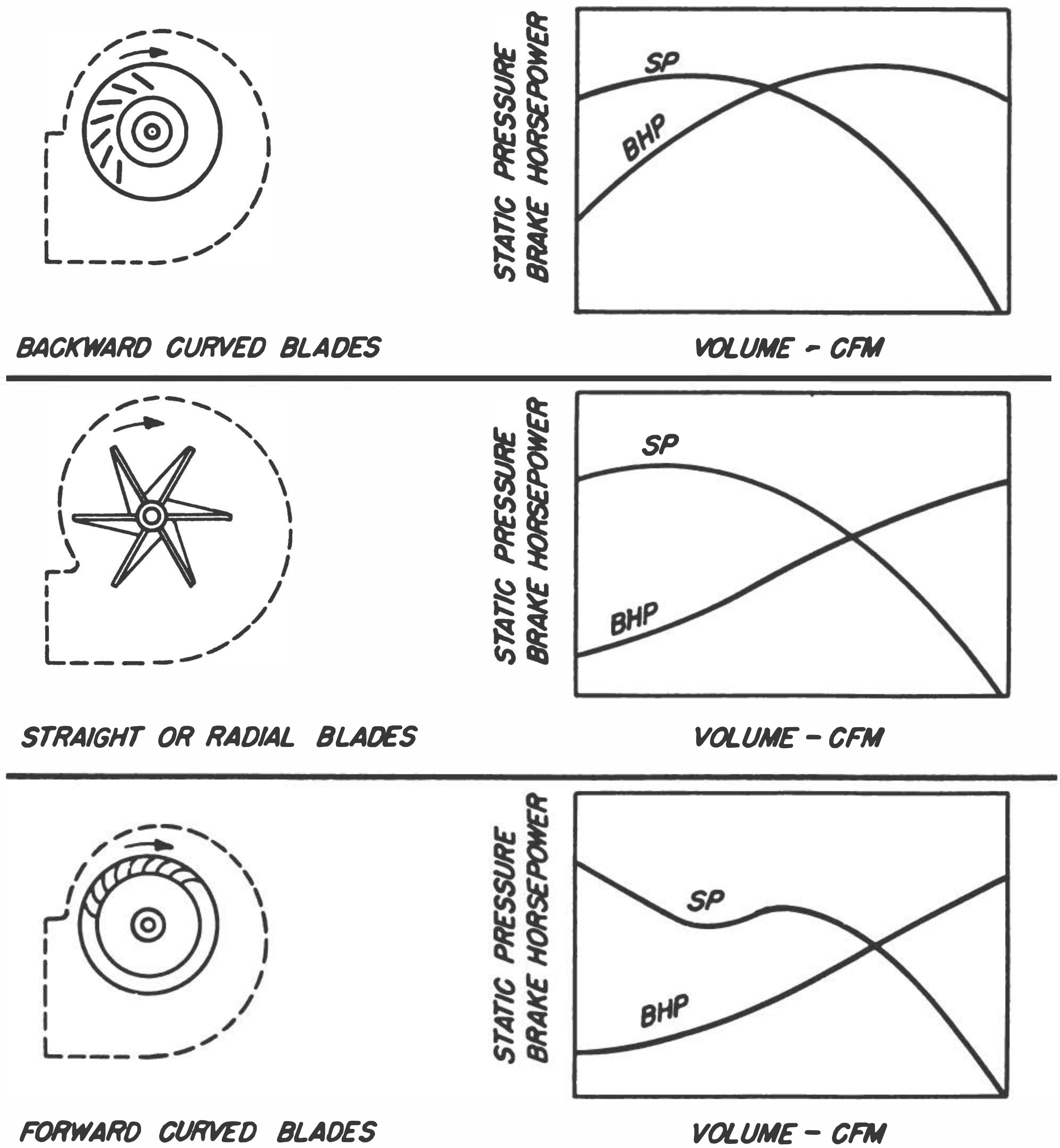


FIGURE 5-2 Centrifugal fans.
(from "Industrial Ventilation", 16th Edition, 1980)

The operating temperature of an exhaust fan determines the kind of bearings it should have. Sleeve bearings are satisfactory for fans operating at up to 250°F. Ball bearings are required at 250°F to 550°F, and special cooling devices are required at higher temperatures. The designer generally should follow the manufacturer's recommendations.

Fan Size and Speed

The size and speed of the exhaust fan for a specific installation should be selected for maximum efficiency. That is, the fan should supply the required airflow and static pressure at minimum horsepower and thus minimum operating cost.

The designer usually can determine the optimum size and speed of the fan from a rating table published by the manufacturer. The best form of table is a multirating table. It gives the airflows, or capacities, for a fan of a given size over the entire range of static pressures and fan speeds. The table also gives the horsepower required over the entire range of static pressures and speeds.

When a fan is running at a given speed, its capacity varies with the static pressure in a manner characteristic of the fan. A range of capacities and the corresponding static pressures at constant speed can be plotted to give a curve that is characteristic of the fan. A typical characteristic curve is shown in Figure 5-3. The second curve in Figure 5-3 shows how capacity--or airflow through the system--varies with the resistance, or static pressure, across the system. The point where the two curves intersect represents the capacity of the fan in a given system at constant speed. In other words, a particular fan running at constant speed in a particular system can have only one capacity, or airflow. That capacity can be changed only by changing the speed of the fan or the resistance of the system.

The slope, or degree of steepness, of a fan's characteristic curve is especially important in a grain-dust system. Figure 5-4 shows a relatively flat characteristic curve (left) and a relatively steep one (right).

It can be seen in Figure 5-4 that a slight increase in the static pressure of the system causes a smaller loss of capacity for the fan with the steep characteristic curve than for the one with the flatter curve. The point is significant because a dust-collection system may occasionally become overloaded with dust. When ducts become overloaded, the resistance of the system rises and airflow declines correspondingly. If the fan's characteristic curve is too flat, airflow may fall to the point where velocity is below the transport velocity, and the system will clog. Thus when choosing among otherwise adequate fans for a particular job, the best selection is the one with the steepest characteristic curve.

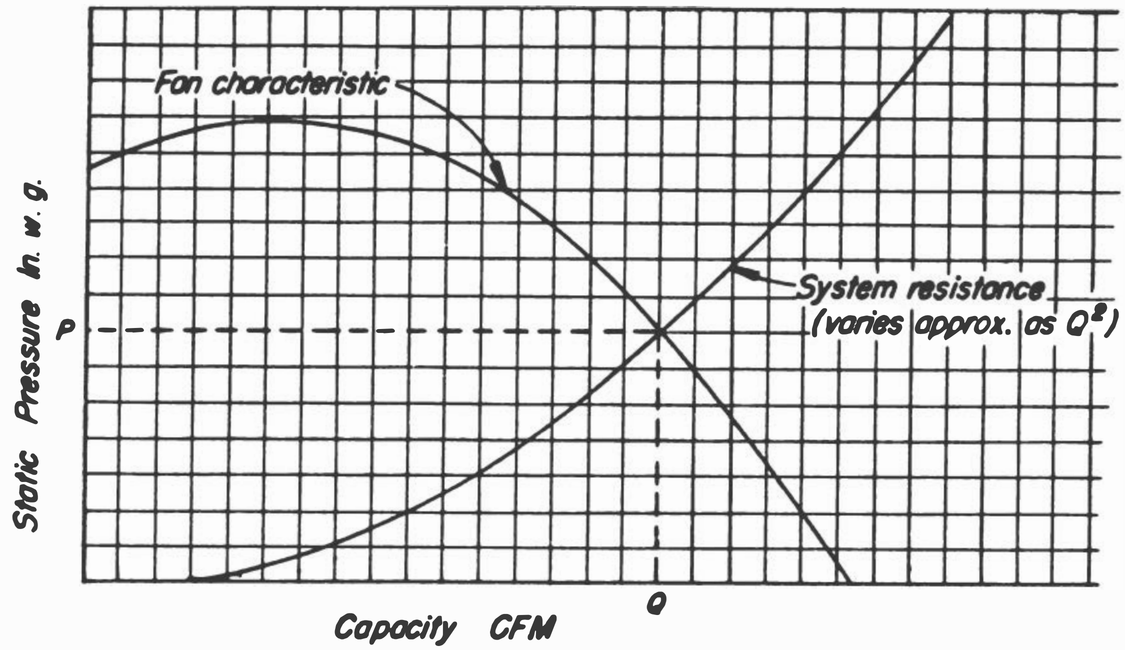


FIGURE 5-3 Typical point of rating.
(from "Industrial Ventilation", 16th Edition, 1980)

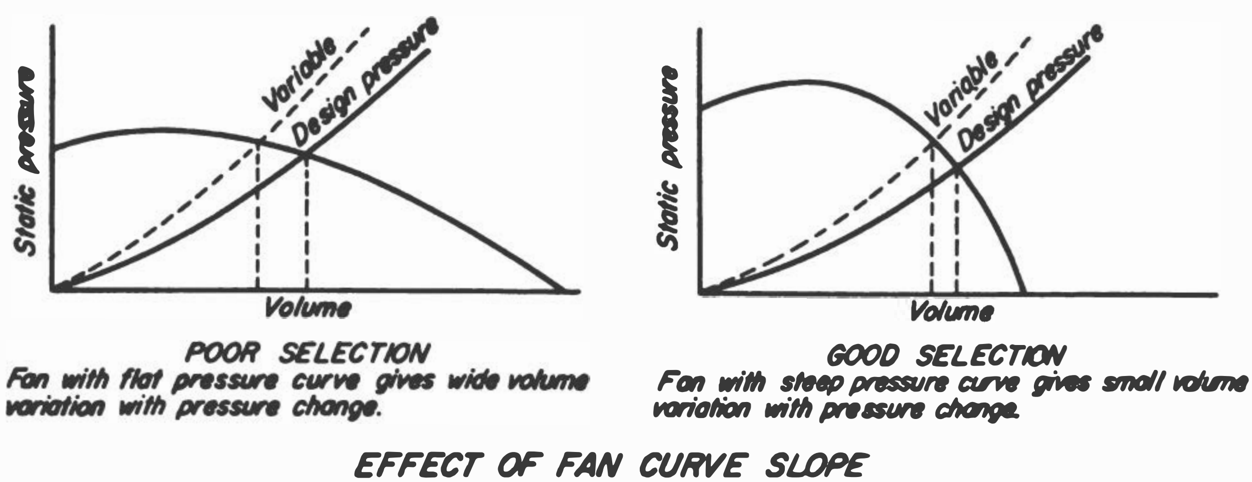


FIGURE 5-4 Fan selection.
(from "Industrial Ventilation", 16th Edition, 1980)

A flat characteristic curve may also cause problems during start-up of a fabric filter. The fabric has very little resistance during start-up because the mat of dust has not yet formed on it. If the fan's curve is too flat, the system will tend to handle much more than the design airflow. As a result, more than the desired amount of dust will be conveyed and will tend to overload the filter and system.

Generally speaking, an oversize fan tends to operate in a flat section of its characteristic curve. To avoid the problems described above, therefore, the size of the fan selected should exactly match the requirements of the system.

An actual example of fan selection is shown in Figure 5-5. The design capacity of the system is 20,200 cfm, and the design static pressure is 16 inches of water (4 inches across the bags and 12 inches owing to friction pressue drop). The fan was selected to give design volume flow at 4 inches pressure drop across the bags. Note that almost doubling the pressure drop across the bags, to 7.6 inches, reduces volume flow only 10 percent. This relationship reflects a good fan selection.

Even the best fan cannot overcome poor maintenance. Note in Figure 5-5 that when pressure across the bags climbs to an excessive 13.6 inches, the fan will deliver only 70 percent of design volume flow. Under these conditions, the ductwork probably would clog. If the design is for a 4" pressure drop across the bag this problem would occur more rapidly.

Fans for Nonstandard Conditions

Rating tables and performance charts for exhaust fans normally are based on the density of clean, dry air at standard temperature and pressure. Standard temperature is 70°F; standard pressure is sea-level pressure--407.5 inches of water or 29.92 inches of mercury. At these conditions, the density of dry air is 0.075 lb/cu ft. If air is not at standard conditions, or if it is humid (contains water vapor), its density will not be 0.075 lb/cu ft. The normal rating tables and performance charts, therefore, will not be accurate guides to fan selection unless corrections are made to account for the difference in density.

The density of air increases as temperature and humidity decrease and as pressure increases. Normal fluctuations in temperature, pressure, and humidity change the density of air very little and can be ignored. Suppose, however, that a fan will be operating at an altitude of 2,000 ft, where pressure is lower than at sea level. At standard temperature (70°F) and no humidity, the density of the air will be 0.070 lb/cu ft. This density is enough lower than standard (0.075 lb/cu ft) to require that corrections be made when using the normal tables and charts to select a fan with proper characteristics.

STORAGE SYSTEM
System No. 4
Design Conditions: 20200 SCFM @ 16" S.P.
Duct Velocity — 4000 fpm

PERFORMANCE CURVES
No. 730 Single Type C-25
Outlet Coned to 6.0 ft^2
70° F 29.98" bar. 0.075 lbs/C.F.
1780 RPM

SP — Static Pressure
TP — Total Pressure
HP — Horsepower
SE — Static Efficiency
TE — Total Efficiency

Sound Power Levels - Fan Discharge
in dB Re 10^{-12} Watts

Octane Band	1	2	3	4*	5	6	7	8
PWL-Outlet	109	105	104	107	102	98	94	90

*Denotes Blade Frequency

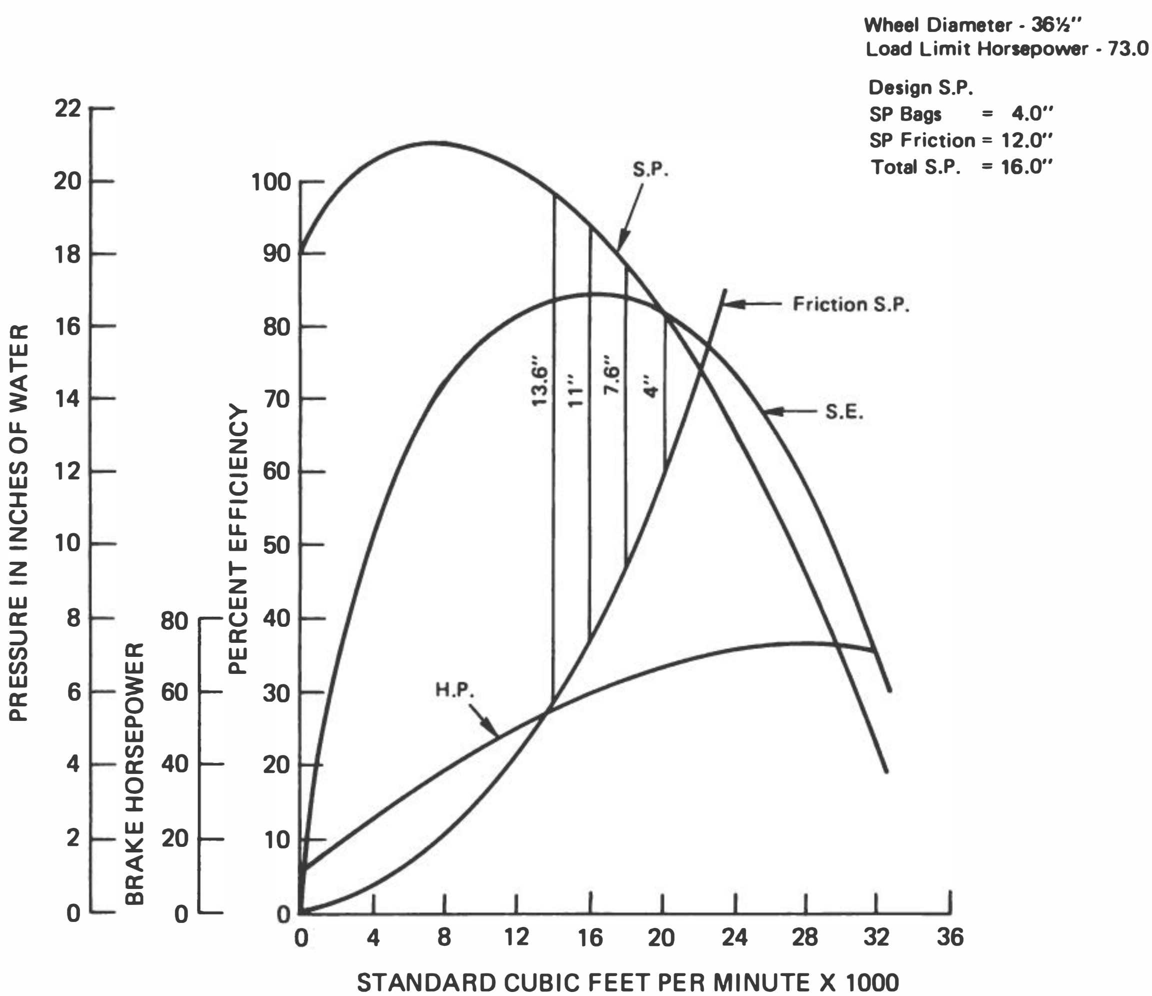


FIGURE 5-5 Typical fan performance chart.

Fan Motor and Drive

The motor and drive for a fan are selected on the basis of the horsepower required to produce the necessary static pressure and capacity. The required horsepower is determined from data supplied by the manufacturer of the fan. However, the final selection of the motor and drive must take into account two additional factors:

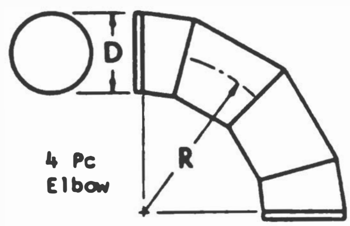
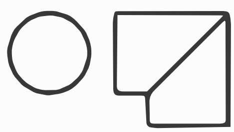
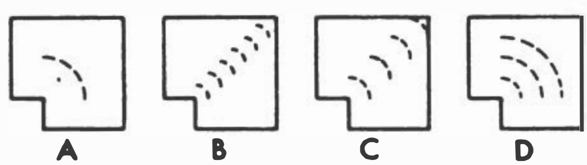
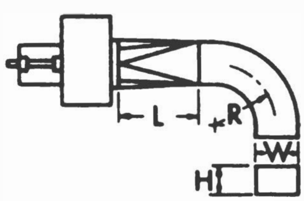
1. Volume flow in the system may well be 10 percent more than design volume flow until a mat of dust has built up on the filter fabric.

2. Start-up of a system in cold weather will require more than design horsepower because of the higher density of the air.

For these reasons, it is suggested that the motor and drive be designed to provide 10 percent more than the design airflow at the lowest temperature expected for the system. This precaution will prevent the drive from cutting out because of overload.

