Air Pollution Control Systems

P. E. Sherman

Follow this and additional works at: https://scholarsjunction.msstate.edu/seedsmen-short-course

Recommended Citation
https://scholarsjunction.msstate.edu/seedsmen-short-course/280

This Article is brought to you for free and open access by the MAFES (Mississippi Agricultural and Forestry Experiment Station) at Scholars Junction. It has been accepted for inclusion in Proceedings of the Short Course for Seedsmen by an authorized administrator of Scholars Junction. For more information, please contact scholcomm@msstate.libanswers.com.
Although air pollution has been a problem in the industrial areas since the dawn of the industrial revolution, only within the past decade have scientists, legislatures, and the public come to recognize it as a serious hazard to health and a costly economic burden which merits national attention.

It is estimated that 150,000,000 tons of pollutants are discharged into the atmosphere in this country every year. This amounts to 3/4 of a ton per every man, woman, and child in America.

Industry accounts for 25% of this amount, with the automobile being the biggest polluter accounting for 60%.

Only 10% of the pollution is in the form of particulate matter, commonly called dust. While 10% may seem small, it is estimated that by 1977, industry will be spending 500 to 700 million dollars each year in control equipment.

Attitudes of industries, the public, and government are changing and will continue to change. I am sure each of you has heard in the past of a large company saying "If we must install air pollution control equipment, we'll move to another city or state." This situation was occurring with a great deal of regularity. The main cause was that some of our larger industrial states, because of extreme public pressure, began enacting stricter regulations requiring the installation of sophisticated air pollution control equipment. There was a great discrepancy between regulations from state to state. In fact, many states attempting to attract industry had no regulations.

This became a very unhealthy situation, and the federal government became involved. Congress passed the Clean Air Act of 1970. In brief, this law defined and established ambient air standards. Each state is required to meet or exceed these air standards by 1975. The first step in meeting these standards is for each state agency to monitor and determine the quality of the air within its jurisdiction. Once having determined this, it must submit a plan to the federal government giving an outline of how it plans to bring the air quality within the federal standards. All of you have probably come in contact with local or state environmental control agents. Their task, at present, is to determine major sources of air pollution and eliminate these sources. The main concern of the state agencies is that if they do not do their job as laid out by the federal guidelines, the federal government

1 Mr. Sherman is with Day Product Sales, Carter-Day Company, 655 Nineteenth Avenue, N.E., Minneapolis, Minnesota 55418.
will step in. Most people are trying to avoid this situation.

Even with the enactment of stricter air pollution regulations, the situation remained that you could create all the dust you wanted as long as it did not leave your plant or property. Now, with the new OSHA requirements, the air quality within any plant must also meet a certain standard.

Each of you in the past has had to become knowledgeable about various pieces of process equipment used in your plants. Now you will find it not only important but necessary to become familiar with air pollution codes, dust dynamics, and the limitations of various types of dust collectors. Some terms I will be using and which are commonly used in air pollution control work should be defined.

1. Dust is particulate matter that can become airborne and varies in size from 1 to 100 microns.

2. The micron is a unit of length or diameter equal to 1 over 25-thousandths four-hundredths of a inch. For example, a 25-micron particle is about one-thousandth of an inch in diameter.

The dust concentration in air streams is expressed in terms of grains per cubic foot of air. A grain is a unit of weight with 7,000 grains equalling one pound. In ordinary dust collection systems, you may encounter dust concentrations of 5 to 10 grains per cu. ft. of air. However, some state codes may restrict emissions from dust collectors to less than .1 grain per CFM; thus, more than 98% of the dust must be collected.

Any dust sample is a mixture of particle sizes. Figure 1 is a graph that shows how a hypothetical dust sample can be distributed.

Particle diameter in microns is plotted along the horizontal axis of this graph (Figure 1), and the percent by weight for each fraction of particle sizes is plotted vertically. According to the graph, there is a small percentage of one-micron particles, a small percentage of 100-micron particles, and a very large percentage of 10-micron particles. This dust would be very difficult to collect in an ordinary cyclone, which would be about 80% efficient at the 30-micron level. In fact, most of this dust would go out the top.

The dust concentration in an air stream expressed in grains per cu. ft. of air can be obtained by simply weighing the dust that is in the air stream. The problem comes in collecting a representative sample. Most samples are taken using an Iso-Kinetic Sampler. If you were to insert a sampling tube into a dusty air stream and provide the same velocity of air flowing into the tube that is immediately adjacent, a representative sample of dust should pass into the tube. If this air is then passed through a suitable filter, the dust can be
PARTICLE SIZE DISTRIBUTION

STANDARD TEST DUST - Q30

Figure 1. Hypothetical size distribution of particles in dust sample.

EXAMPLES OF ALLOWABLE RATE OF EMISSION BASED ON PROCESS WEIGHT RATE

<table>
<thead>
<tr>
<th>PROCESS WEIGHT RATE LBS./HR.</th>
<th>ALLOWABLE EMISSION LBS./HR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.55</td>
</tr>
<tr>
<td>1,000</td>
<td>2.58</td>
</tr>
<tr>
<td>5,000</td>
<td>7.58</td>
</tr>
<tr>
<td>10,000</td>
<td>12.0</td>
</tr>
<tr>
<td>50,000</td>
<td>35.4</td>
</tr>
<tr>
<td>100,000</td>
<td>44.6</td>
</tr>
<tr>
<td>500,000</td>
<td>63.0</td>
</tr>
<tr>
<td>1,000,000</td>
<td>69.0</td>
</tr>
</tbody>
</table>

Figure 2. Typical dust emission allowances.
caught, weighed, and saved for particle size analysis. This is a procedure used by most state agencies and independent testing firms to determine the amount of dust being emitted to the air from a dust control system or collector.

Dust particles are subjected to a variety of forces, such as gravity or centrifugal forces. They react to these forces with certain motions that can be described as "Stokes Law." One form of "Stokes Law" simply states that the settling rate of a small particle is proportional to the product of the square of the particle diameter and its specific gravity. The specific gravity of water is 1, the specific gravity of most dust is between 1 and 3. An example will illustrate what happens to a small particle suspended in an air stream. Consider a 2-micron particle with a specific gravity of 2. It can be shown that the settling rate of this particle will be 3 ft. per hour in still air. If this particle is emitted 3 ft. off the ground in a light wind of 5 miles per hour, it will take 1 hour for it to settle, and the wind will have carried it 5 miles, probably far beyond your property line. This principle is used in the design of dust control systems to obtain a minimum conveying velocity, so that the dust does not settle out in the duct work. We will look at this in more detail later.

Most state regulations specify the maximum allowable dust emissions from a process in terms of a process weight rate. Figure 2 is an example of the table used in most states. Assume you have an unloading facility that handles 50,000 lbs. per hour of grain (the process weight rate). There is a maximum dust emission that can be discharged from your process that is found in the process weight rate table. At 50,000 lbs. per hour, we see that the maximum allowable emission would be 35.4 lbs. per hour; calculating this out would show that you would have to collect 99.93% of the dust to meet the regulation, far beyond the capability of cyclones.

All dust control systems are made of four major components: the hoods, duct work, fan, and collector. We will discuss the collector first because it is the heart of a good dust control system.

Cyclones - I am certain most of you are familiar with cyclones (Figure 3). They have been used by the grain and feed industry for years. Their design varies from those fabricated by a local sheet metal man to those with a great deal of scientific design.

The graph in Figure 4 shows the collection efficiency (in percentage) of two