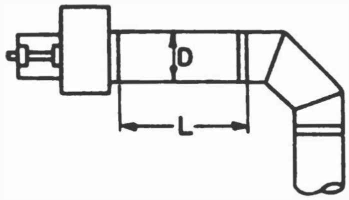
Fan Installation

Manufacturers' data on the performance of fans are obtained from tests conducted under ideal conditions. A fan installed in a dust-collection system, however, normally does not operate in ideal conditions. To obtain maximum performance, therefore, certain guidelines should be observed when installing a fan. A fan's inlet and discharge ducts should be designed to minimize nonuniform (turbulent) flow. The reason is that nonuniform flow increases pressure drop and so decreases volume flow. Figure 5-6 shows the losses in volume flow caused by various inlet fittings. The figure also shows the increases in static pressure that the fan must provide to compensate for those losses. The situation is generally the same for fan-discharge fittings (Figure 5-7). Elbows in discharge ducts, for example, should be avoided to minimize pressure drop.

DESCRIPTION		% LOSS IN CFM IF NOT CORRECTED	% INCREASE NEEDED IN FAN SP TO COMPENSATE
 3 piece elbow	R/D = .5	12	30
	1.0	6	13
	2.0	5	11
	6.0	5	11
4 piece elbow	R/D = 1.0	6	13
	2.0	4	9
	8.0	4	9
5 or more piece elbow	R/D = 1.0	5	11
	2.0	4	9
	8.0	4	9
 Mitered elbow		16	42
Square Ducts with Vanes 	No Vanes	17	45
	A	8	18
	B	6	13
	C	5	11
	D	4	9
Rectangular Elbows without Vanes* 	$\frac{H}{W}$ = .25, & $\frac{R}{W}$ = .5	7	15
	1.0	4	9
	2.0	4	9
	$\frac{H}{W}$ = 1.00, & $\frac{R}{W}$ = .5	12	30
	1.0	5	11
	2.0	4	9
	$\frac{H}{W}$ = 4.00, & $\frac{R}{W}$ = .6	15	39
	1.0	8	18
	2.0	4	9

*In all cases use of 3 long, equally spaced vanes will reduce loss and needed sp increase to 1/3 the values for unvaned elbows.

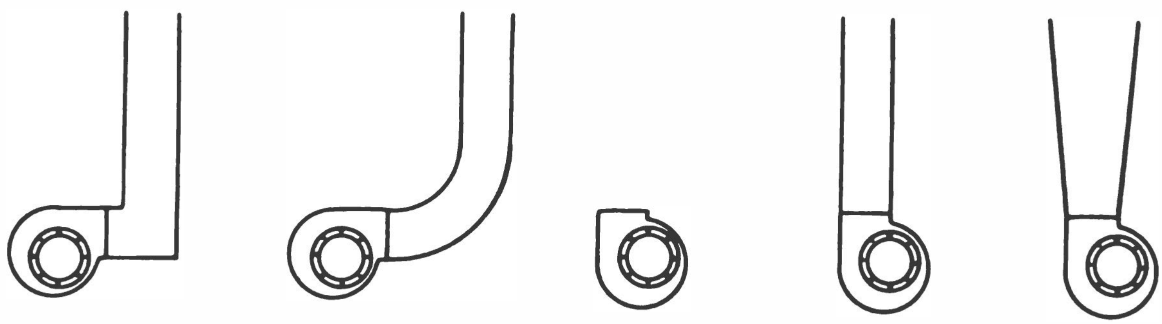
The maximum included angle of any element of the transition should never exceed 30°. If it does, additional losses will occur. If angle is less than 30° and L is not longer than the fan inlet diameter, the effect of the transition may be ignored. If it is longer, it will be beneficial because elbow will be farther from the fan.



Each 2½ diameters of straight duct between fan and elbow or inlet box will reduce the adverse effect about 20%. For example, in the case of the poorest 3 pc. elbow above:

	CFM loss =	Additional fan SP needed =
No duct	12%	30%
L/D = 2½	10%	24%
5	7%	18%
7½	5%	12%
10	2½%	6%

FIGURE 5-6 Probable effects of various inlet connections. (These losses do not include friction losses.) (from "Industrial Ventilation", 16th Edition, 1980)



S.P. = static pressure

FIGURE 5-7 Effects of fan discharge methods upon static pressure.

Fan Location

Nonuniform flow, as well as other problems, can be avoided or minimized by selecting the optimum location for a fan. If at all possible, the installation should conform to these guidelines:

1. Locate the fan downstream from the filter to minimize erosion and abrasion.

2. Locate the fan so as to avoid elbows and other obstructions in the inlet.

3. Arrange the direction of rotation and the discharge of the fan so that it exhausts in the direction finally desired, thus avoiding unnecessary bends.

4. As noted previously, do not install V-belt drives inside an elevator because they can be a source of ignition in the event of failure.

5. Locate small fans on the filter itself. Locate larger fans so as to minimize vibration--usually they are best mounted on a concrete pad at ground level.

6. Locate fans for easy inspection and maintenance.

Modifying a System

The capability of the exhaust fan must be carefully checked when a dust-collection system is to be modified. When replacing a cyclone with a fabric filter, for example, it is extremely important to ensure that the existing fan can perform satisfactorily in the modified system. A fabric filter generally will entail higher pressure loss than a simple cyclone. The fan must produce correspondingly higher static pressure to keep the system operating properly. If it cannot, it should be replaced by a fan of greater capacity.

It may be possible to obtain the necessary increase in static pressure by speeding up the existing fan. However, an exhaust fan should be speeded up only after the fan's manufacturer has been consulted.

Booster Fans

Booster fans may be used in some circumstances. Where additional static pressure is required, as in the case above, it might be obtained by putting a second fan in series with the existing fan. In other instances, small booster fans may be used to provide additional static pressure in particular sections of complex dust-collection systems. In any event, extreme care should be exercised when considering the use of booster fans. Generally they will handle grain dust and so must be spark-proof and otherwise properly selected for a dust location.

Section 6

DUST CONTROL IN PROBLEM AREAS

Effective dust control is especially important in certain problem areas in grain elevators. These areas involve both enclosed and open sources of dust. Examples of enclosed sources are bucket elevators (legs), horizontal conveyors (drag or screw), and distributors. Examples of open sources are trippers, conveyor belts and belt loaders, and loading/unloading facilities (truck, rail, marine). This section outlines the basic principles of pneumatic dust collection in problem areas and gives specific examples.

It is extremely important to recognize that a dust-control program has two goals. One goal is to keep the levels of dust in the workplace and environment from creating inhalation health hazards. The other goal is to prevent explosions. Measures that attain one of these goals will not necessarily attain both. In other words, an elevator that easily complies with environmental and occupational regulations is not necessarily free of the hazard of grain-dust explosions. A program based on a pneumatic system can easily meet the respiratory standards on dust levels and still permit dust in enclosed spaces to reach explosible concentrations. On the other hand, a properly designed pneumatic system can eliminate explosible concentrations of dust in enclosed spaces, as well as satisfy the environmental and occupational requirements.

Ideally, the materials-handling system in an elevator should be designed from the start with proper dust control in mind. Desirable features include very short free-falls, choke-fed spouts, and slow-running belts and elevators. Depending on the circumstances, such features minimize the generation of dust, the entrainment of air, or both.

In a poorly designed elevator, proper dust control may be next to impossible. It will certainly not be economical. In such elevators it may be best to revise the materials-handling system to avoid the difficult dust-generation problems and then apply normal dust-control techniques.

A pneumatic system must collect dust from every enclosed space in an elevator if it is to work effectively. The system also must collect dust at all grain-transfer points that are not enclosed.

Enclosed Problem Areas

The use of pneumatic dust control with enclosed equipment is relatively straightforward. As noted earlier, the equipment is on the intake side of the exhaust fan and is connected to the fan by ductwork. The fan creates a slight negative pressure inside the enclosed space and ductwork; the negative pressure creates a flow of dust-laden air through the system toward the fan. Since the system works by controlling the movement of air, enclosures around equipment should surround all possible dust emission points with adequate inflow of air.

A pneumatic system must maintain an airflow large enough to remove the dust that is generated. To do so, the system must continuously remove from enclosed equipment both the air displaced and the air entrained by the entering grain. A bushel of grain displaces 1.25 cubic feet (cu ft) of air. When grain is fed to enclosed equipment, therefore, the dust-collection airflow must be at least 1.25 cfm per bushel of grain fed per minute to remove displaced air. If the grain is choke-fed, it will entrain relatively little air. However, grain that is fed by a long free-fall, particulary one with free inflow of air at its source, can entrain 10 or more times the volume of air it displaces, and the dust-collection system must also remove this entrained air.

It is clear that proper grain-feeding techniques help to minimize the size and cost of dust-collection ductwork and fans. The power consumed by the system is reduced correspondingly.

Enclosed grain-handling equipment must be self-cleaning. It should be free of ledges or other surfaces where dust can build up. Conveyors should be designed to avoid dust buildup on the bottom surfaces of enclosures and there should be no internal structural members upon which dust can accumulate. Enclosing a poorly designed grain-handling device in sheet metal can make it more hazardous than it was when unenclosed.

Bucket Elevators

The most common vertical conveying device in the grain industry is the continuous bucket elevator. The buckets on the device scoop grain from the boot, at the bottom of the elevator, raise it to the head, discharge it, and return to the boot. The up-moving and down-moving sections of the elevator may be enclosed in separate, sheet-metal casing; in other designs, the entire bucket elevator may be enclosed in a single, concrete housing. The combination of bucket elevator and housing usually is called the "leg."

The leg is the most dangerous component of a grain elevator as the preponderance of grain dust explosions originate here. As the buckets scoop grain from the boot they stir up more dust than any other operation in the elevator. Furthermore, most pneumatic dust-collection systems maintain only enough negative pressure in the leg to prevent dust from escaping. Such systems do not prevent buildup of explosible concentrations of dust in the housing. The hazard is reinforced by the bucket elevator's potential for producing sparks and hot spots.

Tests have shown that a properly designed pneumatic system can avoid explosible concentrations of dust in a leg (see Appendix C). The airflow needed will vary with the design and other factors. However, there is a rule of thumb for calculating the necessary airflow (Figure 6-1). The calculation involves the cross-sectional area of the leg casing, the speed of the elevator belt, and a factor (f) ranging from 1.25 to 1.50, the f factor to be selected according to the dust load. The factor f remains the same regardless of the cross-sectional area and belt speed. The equation is:

$$W \times D \times B \times f = \text{Airflow}$$

In this equation, W and D are the width and depth of the leg casing in feet, B is the belt speed in feet per minute, and the airflow is in cubic feet per minute.

In the example of Figure 6-1, the leg casing is 2.0 ft wide and 2.5 ft deep, and the belt speed is 700 fpm. The volume flow required in the leg is:

$$2.0 \times 2.5 \times 700 \times 1.25 = 4375 \text{ cfm}$$

That is, a volume flow of 4375 cfm should be sufficient to reduce internal dust suspensions adequately, provided the aspiration pattern is properly designed.

A volume flow of more than 4000 cfm is much higher than is usually used in elevator legs. It has been commonly believed that a volume flow of about 750 cfm was sufficient to accommodate a typical 20,000 bph leg. We now know, however, that 750 cfm will not avoid explosible concentrations of airborne dust; such a volume flow in some cases may not even handle the air displaced by the entering grain. In the tests reported in Appendix C, numerous samples were taken by a vacuum method from various points in legs with no aspiration and in legs with conventional aspiration (i.e., suction on top of boot housing). It was shown that adequate volume flows applied properly could reduce the levels of airborne dust in legs below the minimimum explosible concentration. The use of adequate volumes of air, combined with proper aerodynamics, has been applied at only a few elevators, but in all cases it substantially reduced the levels of airborne dust.

It should be remembered that the calculation given here is a rule of thumb. The volume flow actually required in the leg will vary not only with belt speed, but also with the way grain is fed to the leg, the suction in associated equipment, and possibly with other factors. Furthermore, as indicated in Figure 6-1, the calculation uses only the cross section of the up leg.

The suction hoods in this kind of system should be on the sides of the up leg above the boot. Hoods must be designed and positioned with care so that air movement does not deflect the belt. Such deflection can cause the buckets, or cups, to strike or rub against the casing. One way to avoid belt deflection is to apply suction equally to both sides of the leg casing. Air should move from the leg into the hood at a face velocity--the velocity at the entrance to the hood--of no more than 1000 fpm; a lower face velocity is desirable if possible. This limit on face velocity, produced by a properly designed transition, is necessary to avoid scalping grain and deflecting the belt.

Reducing the speed of the belt can sharply reduce the generation of dust in a leg. The airflow needed in the leg is reduced correspondingly, as shown by the airflow equation above. On the other hand, if the belt runs too slowly, the buckets will not discharge properly. If the diameter of the head pulley is 48 inches, the minimum belt speed for proper discharge is about 480 fpm. However, belt speed in U.S. elevators typically is about 800 fpm. Thus operators should have some leeway in selecting the belt speed that is the best compromise between dust generation and grain-handling capacity.

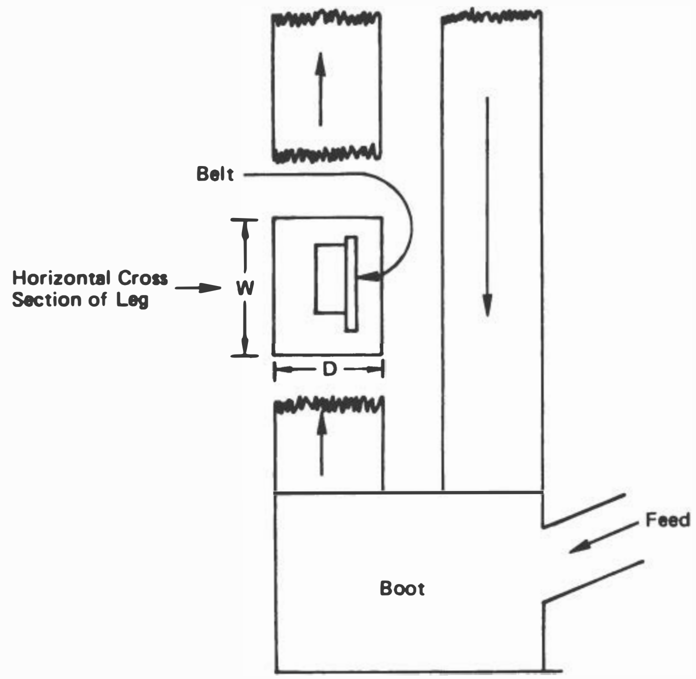


FIGURE 6-1 Rule of thumb for calculating airflow in elevator leg.

Horizontal Conveyors

Enclosed horizontal conveyors are usually screw or drag conveyors. Common methods of airflow control for these devices are shown in Figure 6-2. It is extremely important that more air be exhausted from the conveyor housing than is displaced by incoming grain, and that adequate makeup air inlets where necessary be provided at the proper locations. It is also important that the face air velocity not exceed 800 fpm. This limitation avoids air-conveying velocities near the moving grain, permitting only the fine dust to enter the dust-collection system.

Scales and Garners

Hopper scales are among the most troublesome dust-emission points in conventional elevators. The emissions are usually intermittent. They tend to be high during the loading or discharge cycle or during both cycles. The capture of dust by pneumatic methods is complicated, in that pressure differentials between the inside and outside of the scale hopper can affect the accuracy of the scale significantly.

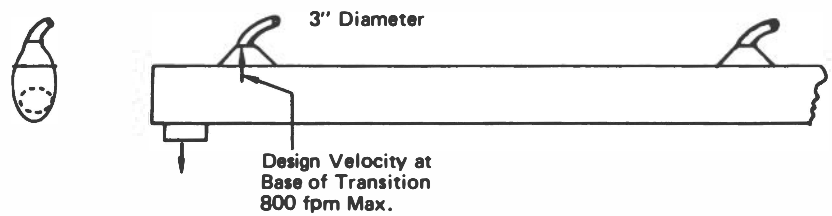
Scale installations vary considerably, but the typical arrangement is an upper garner, a scale hopper, and a lower garner. This bin-scale-bin sequence can be used to illustrate workable dust-collection methods.

The upper garner usually is filled from the elevator head. The incoming grain and the air entrained with it build pressure and release dust in the bin. Dust-laden air is thus forced from any openings in the bin or the spouting leading to it. A dust-collection take-off at the top of the upper garner can create negative pressure in the bin, thus eliminating dust emissions.

The pressures inside and outside the scale hopper must be equal during the weighing cycle to obtain accurate weight. Therefore, the hopper cannot be under negative pressure, or suction, during the weighing cycle, nor can the scale room be under significant negative or positive pressure. If the scale hopper is under negative pressure or the scale room under positive pressure, the hopper is buoyed by the higher pressure in the room. Additional grain is required to overcome this flotation effect, so the scale will weigh heavy. If the scale room is under negative pressure during the weighing cycle, the scale will weigh light.

Two general methods can be used to prevent dust emissions from hopper scales. One method assumes an airtight bin-scale-bin sequence. The other method allows for leaks, which usually exist.

In the first method (Figure 6-3), pressures generated in the bin-scale-bin sequence are vented to a "Chinese hat" (see Figure 6-3). Aspiration by the dust-collection system creates an area of negative pressure at the Chinese hat, where displaced dust is collected. However, the arrangement does not create negative pressure in the scale hopper, so accurate weight is obtained.



NOTES: Cover must be complete and tight. Add additional take-offs to remove displaced air, cfm = bpm x 1.25. Makeup air inlets may be required when the system is airtight.

FIGURE 6-2 Horizontal screw, drag, belt conveyor aspirating.

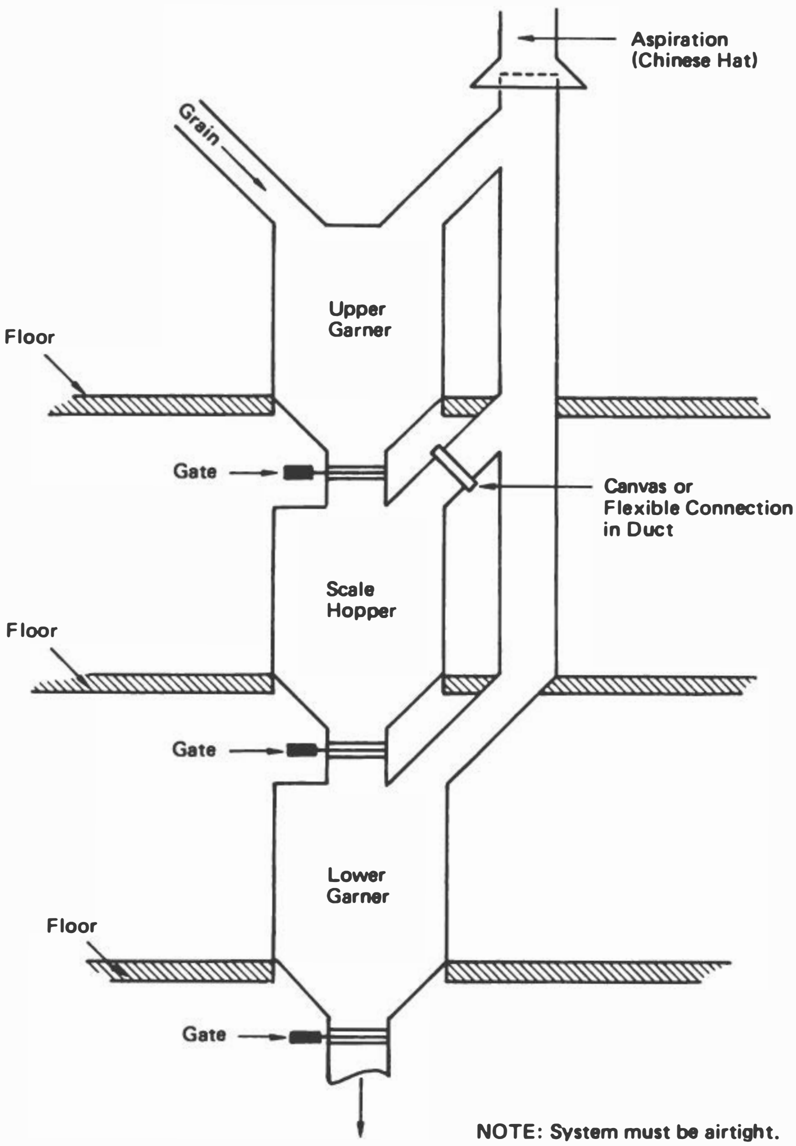


FIGURE 6-3 Scale--Garner intervent system.

The second method (Figure 6-4) places the entire bin-scale-bin sequence under negative pressure, except during the weighing cycle. Only the upper garner is under suction during the weighing cycle. Cycling of the slide gates and suction damper is shown in Figure 6-4.

Distributors

The term "distributor" is applied to many significantly different devices that have the same function: distribution of grain in variable directions. Distributors are sometimes very troublesome emitters of dust. They are not troublesome because they generate dust or pressure themselves. The problem is that distributors are often the points of release of high pressure and large amounts of dust created during long free-falls of incoming grain.

The most common conventional type of distributor, particularly in older elevators, is the Mayo spout. Other conventional distributors are the turnhead and the distributor box. The Mayo spout is connected to one source of grain, is angled downward, and is rotatable, usually through 360 degrees (see Figure 6-5). Thus the spout can deliver grain to any porthole around its lower circle of rotation. The turnhead is a rotating enclosure that receives grain from one spout and directs it to any of several others. The distributor box differs from the turnhead in that it is stationary and uses internal valves or gates to divert the grain (see Figure 6-6).

It is the rule in dust control that use of free-falls and long, steeply inclined, unrestricted spouts should be minimized if not eliminated. The lower the speed of the grain entering a distributor, the easier it is to maintain negative pressure in the device and capture airborne dust. The closest feasible approach to choke-feeding should be used. Even then, however, suction on the distributor will be required to avoid dust emissions.

Installation of Mayo distributors is not recommended because of the difficulty of controlling the associated dust emissions. The main problem is providing adequate suction at the many escape points without interfering with the rotation of the spout. Flexible suction ducts can be used, but generally require too much maintenance.

The pressure generated in a steeply angled Mayo spout can sometimes be handled by taking suction from the bins fed by the spout (Figure 6-5). In such cases each bin must be kept under negative pressure while it is being fed to avoid blowback through the porthole. It is also good practice to fit the end of the spout with a flared skirt or circular bristle brush that encloses the opening between spout and porthole. The diameter of the porthole should not exceed the diameter of the spout fitting by more than 20 percent.

The turnhead distributor presents dust-collection problems similar to those of the Mayo spout. Again, these problems can be solved by placing suction on the bins that the turnhead is feeding. Also, the turnhead distributor can be tightly enclosed with sheet metal (Figure 6-6) so that it can be treated as a box distributor.

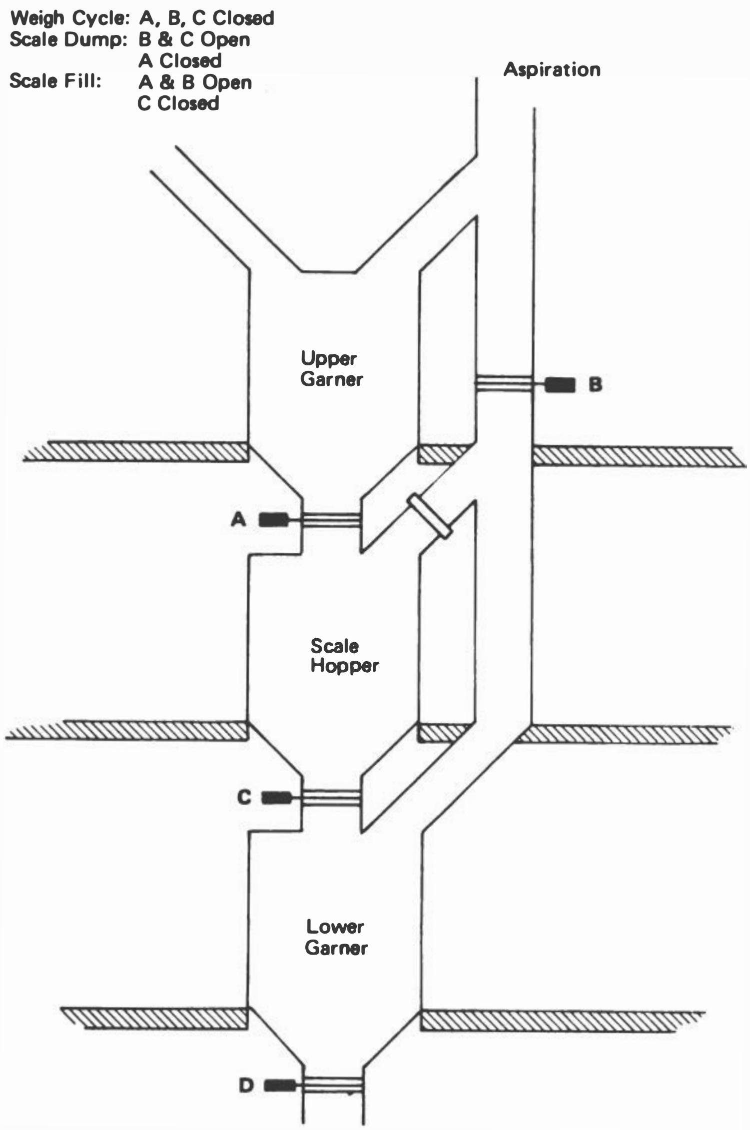


FIGURE 6-4 Scale--Garner intervent system.

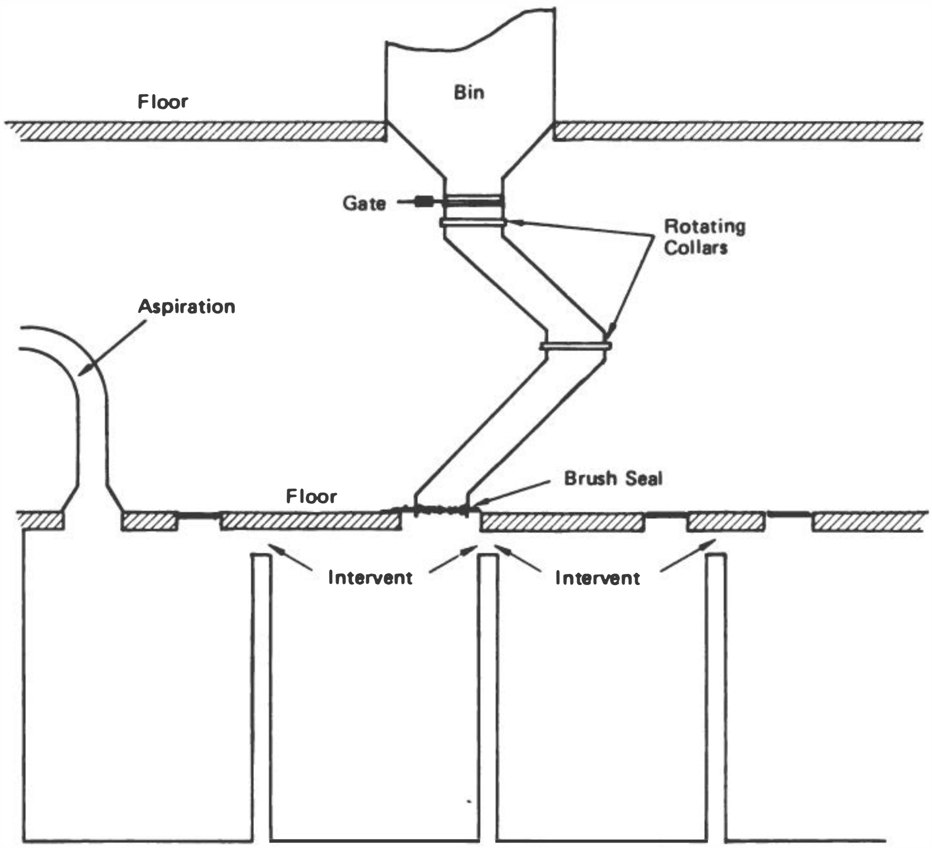


FIGURE 6-5 Rotating or Mayo spout dust control.

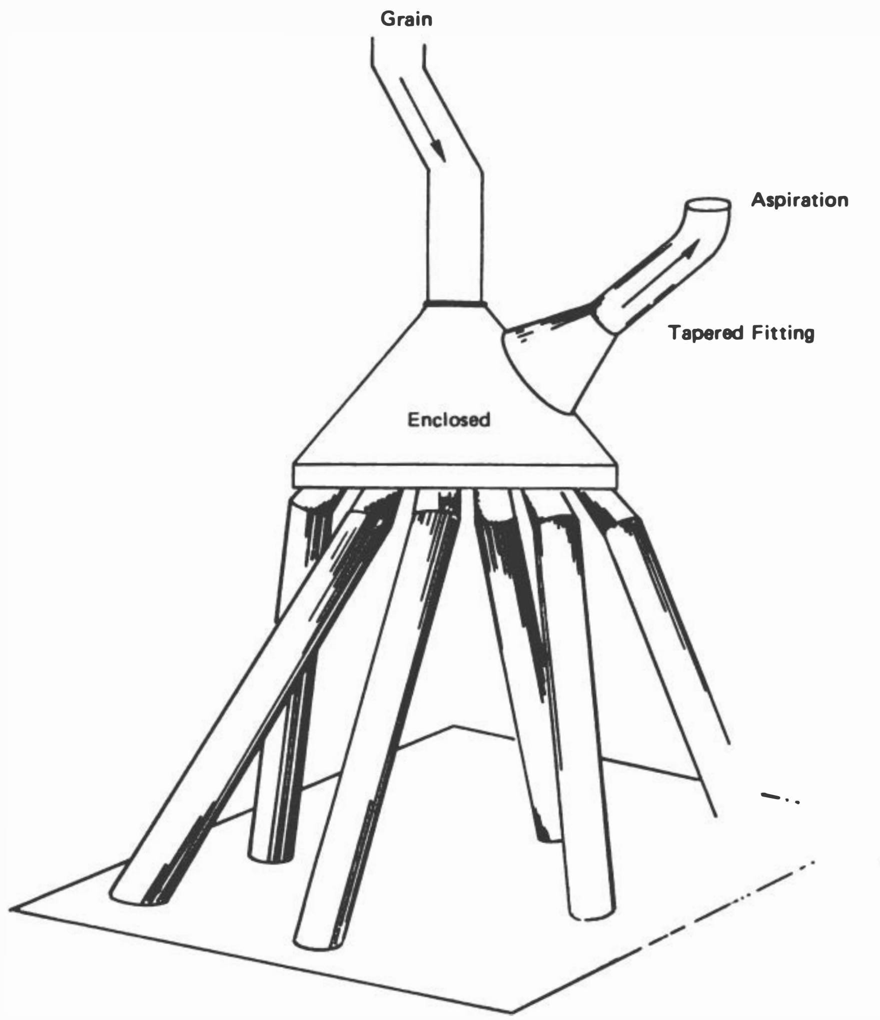


FIGURE 6-6 Enclosed distributor dust control system.

The box distributor is immovable and relatively tight and can be kept under negative pressure rather easily. The device has few leaks. Also, it has a large top-surface area from which suction can be taken, using a proper transition fitting, without scalping grain.

Unenclosed Problem Areas

It is essential that a pneumatic system collect the dust generated at all unenclosed grain-transfer points in an elevator. There is little danger that an explosion will be initiated in unenclosed spaces. However, if airborne dust is not collected at grain-transfer points, most of it will settle on surfaces in the working space. This dust can then fuel secondary explosions in tunnels, galleries, and headhouses. Furthermore, layers of dust around working equipment are ideal sites for hidden, smoldering fires. Such fires can be the source of ignition for an explosion.

Galleries--Trippers and Bins

Dust in the gallery of an elevator results mainly from the operation of trippers, "blowback" from tanks being filled, loaders, and excessive conveyor belt speeds. This dust can be collected pneumatically. The type of installation depends on whether the bins are filled by traveling belt trippers or by stationary trippers and distributors.

Trippers. The traveling tripper should have a well-fitted suction hood above and enclosing the ends of the tripper pulley. Suction hoods below the tripper pulley usually plug with grain and should be avoided. There should also be a hood at the head pulley of the tripper belt. In addition, hoods should be fitted at the spouts.

Stationary trippers should have hoods at the discharge of each tripper. Hoods should also be fitted at the belt reloaders and distributors. Belt reloaders should not be treated like typical belt loaders because they require substantially more air.

Figure 6-7 shows two typical dust-collection arrangements for manual or automated traveling trippers. Table 6-1 shows the airflows required for typical belt widths and capacities. These air volumes are for the tripper only. They do not include air for the hoods at the head pulley or belt loader.

Both whole grain and dust must be handled at the belt discharge of a traveling tripper. The best approach usually is to return spilled grain to the topside of the belt with a miniature loop conveyor.

Whole grain must also be handled along with dust at the head pulley of the tripper belt. It is not possible mechanically to return this grain to the grain stream. The grain can be captured by the dust hood at the head pulley by using high air velocity for pickup and relatively high velocity in the associated duct. Air velocity in the duct should approach that used for pneumatic conveying--4,500 to 5,500 fpm. Otherwise, grain will not remain airborne in the duct. The head-pulley duct should never be connected to the end of the tripper duct. This arrangement would make it impossible to provide enough suction at the head pulley at all times. Instead, the head-pulley duct should be tied into the main duct ahead of the tripper duct.

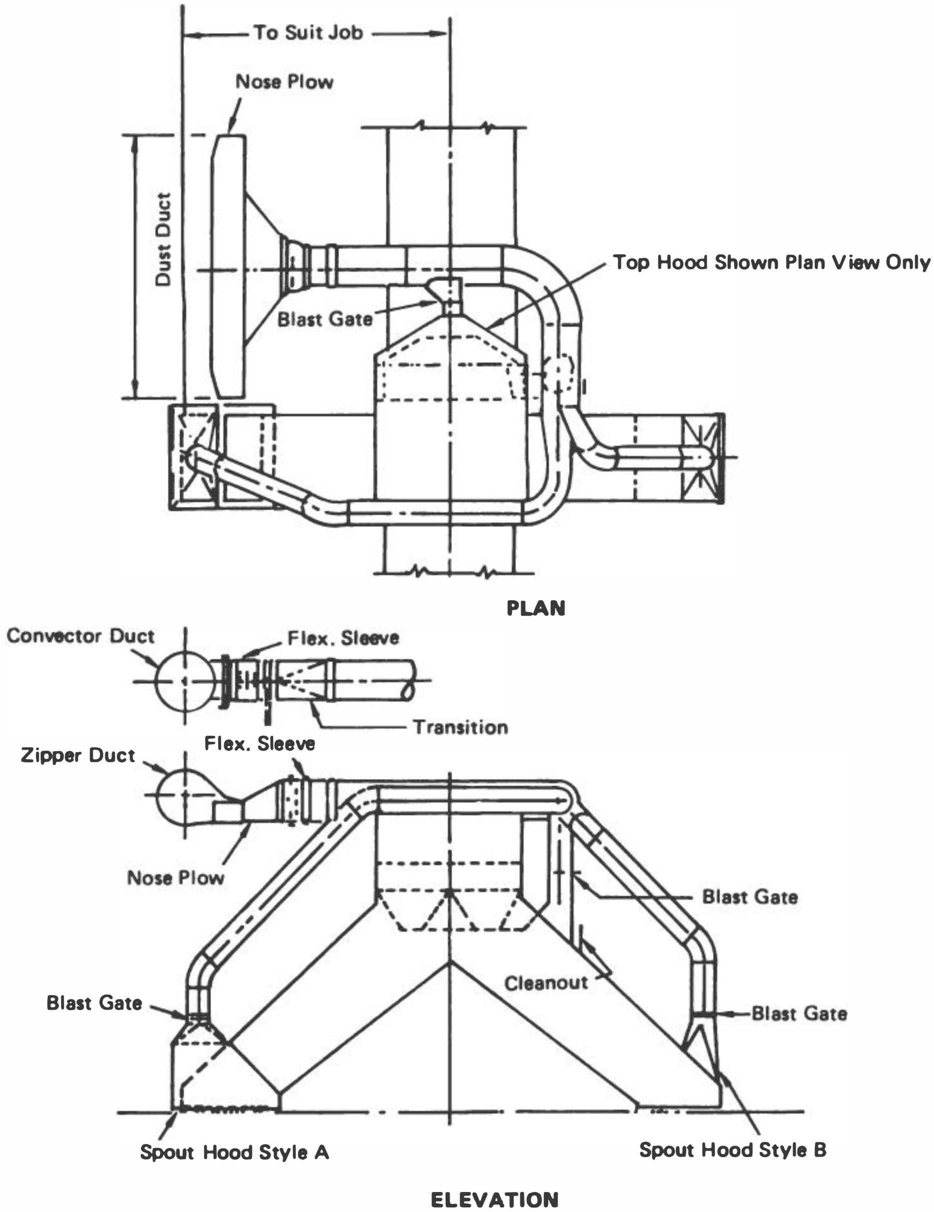


FIGURE 6-7 Zipper suction for tripper.

Whole grain at the head pulley of the tripper belt can also be caught in a hopper under the pulley. The hopper would discharge through an opening into the bin. However, this alternative may not be practical where grains cannot be comingled.

TABLE 6-1 Air Volume for Traveling Trippers[a]

Belt Width	Approximate Capacity	Air Volume
24 inches	10,000 bph	3,500 cfm
30 inches	15,000 bph	3,800 cfm
42 inches	30,000 bph	5,500 cfm
48 inches	40,000 bph	6,000 cfm
60 inches	60,000 bph	6,800 cfm

[a] The figures above assume belt speeds of 500 fpm or less. Speeds in excess of 500 fpm should be avoided because of a) excessive dust emission, b) maintenance problems, and c) grain breakage.

Bins. Grain entering a bin from the gallery forces air out of the bin. Normally this displaced air contains dust and should be captured by the pneumatic system.

The required bin suction usually is applied at the end of the tripper spout. This is the least costly way to vent the bin, but it may not be the best way. Often the spout is almost as big as the opening to the bin; the entering grain keeps displaced air from rising freely through the opening and into the dust hood. When this is the case, dust-laden air sometimes forces its way from the bin through a manhole or gravity vent. It would be better to provide a separate bin opening and hood to capture displaced air and dust that cannot leave the bin at the spout. The hood could be connected to the tripper duct or to an external bin-vent manifold.

Dust collection from bins can be simplified if the bins are interconnected. One dust-collection take-off can effectively maintain negative pressure in a group of interconnected bins. Various codes have different requirements for interconnections, however, and some codes prohibit interconnection of bins in new construction on the theory that intervents can propagate explosions from bin to bin. However, numerous investigations show that as a result of high pressure the explosion will propagate to other spaces regardless of openings. In many cases interventing may be the only practical way to provide for a clean gallery.

When bins are not interconnected, each must have its own dust take-off and exhaust fan. This approach requires no interconnecting ductwork. Also, a fan need run only when its bin is being filled, so less power is consumed than by a large, centralized system with a high-horsepower fan. Even so, the system may be complex and expensive.

Alternatively, a manifold could be used to connect many bins into a central system. Blast gates, or valves, could be used to isolate suction to the proper bin. Grain-dust explosions, sufficiently confined, may generate pressures of up to 120 psia. At pressures below 10 psia bin walls, tops, and discharge spouts through failure would propagate the explosion.

Any bin-venting system, regardless of its design, should provide for free intake of air by the bin. Free intake of air is required to prevent the bin from collapsing when it discharges grain.

Belts

The head pulley on most belts presents two problems: carry-over of whole grain and carry-over of dust. It is best, where practical, to treat these problems separately.

Whole grain that carries over the head pulley usually is released directly under the pulley. This grain is best handled by a mechanical pickup, such as a minature loop conveyor or screw conveyor. The reclaim conveyor can be used to return the collected grain to the grain stream on the top side of the belt. A short screw conveyor can be used to carry the grain to a discharge point where it can be picked up pneumatically or reelevated to the grain stream on the belt.

Dust that carries over the head pulley most often will become airborne at the first return idler pulley. It should be collected at that point by a suction hood. Sometimes, however, dust will become airborne at several return idlers. This can be handled by a high velocity air sweep at the first return idler.

In some cases it is not possible to return the collected grain to the grain stream. An example is the head pulley on a tripper belt (see above, under Trippers). There are two ways to solve this problem. One approach is to handle the grain with a suction hood at the point of carry-over, using high air velocities for pickup and transport to the primary separator. Here a primary separator should be used to remove the grain from the dust stream before it reaches the filter. The other approach is to provide an opening in the bin directly under the head pulley. Grain that carries over the pulley can fall directly into the bin.

Cleaners and Small Scales

Other sources of grain dust in an elevator are cleaners and small open hopper scales. These devices should be enclosed insofar as possible. Ledges and other flat surfaces that can collect dust should be avoided. Aspiration should be applied to the enclosure of each cleaner and scale with sufficient makeup air to provide a sweep of the emission area. Enough suction should be applied to handle the air displaced by entering grain and still create an indraft velocity of 200 fpm at each opening in the enclosure.

Truck and Rail Unloading

Critical areas for controlling grain dust outside elevators are the receiving pits, where trucks and railroad cars are unloaded. Still, there are basic methods for solving the problem. When used properly, they will help to control dust emissions around truck and rail dumps.

Truck Dumps. Control of grain dust at truck dumps is illustrated by Figure 6-8. In the figure, the plan view of the pit at grate level is divided into Areas B, C, and D. The truck crosses the pit from right to left--entering via Area B and leaving via Area C. Options X and Y in the figure are possible arrangements of the dust-collection system.

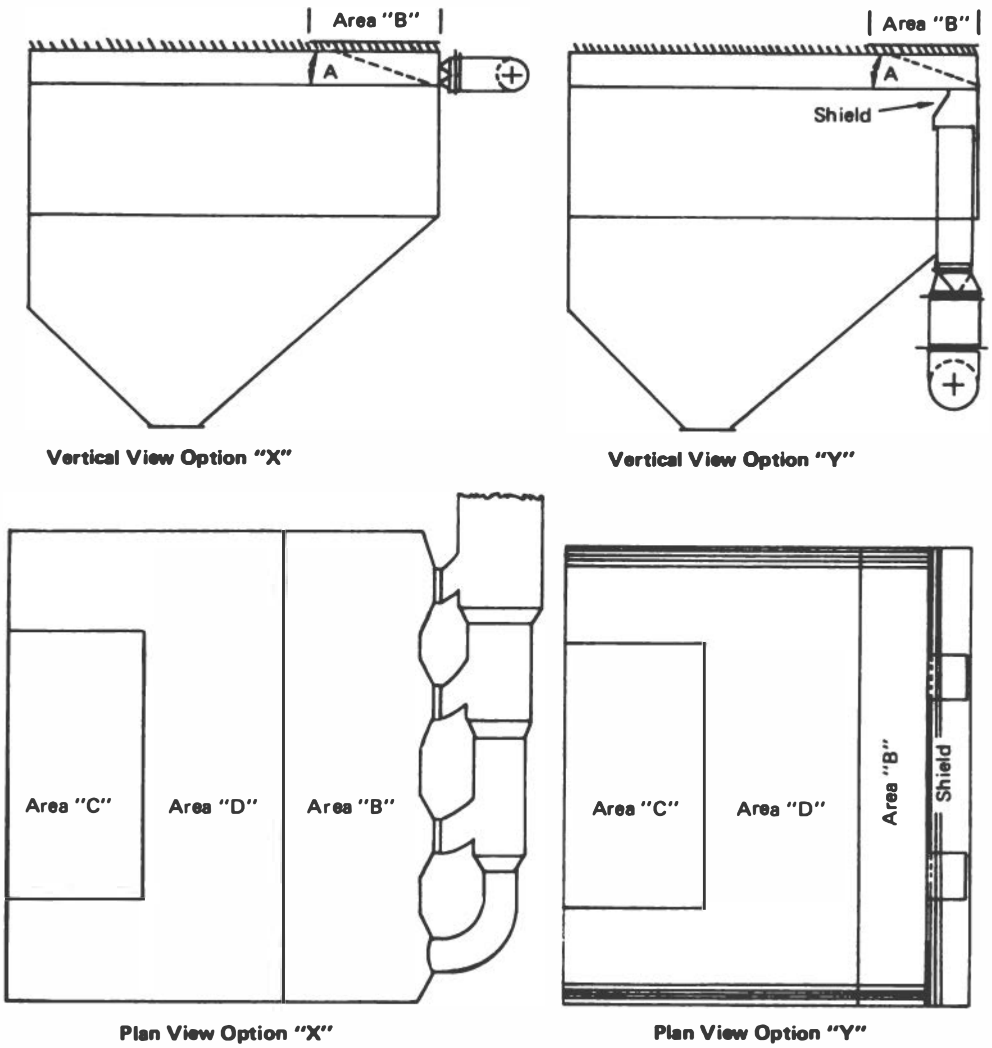
Areas C and D of the pit should be protected by a three-sided building. The back wall of the building should be in Area B, parallel to and 2 or 3 inches from the line dividing Areas B and D. This back wall is an automatic door. It should be closed when grain is being unloaded to keep wind from interfering with the dust-collection system. The door also prevents grain from being spilled on most of Area B, which is covered, thus eliminating a housekeeping problem. The two parallel walls of the building should extend at least 6 ft beyond the front of the pit (the left edge of Area C) to help prevent dust from escaping in that area.

Area B is covered to keep grain from entering the dust-collection system. The cover also creates a space below grate level where airborne dust can be trapped long enough for the pneumatic system to collect it. If the collection system is connected to the pit at only one point (Option Y), a shield should be installed around the pit under the grate to provide an unobstructed air passage to the take-off. The shield prevents grain from filling the pit and restricting the airflow to areas where dust emissions could be a problem.

Relatively little grain enters the pit through Area D. That area should be closed off with baffles that will swing to one side to let grain enter the pit. The baffles are designed to block the escape of dust-laden air from the pit to above floor level. By doing so, they sharply reduce the power consumed by the dust-collection system.

The bulk of the grain falls into the pit through Area C, which should be left open except for the grating. Baffles in Area C would only reduce the unloading rate.

A very important aspect of dust control at a truck dump is to provide the proper airflow through the pit area. The method of computing volume flow is shown in Figure 6-8. The major concern is to supply adequate airflow in all critical areas when the pit is full of grain.



Angle "A"	15 degrees from low point of air outlet to top of grate, determines Area "B".
Area "B"	Cover this area with solid steel plate to keep grain from entering dust system.
Area "C"	4' x 8' open area for easy entry of grain to pit.
Area "D"	Baffles to be installed under grain grate--baffles to cover 2/3 of open area.

Computation of air required to control dust

1. Air displacement caused by grain flow ________________ cfm
   Example: 500 bushels goes into pit in 10 seconds.
   500 bushels/10 seconds = 50 bps x 60 seconds =
   3000 bpm x 1.25 cu ft/bushel = 3750 cu ft/minute
2. Square feet of Area "C" x 100 cfm = ________________ cfm
3. Square feet of Area "D" x 33 cfm = ________________ cfm

Total 1, 2, 3 __________ cfm

FIGURE 6-8 Suggestions for control of grain dust at truck dumps.

It should be noted here that truck and car dumps have been persistent problems with respect to dust emissions. The difficulty has been an inability to concentrate sufficient inlet air in the center of the pit face from where most emissions escape. The treatment first described represents the most successful approach to date, but experimentation is currently underway with a new concept; one which is intended to serve the dual purposes of controlling emissions and cleaning incoming grain, all with less horsepower than is now typically applied.

Rail Dumps. The methods of dust control at truck dumps also apply to railroad hopper cars. Most hopper-car pits are long and narrow and require less airflow than truck dumps. However, the length of the train makes it impossible to close in the ends of the building. Without this control on wind, somewhat higher air velocity than is used in truck dumps may be needed to control cross-drafts.

Truck and Rail Loading

There are several ways to control dust when loading trucks and railroad cars with free-pouring grain. The methods for open-top trucks, hopper cars, and boxcars are generally similar. However, trucks vary much more than railroad cars in height, length, and configuration.

Flex Hoses and Hoods

Dust from loading railroad cars can be captured relatively inexpensively with two flex hoses. Their free ends can be suspended by ropes.

With hopper cars, the end of one hose is suspended near the spout at the top of the grain pile. The other hose extends into the hopper and collects most of the dust there before it escapes. With boxcars, a hose is placed on each side of the grain spout. The hoses can be held in place extended into the boxcar.

The design airflow for this system, for both hopper cars and boxcars, should be 4,200 cfm for each hose or a total of 8,400 cfm. This airflow is based on an air velocity of 4,000 fpm.

A hood over a hopper car can control dust effectively during loading. If the hood extends on both sides of the spout, the car can move in either direction during loading. The hood should be about 16 ft long and 20 inches wide and should have a flexible skirt. Suction should be ducted into each end of the hood. The device should be able to move at least 4 ft vertically, preferably by means of a powered hoist. A telescoping grain spout must be used, and the suction ducts must be telescoping or flexible. The closer the hood fits to the hopper car, the better it will work.

Deadbox Spouts and Hoods

The deadbox spout can be used effectively with both trucks and railroad cars (Figure 6-9). Grain falls freely down the spout, is stopped momentarily in the deadbox, and then drops about 1 ft to the grain pile. The short fall from the deadbox minimizes the generation of dust. Entrained air and dust liberated in the deadbox are aspirated back up the spout by the dust-collection system. On a grain spout 14 inches in diameter, the cross-sectional area of the air conduit will be about 3.2 sq ft. Air velocity should be 1,500 fpm, so the design airflow should be about 4,800 cfm (1,500 fpm x 3.2 sq ft).

The deadbox spout requires vertical clearance and must be retractable and power operated. The nose of the spout must be kept close to the grain pile, but not buried, which can be a problem for the operator. At flow rates lower than about 25 percent of design capacity, grain falls uninterrupted through a deadbox, generating considerable dust on impact with the grain pile. A deadbox should have plug-relief doors to prevent back-up and choking.

A very effective dust-collection system is a combination deadbox and hood. Suction is taken from the deadbox itself and from a hood on each side of the deadbox (see Figure 6-10).

Proprietary Loading Devices

Various proprietary devices are available for controlling grain dust during loading operations. These devices employ the deadbox (and other choke feeding), venturi, centrifugal force, or reverse airsweep principles. They operate most efficiently when held close to the grain pile.

Spout Design, Wind

Spout design is an important aspect of dust control during loading. The best design is a short spout with no air inlet at the top (Figure 6-11). The worst design is a spout that permits air to enter at the top and has a long free-fall. The volume of air entrained with such a spout can be more than 30 times the volume of the entering grain. This condition can create a severe dust problem at the discharge point.

Wind can sharply reduce the effectiveness of dust-control measures during loading. Wind currents are best controlled by enclosing one end of the loading building with roll-up or bi-fold doors. This approach works well when loading trucks, but is less convenient with railroad cars.

Marine Loading

Controlling dust when loading vessels with free-pouring grain involves methods much like those used with trucks and railroad cars. Ships vary much more than barges in hatch size and in height above the waterline at light and full draft. At export elevators radical changes in water level have to be considered when designing dust control for loading spouts.

The most flexible means of controlling grain dust when loading vessels is the hatch tent. Other devices generally have two disadvantages when used with existing loading installations. The first is that the added weight usually cannot be supported without extensive structural changes. The second drawback is that most existing installations were not designed to hold dust-control devices near the grain pile in all loading conditions.

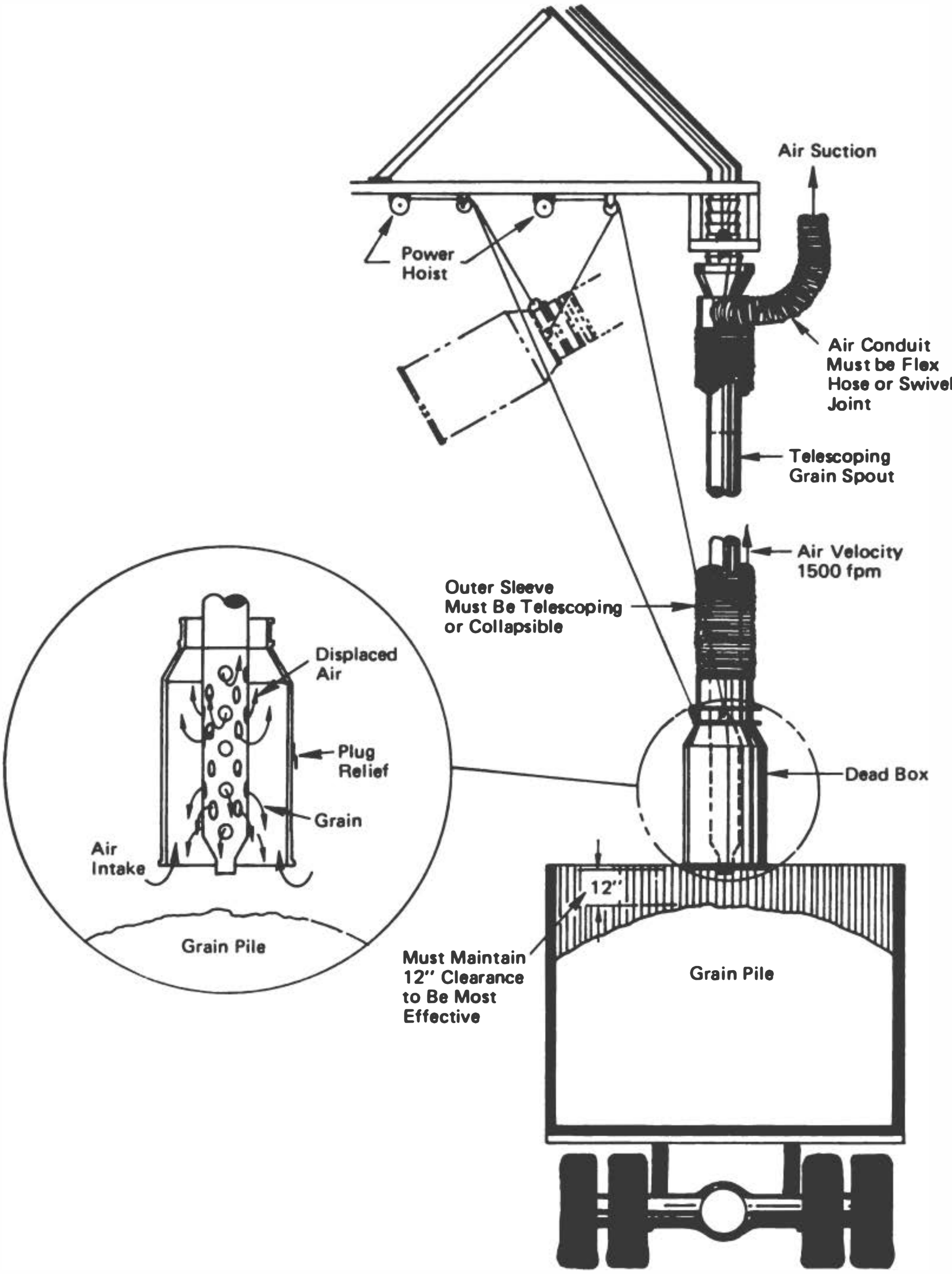


FIGURE 6-9 Retractable spout deadbox for truck load-out.

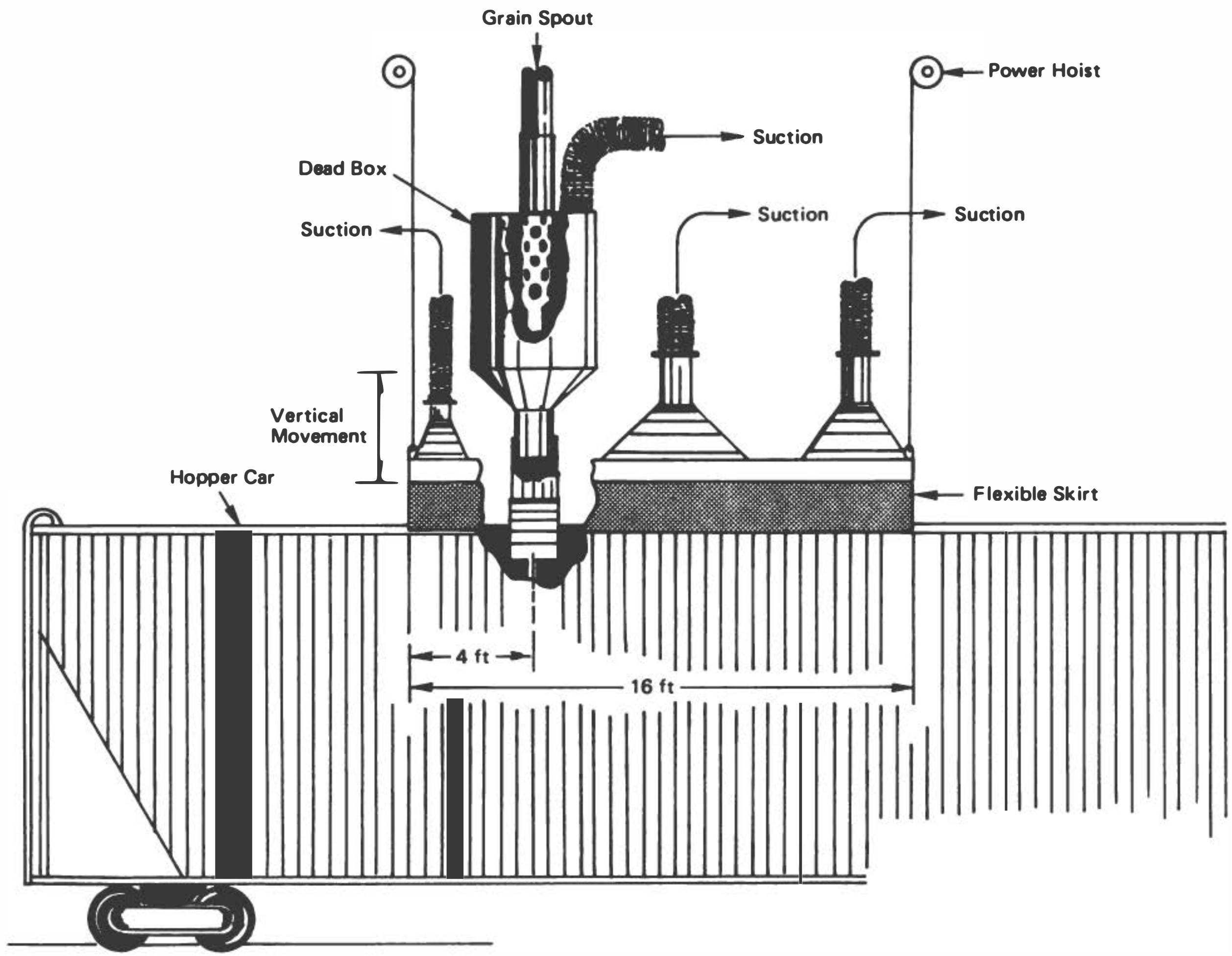
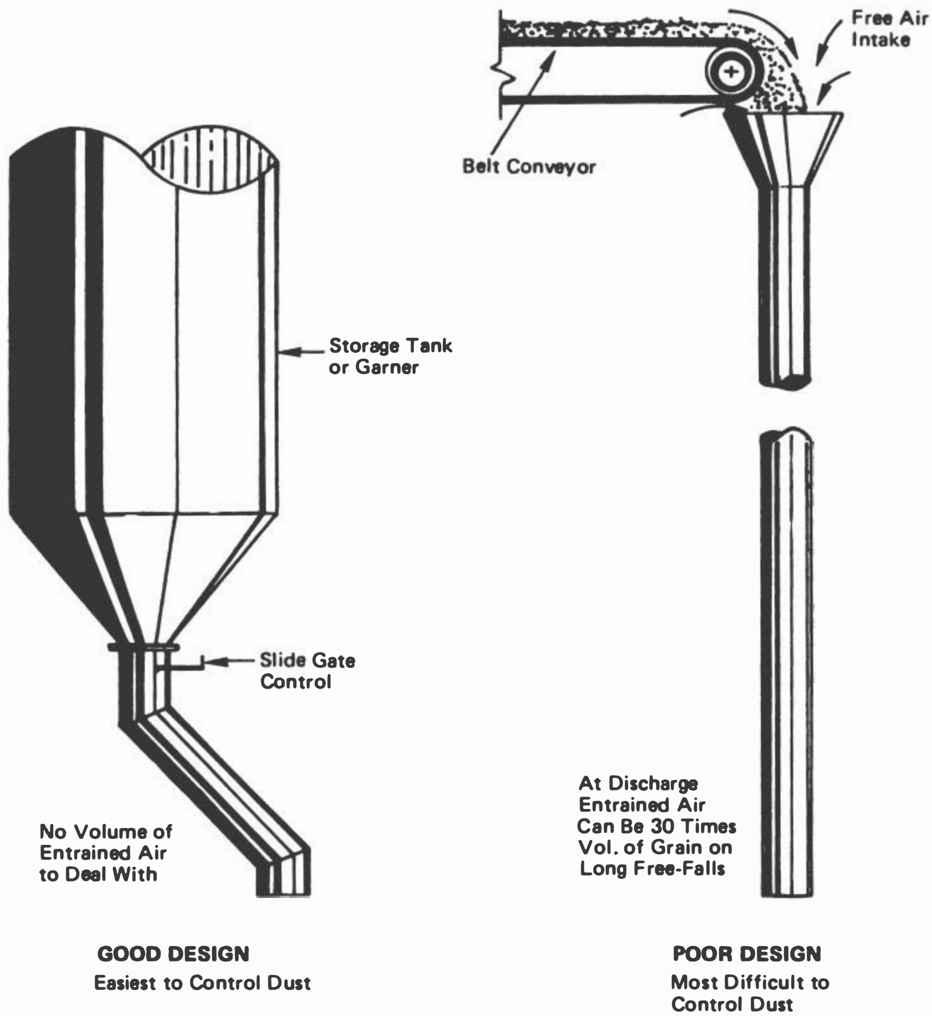


FIGURE 6-10 Combination deadbox with suction hood.



FIGURF 6-11 Load-out spout design.

Hatch Tents

The hatch tent, or covering, is the basis of a number of dust-control systems for marine loading. With the tent in place, negative pressure can be maintained on the hatch using flexible hoses that collect the dust. Little if any structural change is needed to install a hatch-tent system. The tent may be hung from the ship's rigging or simply draped across the hatch. The latter approach is not effective during topping-off procedures.

Other Loading Devices

The deadbox principle described under Truck and Rail Loading (Figure 6-9) is also used with vessels. The same proprietary devices mentioned on page are also used for marine loading operations. Such systems require additional height to accommodate the devices. As noted earlier, the installation must be strong enough to support the extra hardware.

A few marine dust-control systems have gravity spouts whose discharge end can reach the grain pile at all times. The spout is partially buried in the grain pile and kept under negative pressure.

Section 7

REQUIREMENTS FOR DESIGN, INSTALLATION, AND ACCEPTANCE OF PNEUMATIC DUST-CONTROL SYSTEMS

Section 1 of this manual pointed out that many pneumatic dust-collection systems in grain elevators do not perform as anticipated when they were installed. A pneumatic system should do two jobs: it should satisfy dust-emission regulations related to the environment and to occupational safety and health; and it should minimize the hazard of grain-dust explosions. Many installations do neither of these jobs. Sometimes, in fact, by building a false sense of security, they actually increase the hazard of explosions. This section proposes measures designed to correct this state of affairs on an industrywide basis.

Pneumatic dust-collection systems may not perform as expected for several reasons. A major reason, however, is that the contractors who design and install the systems often are poorly qualified for the work. Grain elevators pose special requirements for such systems. These requirements are unlikely to be met by designers and installers who are qualified mainly in heating and air conditioning and in sheet-metal work. Yet elevator operators regularly have relied on contractors so qualified.

Neither operators nor contractors can really be blamed for this situation. There have been no carefully developed standards of performance for pneumatic systems in grain elevators. Moreover, the special problems posed by these systems have not been widely publicized in the industry. Some such problems, in fact, have only recently become evident. Thus elevator operators have not known what performance to expect of their dust-collection systems. Similarly, many contractors have been unaware of the problems in design and installation that they must solve.

The simplest approach to the overall problem would be for the grain industry to specify clearly what it needs in the design and installation of pneumatic dust-collection systems. This task might well be undertaken by one of the industry's trade or technical associations. Likely candidates are the National Grain and Feed Association (NGFA) and the Grain Elevator and Processing Society (GEAPS).

Measures that the appropriate trade or technical association could develop include qualifications for contractors and detailed procedures for specification and acceptance of dust-collection systems. These measures are spelled out in the remainder of this section.

Qualifications for Designers and Installers

A formal, industrywide procedure is proposed here for qualifying contractors to design and update pneumatic dust-collection systems for grain elevators. The procedure would be implemented by an appropriate organization acceptable to the industry. The proposed procedure follows:

A. A permanent, five-member committee shall meet four times each year to compile and update an approved list of designers and installers of dust-collection systems for grain elevators. The committee shall be made up of:

1 Engineer who is actively employed in the grain or an associated industry, is familiar with dust-control design, and is aware of the needs of the grain industry.
1 Operating superintendent.
1 Fire underwriter.
2 Members-at-large.

Members shall serve for two years. Three of them shall be appointed in odd-numbered years and two in even-numbered years by majority vote of the Board of Directors of the sponsoring organization.

This committee should be assigned the primary authority and responsibility for selecting designers and installers who are qualified to meet the needs of the grain industry.

B. Applicants for the approved list of installers shall meet the following criteria:

1. Contractor shall apply to the committee by letter 30 days before a quarterly meeting. Application shall include completion of a document developed for the purpose and generally resembling the Contractor's Qualification Statement of the American Institute of Architects (see Appendix B).
2. Contractor shall provide proof of bonding capacity.
3. Contractor shall provide a current Certificate of Insurance.
4. Contractor shall demonstrate a working knowledge of the guidelines in this manual or of any improved techniques that may be developed in the future.

The application, in addition to providing sufficient information to identify the contractor, shall include the following:

1. List of dust-control jobs contracted during the past five years.
2. Names of employees who have successfully completed the Advanced Course of the Industrial Ventilation Conference.
3. Description of shop facilities.

C. Applications for the approved list of design engineers shall meet the following criteria:

1. Designer shall apply to the committee by letter 30 days before a quarterly meeting.
2. Designer shall demonstrate a working knowledge of the guidelines in this manual or of any improved techniques that may be developed in the future.

The application, in addition to providing sufficient information to identify the designer, shall include the following:

1. List of dust-collection systems designed for grain elevators.
2. Name of employee last completing the Advanced Course of the Industrial Ventilation Conference given under the auspices of the American Conference of Governmental Industrial Hygienists, and date of completion.
3. List of engineering qualifications and description of expertise.

Summary of Intent

The foregoing procedure is proposed as a means by which the grain industry can improve the quality and performance of the dust-collection systems that it buys. The procedure no doubt would introduce a degree of regimentation and standardization. However, it is not intended to exclude any qualified designers and installers from the business, nor to hinder the introduction of new dust-collection technology.

Specification and Acceptance Testing

Acceptance testing, in its simplest form, means "try before you buy." It is the elevator operator's means of insuring that he is getting exactly the dust-collection system he specified and that it is meeting his needs as expected. The operator should thoroughly check the condition and operation of both new and modified dust-collection equipment. He should not pay for a job until he is satisfied with it. This condition should always be specified in design, installation, and purchase contracts.

Besides the obvious benefit to the buyer, acceptance testing--as well as warranties and contractually stated break-in periods--offers benefits to the seller. By clearly defining these matters in the contract, the seller effectively limits his liability for the job.

From another perspective, acceptance testing of dust-collection equipment is an important means of minimizing the hazard of fire and explosion. The competent elevator operator makes sure that his equipment is performing according to design and that it will continue to perform within acceptable tolerances. Besides minimizing hazard, insistence on quality minimizes costs in the long run.

The operator who is buying a dust-collection system should specify clearly, to designers and installers, the performance he requires. The specifications should be written into the contract and should include procedures for acceptance testing. The following guidelines are recommended.

Guidelines for Specification and Acceptance Testing

1. Specifications

   The buyer's specifications to the designer should always call for a given level of performance under specific conditions. The designer is responsible for specifying the equipment and installation to meet the owner's performance requirements.

   A. Legs No visible dust emission and sufficient volume flow and proper design aerodynamics to provide airsweep.

   B. Enclosed Equipment (conveyors, cleaners, etc.) No visible dust emission from enclosed equipment operating at design capacity, except where structural or mechanical conditions make such performance impossible. Exceptions should be identified in the specifications.

   C. Scales No visible dust emission from scales operating at design capacity (same exceptions as in 1B). No effect on the accuracy of the scales as a result of differential pressure in the system.

   D. Dust Hoods and Loaders No visible dust emission, at design airflow, from hoods and truck, rail, and vessel loading and unloading.

   E. Grain Loading and Unloading--Truck, Rail, Vessel Should comply with local regulations related to the environment and occupational safety and health.

   F. Driers Should comply with local regulations related to the environment and occupational safety and health.

   G. Fabric Filter Pressure drop across fabric filter, after 45 days of operation, shall not exceed the maximums stipulated in the agreement and shall not in any case exceed 5 inches of water.

   H. Blast Gates and Cleanout Opening Location and type.

   I. Instrumentation Number and location of magnehelic or photohelic gauges, pitot tubes, and manometers.

   J. Conveyor-Belt Head Pulley Specify how dust carried over the head pulley will be recovered and conveyed to the dust or grain stream.

2. <u>Review of Design to Increase Safety Factor in Performance</u>

By reviewing the design, the buyer may be able to specify upgrading of equipment so as to increase the safety factor in performance at little increase in the total cost of the dust-collection system. The buyer and designer can assess the possibilities by checking the following points:

A. Types, sizes, and horsepower of fans.

B. Filter media.

C. Air-to-cloth ratios.

3. The agreement should stipulate adherence to the specified design standards, especially those for inlet and transport velocities, hoods, volume flows, transition fittings, and air-to-cloth ratios.

4. <u>Important Miscellaneous Specifications</u>

A. Types and gauges of metal.

B. Types and sizes of fans.

C. Design static pressure.

D. Volume of air to be removed per minute at all takeoff points.

E. Nominal transport velocities.

F. Air-to-cloth ratios of all fabric filters.

G. Types and sizes of motors.

H. Explosion-vent ratios on fabric filters.

I. Locations of filters.

J. Types and sizes of rotary valves on filters.

K. Types and locations of monitoring instruments (magnehelic gauges, etc.) for filters.

L. Requirement and equipment for compressed air (if applicable).

M. Provision for maintenance platforms.

N. Initial instructions for operation and maintenance.

O. Certification of bidder's accreditation by permanent committee on qualifications proposed earlier in this section.

5. Acceptance Testing The buyer shall perform an acceptance test of the dust-collection system according to the foregoing specifications. This test should be performed after 45 days of operation. A sample check list for the acceptance test is shown in Table 7-1.

TABLE 7-1 Sample Check List for Acceptance Test

Description of Item to be Checked	Design Value	Actual Value at 45 Days
1. System airflow (cfm)		
2. Air-to-cloth ratio		
3. Fan performance (rpm, cfm, static pressure, brake horsepower)		
4. Static-pressure drop across filter		
5. Air velocity in duct at		
Point 1		
2		
3		
4		
5		
etc.		

Section 8

INSTRUMENTATION, OPERATION, AND MAINTENANCE

A pneumatic dust-collection system is made up of many interrelated components. The efficiency of the entire system suffers if a single component is not working properly. To assure maximum efficiency, operating personnel must monitor the system continually and inspect and maintain it on a regular schedule. This section covers basic aspects of the instrumentation, operation, and maintenance of dust-collection systems. The section is not intended to be comprehensive. Day-to-day operation and maintenance of a system requires much more information than can be given here.

Operators should have at hand the original design data and drawings for their dust-collection systems. When a system is modified, the data and drawings should be modified accordingly. The responsible people should study these materials until they are thoroughly familiar with the layout and intended performance of the system. They should also study the instruction manuals provided with the equipment and keep the recommended tools and spare parts readily available.

Instrumentation

Various instruments and associated hardware are available for monitoring and controlling dust-collection systems. Besides contributing to efficient operation, this equipment warns of potentially hazardous breakdowns. Commonly used equipment and its functions are described briefly below.

Types of Equipment

A magnehelic gauge is a pressure-measuring device with a direct-reading dial. Normally it is used to measure the pressure drop across a fabric filter.

A photohelic gauge is also a pressure-measuring device. It has a direct-reading dial like a magnehelic gauge, but also has electrical contacts that can be wired to an alarm, such as a light or horn, on a control panel. The contacts are actuated by pressure. Usually they are set at the upper and lower pressure limits.

A manometer is a handy device for measuring static pressure at any point in a dust-collection system. It is a glass or plastic tube shaped like a long U and filled with oil or antifreeze. The tube is marked to indicate pressure in inches of water.

A pitot tube is a device that can be used with a manometer to measure velocity pressure--the pressure exerted on a flat plate by a stream of air flowing perpendicular to the plate. Velocity pressure can be used to determine volume flow in a duct.

A level indicator is used to detect plugging of a filter hopper with dust. One type of level indicator is a rotating paddle wheel driven by a torque motor through a friction clutch. The clutch slips when dust builds up in the hopper and covers the paddle wheel. A second type of level indicator is a pressure-sensing diaphragm that detects a buildup of dust. A third type is a probe having a dielectric field that changes when the probe is surrounded by dust.

Each type of level indicator is tied electrically to an alarm that signals when the hopper is plugging.

A broken-bag detector usually is a photoelectric cell in the air outlet of the filter. It detects abnormal discharge of dust from the filter and actuates an alarm.

A zero-motion switch signals failure of rotating equipment, such as the rotary discharge valve on a filter.

A pressure-differential switch can be preset to close and open at specified pressures. It is used to control "demand cleaning" of filter bags. The cleaning system starts when the pressure drop across the filter reaches the high setting of the switch and stops when it returns to the low setting.

A recording pen can be used with a pressure sensor to record a permanent, continuous log of pressure at a desired point.

Basic Monitoring Equipment

It is recommended that a dust-collection system be equipped with basic monitoring devices at least sufficient to warn of potentially hazarous malfunctions. An adequate installation would include the following devices:

Filter

1. A magnehelic gauge to give the pressure drop across the unit. A manometer could be used instead, but may not work properly in extreme heat or cold. If the operation of the elevator is monitored from a central control panel, it may be desirable to replace the magnehelic gauge with a photohelic gauge wired to an alarm at the control panel.

2. A pressure-differential switch to control "demand cleaning" of the bags.

3. A broken-bag detector.

4. A level indicator in the filter hopper.

5. A pressure gauge with recording pen to log pressure drop across the filter.

6. A microswitch at the filter inlet to close down the system when cleaning.

7. A zero-motion switch to signal stoppage of the rotary discharge valve on the filter hopper.

Exhaust Fan

1. A magnehelic gauge to give static pressure between inlet and outlet of fan.

2. A pitot tube calibrated to give direct reading of airflow in system.

Ductwork

1. A manometer installed at each hood to indicate suction at hood.

Electrical Interlock

Besides being equipped with basic monitoring and control equipment, the moving components of a dust-collection system should be electrically interlocked. The interlock should be arranged so that shutdown of any component will shut down the system. It is also recommended that a time-delay sequence be built into the electrical system. The order of start-up would be:

1. Pneumatic system or screw conveyor taking dust away from filter.

2. Rotary discharge valve on filter.

3. Bag-cleaning motors on filter.

4. Exhaust fan on the system.

To shut down the system, the foregoing sequence would be reversed. The grain elevator handling should be interlocked so that they cannot operate without the dust system in operation.

Using the Instruments

Proper instrumentation can tell you basically how a pneumatic dust-collection system is performing. Figure 8-1 shows the relationship of the components of a typical system and the points where instruments may be installed. The uses of the instruments are described briefly below. Again, however, keep in mind that the description is not intended to be comprehensive.

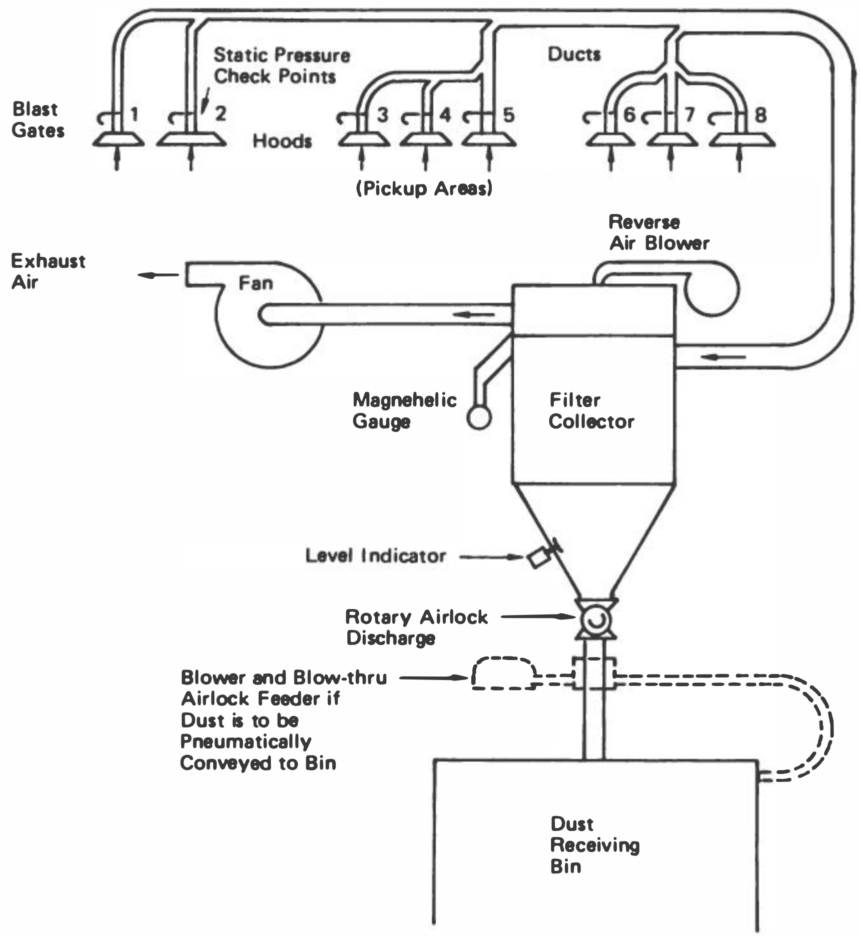


FIGURE 8-1 Typical dust control system. The figure shows an exhaust system because the fan draws air through the collector. If the fan is ahead (i.e., pushing air through) of the collector, it is a blow system. Most cyclone collectors are attached to blowing systems, and most filter collectors are attached to exhausting systems.

Filter Pressure

A typical installation of a magnehelic (or photohelic) gauge on a fabric filter is shown in Figure 8-2. It is useful to mark (red-line) the face of the gauge to show the lower and upper pressure limits for acceptable operation.

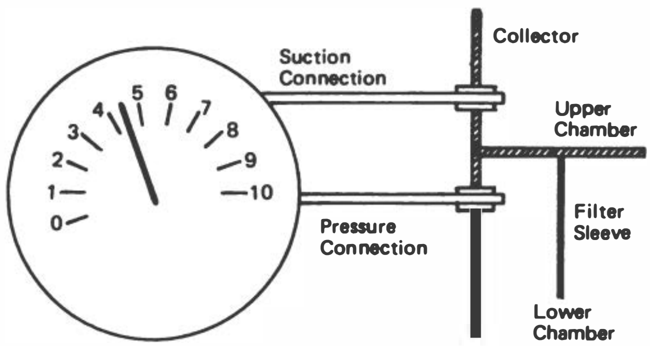


FIGURE 8-2 Typical magnehelic gauge installation. The best method of determining whether a collector is operating effectively is to check the magnehelic gauge. If filter resistance is above 3-4 inches of static pressure (SP difference between the upper and lower chamber), check the filters for excessive dust accumulation.

Filters are designed to operate at a pressure of 3 to 5 inches of water. (Pressure at start-up may be less than 1 inch until a mat of dust begins to build up on the fabric.) Once the filter reaches equilibrium pressure, the magnehelic (or photohelic) gauge becomes an indicator of the operation of the entire system. So long as the gauge reads between 3 and 5 inches of water, the system will be delivering design volume flow.

When pressure exceeds the upper limit, the filter should be checked for malfunction. If none is found, the excessive pressure means that the bags should be cleaned or replaced. Normally, the bags should not require attention until after many months of operation.

When filter pressure falls below the lower limit, the system, again, should be checked for malfunction. The most likely problems are broken filter bags, a partially plugged main duct, closed blast gates in branch ducts, or slipping belts on the system's exhaust fan.

Filter Hopper

Level indicators should be included with all new filters, and retrofit is recommended for existing filters. An indication of dust buildup in the filter hopper points to one of several problems: failure of the rotary discharge valve on the hopper; plugging downstream of the filter; or bridging of dust in the hopper.

Manometer-Pitot Tube

The manometer is used to balance a dust-collection system initially. It is also used periodically to recheck static pressures at hoods or other points. The use of the instrument is shown in Figure 8-3. Note that atmospheric pressure at the open end of the manometer depresses the column of water against the lower pressure inside the duct. The instrument is marked so that the vertical distance between the ends of the column is pressure in inches of water.

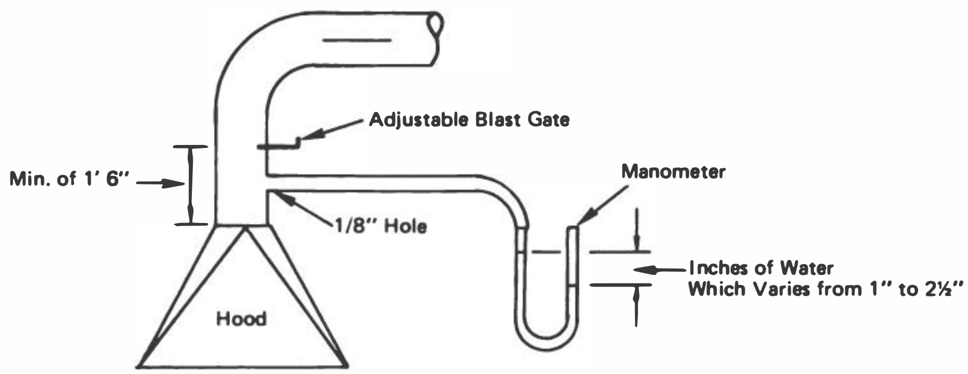


FIGURE 8-3 Typical hood and blast gate.

Figure 8-4 shows the use of the pitot tube and manometer to measure velocity pressure. The pitot tube is a combination of two tubes, as shown. The leading tube measures total pressure in the duct, and the trailing tube measures static pressure. The difference--the velocity pressure--is shown by the manometer.

Velocity pressure can be used to obtain airflow in a duct. The velocity of the air in the duct in feet per minute is 4,000 times the square root of the velocity pressure in inches of water as shown in Figure 8-4. The velocity (V) times the cross sectional area (A) of the duct gives airflow (Q) in cubic feet per minute (i.e., Q = AV). Tables are available that give airflows for a range of velocity pressures and duct sizes.

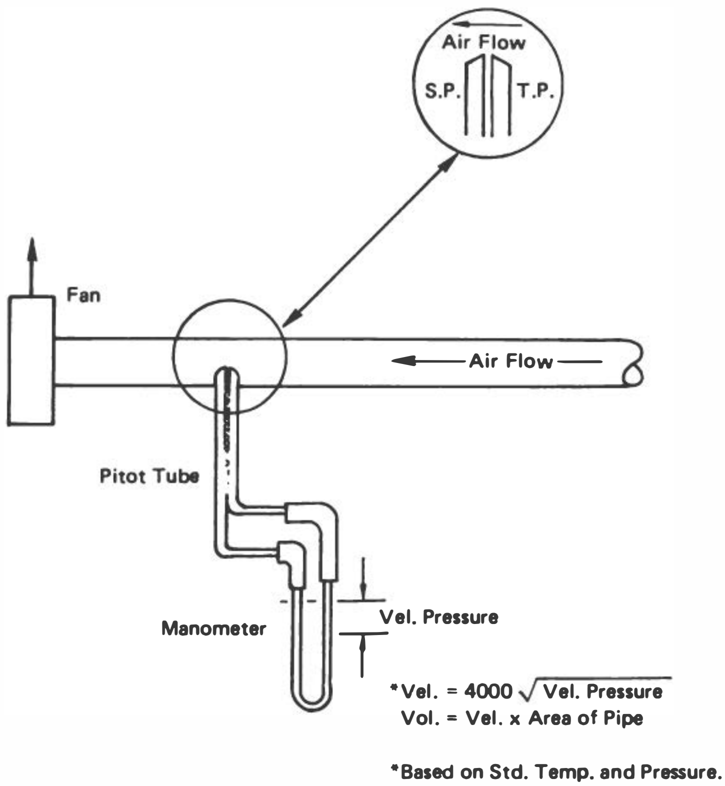


FIGURE 8-4 Pitot tube. The pitot tube, an instrument for measuring velocity pressure, consists of two tubes joined together as shown. Special pitot tubes are required for measuring air flow in a pipe containing dust. The standard ASME tube is unsatisfactory because the holes in the tube plug with dust quickly. The pitot tube is inserted in the pipe at right angles to the air flow and a traverse is made to get the average velocity pressure reading.

Maintenance

Maintenance should be kept constantly in mind when designing and installing dust-collection systems. Likely problem points such as elbows, long horizontal runs, should be made accessible for inspection and routine maintenance or repair. Inspection ports should be provided as necessary. Remember that a poor design cannot be well maintained.

It is recommended that one individual be assigned to monitor the operation of the dust-collection system. The individual assigned should have all manufacturers' maintenance manuals readily available. He should be thoroughly familiar with the manuals so as to be able to pinpoint trouble should it occur.

The individual responsible for the system should follow a regular schedule of inspection and maintenance. The exact schedule will depend on the particular system and the number of hours it operates per day or week. However, a sample maintenance schedule is shown below. Table 8-1 shows a sample trouble shooting guide.

Sample Maintenance Schedule

Daily

1. Check magnehelic-gauge readings on all filters.
2. Check for dust in clean-air outlet from filter.
3. Check filter hoppers for continuous discharge of dust.

Weekly

1. Check and record magnehelic-gauge readings on all filters.
2. Check fan and motor bearings for excessive heat or vibration.
3. If high-pressure pneumatic conveying equipment is used to dispose of dust, check the positive-displacement pump for vibration, overheating, and proper lubrication. Also, compare reading on pressure gauge with previous readings. Clean air-inlet filter or replace as necessary. It is important to follow the manufacturer's recommendation on this piece of equipment.

Monthly (or at manufacturer's recommended intervals)

1. Check oil in all gearmotors. Do not overfill.

Six Months

1. Check belt tension on all V-belt drives.

TABLE 8-1 Sample Troubleshooting Guide

Problem	Possible Source
Abrupt rise in magnehelic-gauge reading	Tubes plugged: tube-cleaning mechanism faulty
No magnehelic-gauge reading	Plugged tubing to gauge: gauge defective; fan off
Dust in (normally) clean air outlet	Filter tube torn or missing
Filter hopper plugged	Debris over outlet, or rotary valve not operating
No airflow	Fan not running; main airflow damper closed
Excessive buildup of dust in ductwork	Low airflow; high filter back pressure or obstruction in hoods; closed blast gates
Main exhaust-fan motor overloads (straight-bladed fan)	Main airflow damper open too far
Rotary-valve gearmotor overloads	Obstruction in valve

Appendix A

DEFINITIONS[a]

Aerosol: An assemblage of small particles, solid or liquid, suspended in air. The diameter of the particles may vary from 100 microns down to 0.01 micron or less, e.g., dust, fog, smoke.

Air Cleaner: A device designed for the purpose of removing atmospheric airborne impurities such as dusts, gases, vapors, fumes, and smokes. (Air cleaners include air washers, air filters, electrostatic precipitators, and charcoal filters.)

Air, Dry: Air containing no water vapor.

Air Filter: An air cleaning device to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: Loadings up to 3 grains per thousand cubic feet (0.003 grains per cubic foot). Note: Atmospheric air in heavy industrial areas and in-plant air in many industries has higher loadings than this, and dust collectors are then indicated for proper air cleaning.

Air Horsepower: The theoretical horsepower required to drive a fan if there were no losses in the fan--that is, if its efficiency were 100 percent.

Air, Standard: Dry air at 70° F and 29.92 inches (Hg) barometer. This is substantially equivalent to 0.075 lb/cu ft. Specific heat of dry air = 0.24 Btu/lb°F.

Air-to-Cloth Ratio: The volumetric rate of capacity of a fabric filter; the volume of air (gas), in cubic feet per minute, per square foot of filter media (fabric).

Anemometer: An instrument for measuring the velocity of air or gas.

Aspect Ratio of an Elbow: The width (W) divided by depth (D) in the plane of the bend. $AR = \frac{W}{D}$ (see Figure 3-9)

Aspiration: The movement of air by suction.

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[a] Compiled in part from Industrial Ventilation: A Manual of Recommended Practice, 25th Edition, American Conference of Government Industrial Hygienists, Lansing, 1978 and "Fundamentals of Fabric Collectors and Glossary of Terms," Publication No. F-2, Industrial Gas Cleaning Institute, Inc., Stamford, 1972.

Atmospheric Pressure: The pressure of the atmosphere as measured by means of the barometer at the location specified.

Backwash: A method of fabric cleaning where direction of filter flow is reversed, accompanied by flexing of the fabric and breaking of the dust cake. Also known as backpressure, repressure, collapse-clean, etc.

Bag: The customary form of filter element. Also known as tube, stocking, etc. Can be unsupported (dust on inside) or used on the outside of a grid support (dust on the outside).

Blast Gate: A sliding plate installed in a supply or exhaust duct at right angles to the duct for the purpose of regulating airflow.

Blinding (Blinded): The loading, or accumulation, of filter cake to the point where capacity rate is diminished. Also termed "plugged."

bph: bushels per hour.

bpm: bushels per minute.

bps: bushels per second.

Brake Horsepower: The horsepower actually required to drive a fan. This includes the energy losses in the fan and can be determined only by actual test of the fan. (This does not include the drive losses between motor and fan.)

Capture Velocity: The air velocity necessary to entrain dust particles.

cfm: cubic feet per minute.

Convection: The motion resulting in a fluid from the differences in density and the action of gravity. In heat transmission this meaning has been extended to include both forced and natural motion or circulation.

Cyclone: Mechanical dust collector using inertial principles for dust separation.

Damper: An adjustable plate installed in a duct for the purpose of regulating airflow.

Density: The ratio of the mass of a specimen of a substance to the volume of the specimen. The mass of a unit volume of a substance. When weight can be used without confusion, as synonymous with mass, density is the weight of a unit volume of a substance.

Density Factor: The ratio of actual air density to density of standard air. The product of the density factor and the density of standard air (0.075 lb/cu ft) will give the actual air density in lbs. per cu ft: d x 0.075 = actual density of air, lbs per cu ft.

Dust: Defined for the purpose of this study as particles of grain and foreign material that will pass through a 200-mesh (74-) screen.

Dust Collector: An air cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: Loadings of 0.003 grains per cubic foot and higher. See Cyclone, Fabric Filter.

Dust Loading: The weight of solid particulate suspended in an air (gas) stream, usually expressed in terms of grains per cubic foot, grams per cubic meter, or pounds per thousand pounds of gas.

Dust Permeability: Defined as the mass of dust (grains) per square foot of medium divided by the resistance (pressure drop), inches WG per unit of filtering velocity, fpm. Not to be compared with cloth permeability.

Entry Loss: Loss in pressure caused by air flowing into a duct or hood (inches H_2O).

Envelope: A common form of filter element.

Fabric: A planar structure produced by interlacing yarns, fibers or filaments. May include felts and woven materials.

Fabric Filter: A dust collector using a fabric for separation of dust from air.

Filter Drag: Pressure drop, inches WG per cubic foot of air per minute, per square foot of filter medium. Analogous to the resistance of an element in an electrical circuit. The ratio of filter pressure to filter velocity.

Filter Medium: The substrate support for the filter cake; the fabric upon which the filter cake is built.

fpm: feet per minute.

Grain: A measure of weight, 1/7000 pounds or approximately 65 milligrams.

Gravity, Specific: The ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2^{o} F is usually the standard substance. For gases, dry air, at the same temperature and pressure as the gas, is often taken as the standard substance.

Hood: A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.

Humidity, Absolute: The weight of water vapor per unit volume, pounds per cubic foot or grams per cubic centimeter.

Humidity, Relative: The ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature. (The amount of water contained in air at a given temperature as a percentage of the total amount of water it can contain at that temperature.)

Inch of Water: A unit of pressure equal to the pressure exerted by a column of liquid water one inch high at a standard temperature. The standard temperature is ordinarily taken as 70°F. One inch of water at 70°F = 5.196 lb per sq ft.

Lower Explosive Limit: (See also Minimum Explosible Concentration.) The lower limit of flammability or explosibility of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume. This limit is assumed constant for temperature up to 250°F.

Magnehelic Gauge: A pressure differential gauge that, when used in filter-type dust collectors, measures the static pressure difference between the dust-laden air intake (lower) chamber of a collector and the clean air outlet (upper) chamber. It is important to know that as the static pressure difference increases, the airflow through the cloth filter is being restricted.

Manometer: An instrument for measuring pressure; essentially a U-tube partially filled with a liquid, usually water, mercury, or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Micron: One micron is approximately 1/25,000 of an inch (0.00004 inches) (human hair diameter ranges from 50-75 microns).

Minimum Design Duct Velocity: Minimum air velocity required to move the particulates in the air stream, fpm.

Minimum Explosible Concentration: The smallest amount of particulate material, which when dispersed in a volume of air, will permit combustion of the dispersion to occur (oz/ft^3, g/m^3).

Permeability, Fabric: Measured on Frazier porosity meter, or Gurley permeometer, etc. Not to be confused with dust permeability. The ability of air (gas) to pass through the fabric, expressed in cubic feet of air per minute per square foot of fabric with a 0.5 inches H_2O pressure differential.

Photohelic Gauge: Same as magnehelic gauge (see above), but has electrical contacts and can be wired to alarm on control panel.

Pitot Tube: A means of measuring velocity pressure. A device consisting of two tubes--one serving to measure the total or impact pressure existing in an air stream, the other to measure the static pressure only. When both tubes are connected across a differential pressure-measuring device, the static pressure is compensated automatically and the velocity pressure only is registered.

Plenum Chamber: A pressure-equalizing chamber connected to one or more ducts.

Porosity, Fabric: Term often used interchangeably with permeability. Actual percentage of voids per unit volume--therefore, the term is improperly used where permeability is intended.

Pressure, Atmospheric: The pressure due to the weight of the atmosphere, as indicated by a barometer. Standard atmospheric pressure is 29.92 inches of mercury; equivalents in other units are 760 mm of mercury, 14.7 psia, and 407 inches of water.

Pressure, Gauge: Pressure measured from atmospheric pressure as a base. Gauge pressure may be indicated by a manometers which has one leg connected to the pressure source and the other exposed to atmospheric pressure.

Pressure Jet Cleaning: A bag-cleaning method where a momentary burst of compressed air is introduced through a tube or nozzle attached to the top cap of a bag. A short blast of air flows down the bag causing bag walls to collapse behind it.

Pressure, Resistance: Resistance pressure (RP) is the pressure required to overcome the resistance of the system. It includes the resistance of straight runs of pipe, entrance to headers, bends, elbows, orifice loss, and cleaning device. It is indicated by the difference of total pressure between two points in the duct system.

Pressure, Static: The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air.

Pressure, Total: The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).

Pressure, Velocity: The pressure required to accelerate air from a state of rest to the particular velocity required. It is the pressure that would be exerted against a flat surface placed in a moving air stream at right angles to the direction of motion.

psi: pounds per square inch.

Pulse Jet: A system of bag cleaning using a momentary burst of compressed air in the discharge nozzle of a filter bag, which stops filter flow and inflates the bag in the opposite direction.

Reverse Jet Cleaning: A cleaning method using a traveling ring traversing the exterior of the filter bag. High-pressure air is blown backward through the fabric through small holes or slots in contact with the cloth.

Shaking (Cleaning): A common, mechanical method of removing dust from filter elements. Backwash, or other supplemental methods, are often used with shaking.

Temperature, Dew-Point: The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

Temperature, Dry-Bulb: The temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

Temperature, Wet-Bulb: Thermodynamic wet-bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications.

Transport (Conveying) Velocity: See Minimum Design Duct Velocity.

Volume, Specific: The volume of a substance per unit mass; the reciprocal of density; usually given in cubic feet per pound, etc.

Water Gauge (WG): A term used after numerical pressure figures, that means the figure is calculated in terms of inches of water as obtained from the differential water levels of the two legs of a manometer. (Example: 2.8 inches WG).

Appendix B
SAMPLE OF A CONTRACTOR'S QUALIFICATION STATEMENT

The following Contractor's Qualification Statement, developed by the American Institute of Architects, illustrates the design of such a document. A qualification statement for designers and installers of pneumatic dust-collection systems for the grain industry would have to be tailored to the needs of that industry.

THE AMERICAN INSTITUTE OF ARCHITECTS

AIA Document A305

Contractor's Qualification Statement

1979 EDITION

Required in advance of consideration of application to bid or as a qualification statement in advance of award of contract. Approved and recommended by The American Institute of Architects and The Associated General Contractors of America.

The Undersigned certifies under oath the truth and correctness of all statements and of all answers to questions made hereinafter.

SUBMITTED TO:

ADDRESS:

SAMPLE

SUBMITTED BY:
NAME:
ADDRESS:
PRINCIPAL OFFICE:

Corporation ☐
Partnership ☐
Individual ☐
Joint Venture ☐
Other ☐

1.0 How many years has your organization been in business as a General Contractor?

2.0 How many years has your organization been in business under its present business name?
2.1 Under what other or former names has your organization operated?

3.0 If a corporation answer the following:

3.1 Date of incorporation:

3.2 State of incorporation:

3.3 President's name:

3.4 Vice-president's name(s):

3.5 Secretary's name:

3.6 Treasurer's name:

4.0 If an individual or a partnership answer the following:

4.1 Date of organization:

4.2 Name and address of all partners (State whether general or limited partnership):

5.0 If other than a corporation or partnership, describe organization and name principals:

6.0 List states and categories in which your organization is legally qualified to do business. Indicate registration or license numbers, if applicable. List states in which partnership or trade name is filed.

7.0 We normally perform the following work with our own forces:

8.0 Have you ever failed to complete any work awarded to you? If so, note when, where, and why:

9.0 Within the last five years, has any officer or partner of your organization ever been an officer or partner of another organization when it failed to complete a construction contract? If so, attach a separate sheet of explanation.

10.0 On a separate sheet, list major construction projects your organization has in process, giving the name of project, owner, architect, contract amount, percent complete, and scheduled completion date.

11.0 On a separate sheet, list the major projects your organization has completed in the past five years, giving the name of project, owner, architect, contract amount, date of completion, and percentage of the cost of the work performed with your own forces.

12.0 On a separate sheet, list the construction experience of the key individuals of your organization.

13.0 Trade References:

14.0 Bank References:

15.0 Name of Bonding Company and name and address of agent:

16.0 Attach a financial statement, audited if available, including Contractor's latest balance sheet and income statement showing the following items:

A. Current Assets (e.g., cash, joint venture accounts, accounts receivable, notes receivable, accrued income, deposits, materials inventory and prepaid expenses):

B. Net Fixed Assets:

C. Other Assets:

D. Current Liabilities (e.g., accounts payable, notes payable, accrued expenses, provision for income taxes, advances, accrued salaries, and accrued payroll taxes):

E. Other Liabilities (e.g., capital, capital stock, authorized and outstanding shares par values, earned surplus, and retained earnings):

Name of firm preparing financial statement and date thereof:

Is this financial statement for the identical organization named on page one?

If not, explain the relationship and financial responsibility of the organization whose financial statement is provided (e.g., parent-subsidiary).

Will this organization act as guarantor of the contract for construction?

17.0 Dated at

this day of 19

Name of Organization:

By:
Title:

18.0

M being duly sworn deposes and says that he/she is the of

Contractor(s), and that answers to the foregoing questions and all statements therein contained are true and correct.

Subscribed and sworn before me this day of 19

Notary Public:

My Commission Expires:

Appendix C

RESULTS OF AN EXPERIMENT TO DETERMINE WHETHER DUST SUSPENSIONS IN BUCKET ELEVATOR LEGS CAN BE KEPT BELOW THE LOWER EXPLOSIVE LIMIT BY PNEUMATIC MEANS*

To determine whether the normal dust suspensions in a typical elevator leg could be reduced below the lower explosive limit, the following tests were made. The purpose of the test was: (a) to measure the effects of various volumes of air removal and (b) to compare the results obtained by taking aspiration from the boot-top, which creates turbulence in the boot and base of the up-leg, as opposed to taking aspiration from the sides of the up-leg, which provides a more laminar air sweep of the boot and is in accord with the natural aerodynamics of the leg. The indications obtained from these tests are significant.

CONCLUSIONS**

The test procedure was to insert probe header into the leg casing at locations indicated in Figure C-1. Two tests were run at each sample location for approximately one minute each, one with the probes up and one with the probes down. Refer to air flow schematic (Figure C-2) for sampling procedure, which illustrates the probes. The three graphs in Figure C-3 show the results from each sample location. The highest concentration of dust was found in the up-leg above the boot. When aspiration was moved from the top of the boot to the up-leg above the boot (dirtiest part of the leg), the dust concentration at all three sample points was lowered to below the lower explosive limit.

This testing procedure may have some weakness and it may not be a totally true representation of the condition within the leg for two reasons.

1. The short duration of tests (approximately one minute) and the small amount of air sampled.

2. Variation in the collected data between probe up readings and probe down readings.

---

* Courtesy of Russell Brackman, MAC Equipment, Inc., Sabetha, Kansas and Ken Buss, The Pillsbury Company, Minneapolis, Minnesota.

** This report and the conclusions herein are based on testing and techniques that are based on assumptions, therefore the accuracy is uncertain. Pillsbury and MAC Equipment, Inc., accept no responsibility in regard to any parties use of any information contained herein. Further, the conclusions drawn may not be applicable to other equipment or operating conditions.

LOCATION: ______________________

____

Air Volume From Bucket Elevator
Suction Location. A & B
--- Duct Size $\frac{A=12"}{B=14"}$ = $\frac{.785}{1.06}$ Ft.^{2}

VELOMETER READINGS

1) ________ 5) ________ 9) ________
2) ________ 6) ________ 10) ________
3) ________ 7) ________ 11) ________
4) ________ 8) ________ 12) ________

Total ______ ÷ ______ = Avg. ______ FPM

______ Ft.^{2} x ______ FPM = ______ CFM

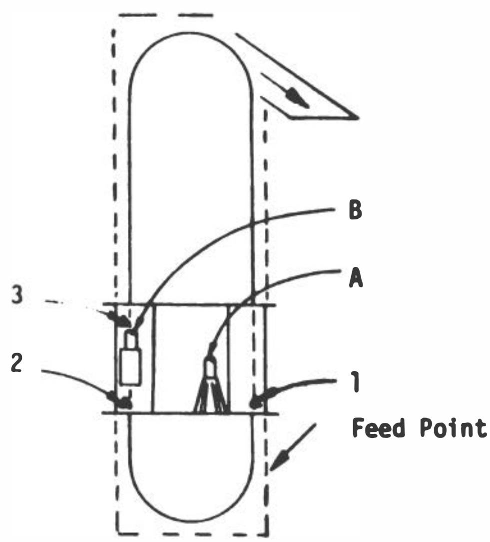
--- PRELIMINARY DATA REQUIRED -----

- Bucket Elevator Capacity 15,000 BPH
- Head Pulley Dia. 60" And RPM 44
- Belt Speed 691 FPM And Width 24"
- Bucket Size * - Spacing 10" Centers
- Bucket Make Maxi Lift
- Casing Size 30"x28" & 30"x110"
- Feed Side Of Leg Down

* 11" x 8' Double Row

- Product Handled #2 Yellow Corn
- Product Moisture 12.2 to 13%

- Air Temperature 65^o
- Relative Humidity 42%
- Barometric Pressure



Sample Points On Elevator Casing

1) Down Side Above Feed Point
2) Up Side Below Suction Point B & Above Feed Point
3) Up Side Above Suction Point B

A) Suction Point On Top Of Leg Boot
B) Suction Point On Up Side Of Leg Above Feed Point

NOTE: Main body of leg is slip form concrete construction.

FIGURE C-1 Preliminary data sheet for a bucket elevator test.

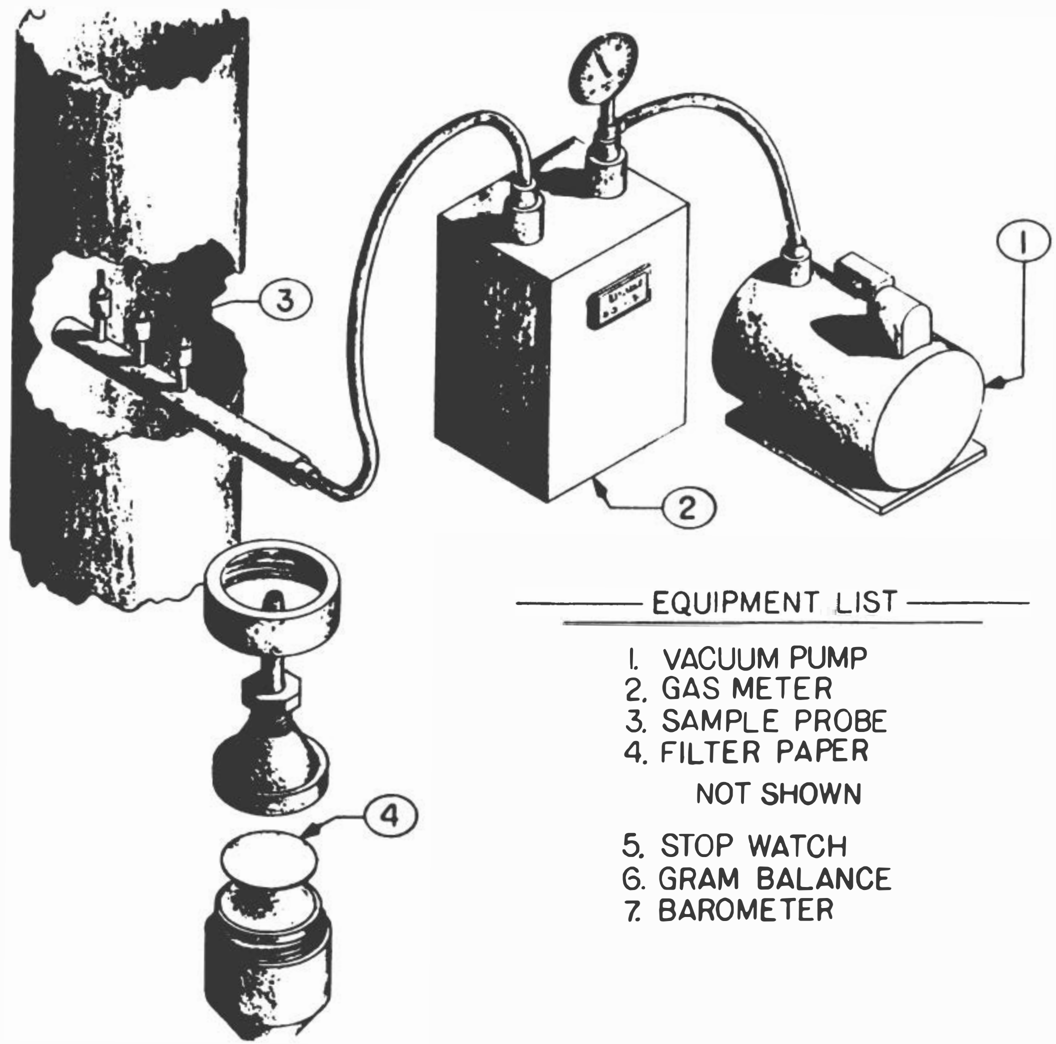


FIGURE C-2 Air flow schematic for sampling procedure.

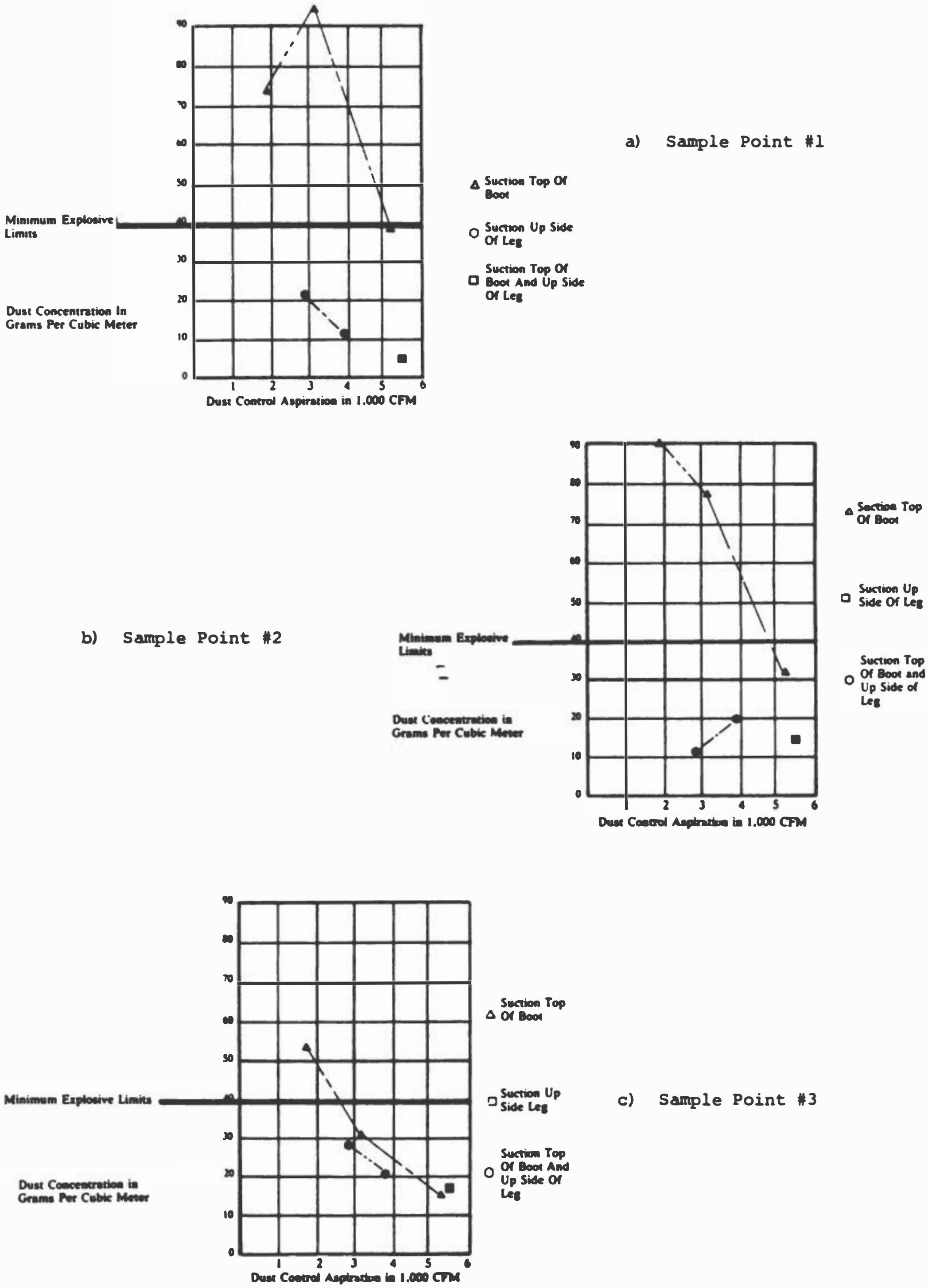


FIGURE C-3 Dust concentrations at three sample points.

These tests indicate the following which correlates with previous tests conducted even though they may not represent the exact condition within the leg.

A. The heaviest dust concentration area is on the up side of the leg above the feed point and below the suction point (B).

B. With increased air suction, dust concentration is reduced.

C. The most efficient use of the air suction is on the up side of the leg above the feed inlet.

Suggestion: Further research and study is necessary to improve sampling technique and accuracy.

TEST PROCEDURE TO DETERMINE DUST CONCENTRATION IN BUCKET ELEVATOR

A. Determine air volume being drawn from bucket elevator

a. Duct cross section in ft^2.
b. Duct velocity in fpm using velometer (see Figure C-4).
c. Identify suction location.

B. Take air measurements to determine dust concentration

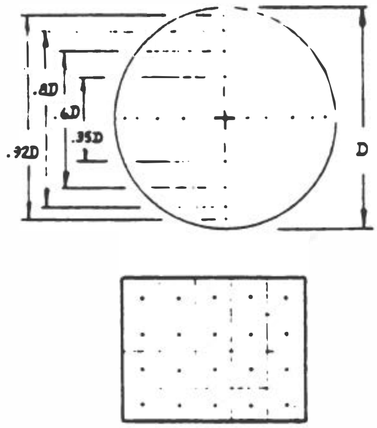
a. Location of sampling point
b. Gas-meter reading before and after test
c. Weight of clean filter media. Weight of filter media after test.
d. Conduct air sample test.
e. Convert collected data to grams per $meter^3$.

C. Record the preliminary data (see test data form of Figure C-1).

CHART I

For accuracy of plus or minus 2%, as in laboratory applications, extreme care is required and the following precautions should be observed:

1. Duct diameter 4" or greater.
2. Make an accurate traverse per sketch at right and average the readings.
3. Provide smooth, straight duct sections 10 diameters in length both upstream and downstream from the pitot tube.
4. Provide an egg crate type straightener upstream from the pitot tube.
5. Minimum number of points considered acceptable versus duct area.
   < 1 ft.^{2} = 8 points
   1 -2 ft.^{2} = 12 points
   > 2 ft.^{2} = 20 points



Now that we have the velocity stated in feet per minute and we have the cross sectional area of the duct stated in square feet we can multiply these two together and determine the cubic feet per minute or CFM, as we normally refer to it.

CFM = Area Ft.^{2} x Velocity ft/min.

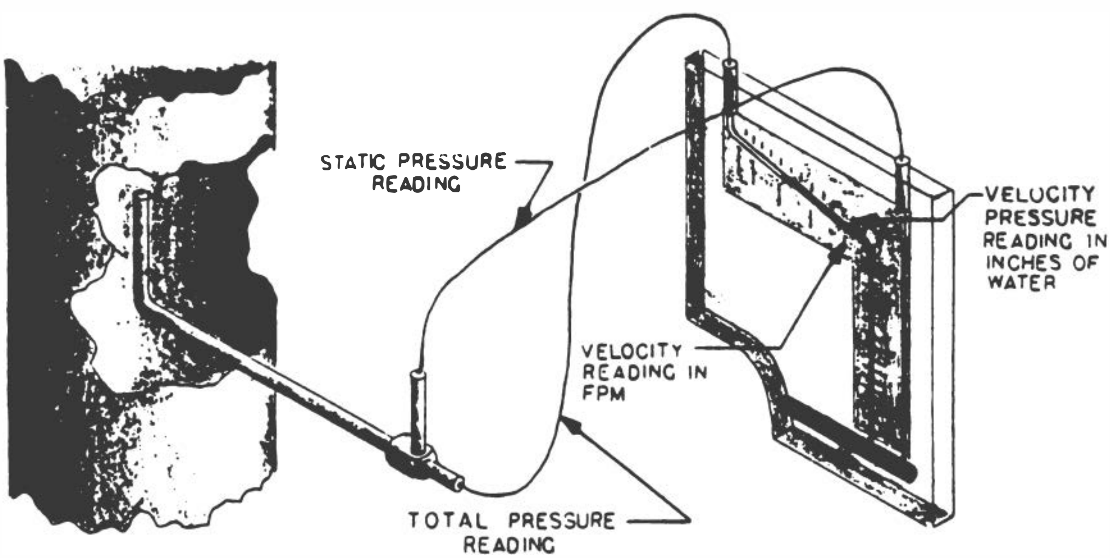


FIGURE C-4 Use of pitot tube and velometer.

Appendix D

STEADY STATE VELOCITIES

During compilation of this manual, it became apparent that there were some widespread misconceptions concerning maximum permissible air velocities at dust pick-up points. It was believed by many designers that velocities in excess of 200 feet per minute would indeed lift whole grains; thus, systems were limited to that value, usually with extremely disappointing results.

To ascertain the minimum vertical air velocities in which various whole grains would remain suspended (steady state velocities), test apparatus were constructed independently by National Agra Underwriters, Inc., and MAC Equipment, Inc.

Test methods are described and results are given in the following pages. The MAC tests calculated air velocities from velocity pressures obtained with an inclined manometer, while the National Agra tests employed a "hot-wire" direct reading velocity meter. Variations of results are attributable to differences in moisture contents, kernel sizes and weights, and velocity measurement methods. However, there is sufficient similarity of results to permit designers to use safely inlet velocities up to 800 fpm for the lightest whole grains.

A. MAC EQUIPMENT, INC. TESTS*

Concept: Air velocities required to maintain various whole grain in suspension.

Background: Efforts to develop standards for mechanical dust control systems in grain elevators have uncovered a basic data deficiency in at least one specific area--air velocity at dust pick-up points. Wide disagreement as to the maximum inlet air velocities, which would remove suspended dust and not whole grain, was found. It was discovered that apparently there is no data on steady-state or terminal velocities for whole grains, and that generally accepted "rules of thumb" are currently being employed with often inadequate results.

So that inlet velocities at critical pick-up points are not arbitrarily limited below functional levels, pick-up velocities for whole grains must be ascertained.

---

* Courtesy of Russell Brackman, MAC Equipment, Inc., Sabetha, Kansas.

Procedure: Several methods were used to determine the air velocity effect on whole grain under various conditions, which to some degree simulate field applications.

Method I: To determine air velocity required to hold grain in a suspended state.

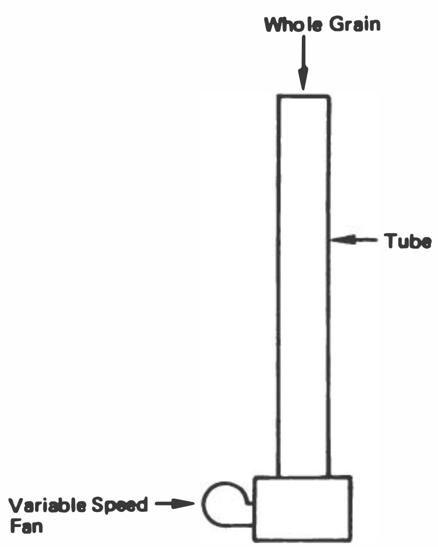
Method II: To determine air velocities required to (1) separate large, light, foreign material, (2) to unstabilize stationary whole grains, and (3) to lift whole grains.

Method III: To determine the inlet velocities, which will (1) lift stationary whole grains, and (2) lift agitated whole grains.

Method I

A 4-foot clear-plastic tube, open at both ends with an inside diameter of 2.75 inches, is mounted vertically in a wood box as an air plenum. A variable speed fan is arranged to discharge air in the box, which is forced up the tube.

Whole grains were dropped in the tube and the fan speed adjusted to a point where the kernels were held in suspension. Average cross-sectional velocity readings were then taken with a hot-wire velocity measuring device at a sampling point 12 inches below the top of the tube.



Results

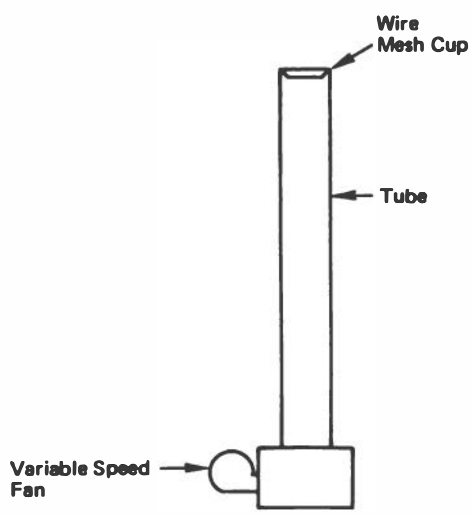
Grain	Steady State Velocity (in fpm)
Corn	2,000
Milo (light)	1,400
Wheat	1,700
Oats (light)	1,300
Oats (heavy)	1,400

Method II

A 4-foot clear-plastic tube, open at both ends with an inside diameter of 2.75 inches, is mounted vertically in a wood box used as an air plenum. A wire mesh cup is placed over the top of the tube. A variable speed fan is arranged to discharge air through the tube.

Whole grain and foreign material are placed in the cup and the velocity is increased to a point where the contents become unstable. The cup was removed and readings taken. (See results, column 1.) The cup was replaced and the air velocity increased to a point where the large foreign material departed. The cup was again removed and velocity readings taken. (See results, column 2.)

Whole grain was placed in the cup and the fan speed was increased to achieve a velocity adequate to dispel the contents. The wire cup was then removed and velocity readings were taken. (See results column 3.)



Results

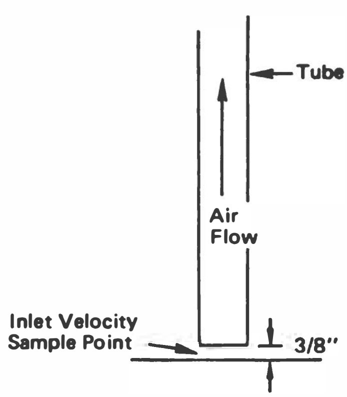
Grain	Departure Velocity of Large, Light Foreign Material	Nonstable Velocity of Whole Grain	Departure Velocity of Whole Grain
Corn	700	1,250	1,900
Milo (light)	650	700	1,600
Wheat	450	650	1,625
Oats (light)	450	650	1,250
Oats (heavy)	450	700	1,300

Method III - Inlet Velocity

A 4-foot clear plastic tube, open at both ends with an inside diameter of 2.75 inches, is placed vertically and 3/8 inch from the floor. A variable speed suction fan was connected to the top of the tube.

Grain was placed around the inlet of the tube and the fan speed was increased to a point where the grain at the inlet became unstable. Velocity readings were then taken in the 3/8-inch air space and the average was noted. (See results, column 1.)

Grain was again placed around the inlet space and agitated with a stirring rod. The fan speed was increased and velocity readings were taken when the grain became unstable. (See results, column 2.)



Results

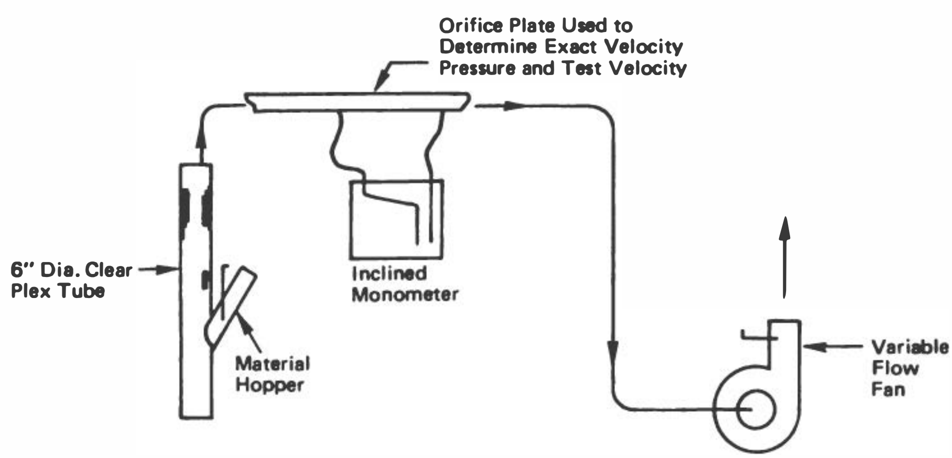
Grain	Pickup Velocity (Still)	Pickup Velocity (Agitated)
Corn	1,700	1,250
Milo (light)	1,000	950
Wheat	1,400	850
Oats (light)	700	800
Oats (heavy)	1,100	550

TEST REPORT

To determine terminal velocity of grain samples:

A) Terminal velocity can be described as that laminar air flow which will suspend the material in a vertical air stream. The material will not rise nor fall at its terminal velocity, which is also referred to as float or suspension velocity.

B) Apparatus



C) Procedure:

1. The air flow is adjusted at the anticipated required velocity.
2. By slightly opening the slide gate on the sample hopper a small amount of material is discharged into the laminar flow air stream.

If the material rises the air flow must be decreased. If it falls it must be increased. Air flow adjustments are then made and another sample is tested. By trial and error the exact terminal velocity can be located.

D) Terminal velocity of the following grains have been determined to be:

1.	corn	1,810 ft/min
2.	beans	1,570-1600 ft/min
3.	milo	1,610 ft/min
4.	wheat	1,525-1,530 ft/min
5.	oats	1,200-1,220 ft/min
6.	grain dust	170-190 ft/min

Other material previously tested for comparison

7.	PVC powder	180 ft/ min
8.	soda ash	450-500 ft/min
9.	foundry dust	250-300 ft/min
10.	wheat mids	400 ft/min

Note: Because of a variation in grain kernel size, density, and the presence of some cracked kernels, there was a noticeable difference between the terminal velocity of the cracked grain (lower terminal velocities) and heavier kernels (required higher terminal velocities). The velocities listed are an average and are considered to be a representative average terminal velocity.

The grain dust sample was taken from MAC dust filter at Sabetha Farmers Cooperative. The suction points on this dust system are from the dump pit and leg boot areas. The dust sample was anticipated to be representative of the typical grain dust as handled in grain dust control systems.

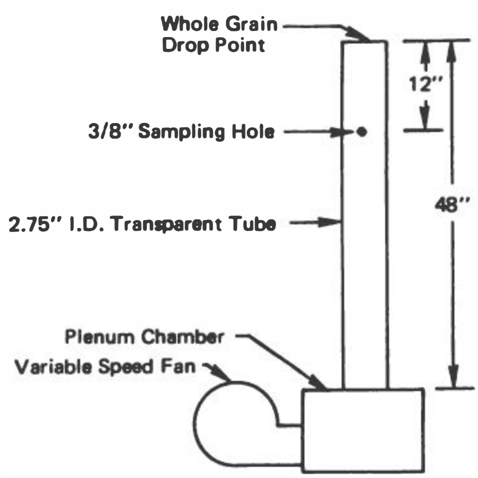
B. NATIONAL AGRA UNDERWRITERS, INC. STUDY OF AIR VELOCITIES REQUIRED TO MAINTAIN VARIOUS GRAINS IN SUSPENSION.*

ABSTRACT

Efforts to develop standards for pneumatic dust control systems in grain elevators have revealed basic data deficiencies. Proper air velocities at dust control pick-up points is an example. There is wide disagreement as to the inlet air velocities, which will prevent the escape of dust without lifting whole grains. Apparently, there is no data on steady-state or terminal velocities for whole grains. Thus "rules of thumb" have been formulated arbitrarily, and performance of many dust control systems has been severely impeded.

Methods for Determining Air Velocity Effects on Whole Grains

A 4-foot, rigid, clear-plastic tube, 2.75 in. I.D., was mounted vertically from the top of a plenum chamber, 8 in. wide by 10-1/4 in. long by 4-1/4 in. high. A variable speed fan was arranged to discharge air into the chamber. Whole grains were dropped into the top end of the tube and the fan speed adjusted to a point where the grains were held in suspension. Average cross-sectional air velocity readings were taken with a Datametrics Airflow Meter, model 100VT, at a sampling point 12 in. below the top of the tube. Results are as follows:



* Courtesy of Duane W. Brown, National Agra Underwriters, Inc., Camp Hill, Pennsylvania

Results

Grain	Test Weight (lbs/bushel)	Steady-State Velocity (fpm)
Corn	56	2,200
Soybeans	57	2,200+
Barley	50.5	1,500
Sorghum (milo)	58.5	1,500*
Oats	37.5	900*
Wheat	62.3	1,500*
Rice	58.0	1,350*
Rice (polished)	-	1,200

*Large trash floats at lower velocities.

CONCLUSIONS

Even though the results are subject to some variations because of differing test weights, kernel shapes, etc., they provide a range of maximums, which are safely above the velocities needed at dust pick-up points for control of dust.

It will be noted that oats have the lowest pick-up velocity (900 fpm) of the common grains tested. Thus, it is not necessary to limit inlet or face velocities at dust pick-up points to the often ineffectual 100 fpm or 200 fpm believed by some designers to be the upper limits.

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16. Abstracts

The danger of dust explosions in grain elevators can be reduced or eliminated only by an effective dust-control program. Such a program includes mechanical housekeeping, manual housekeeping, and various measures that minimize the creation of dust. The only mechanical housekeeping system that is known to be effective is the pneumatic type, however, for several major reasons, such systems have not been designed, fabricated, installed, or maintained properly.

This manual addresses the shortcomings of pneumatic dust-collection systems for grain elevators and presents guidelines for designers, installers, and contractors involved with these systems to correct these shortcomings. The manual also contains much information that should be useful to grain-elevator management.

17. Key Words and Document Analysis. 17a. Descriptors

Grain dust
Grain elevators
Dust control
Dust collection
Dust disposal
Hoods
Transitions
Ductwork
Filters
Fans
Instrumentation

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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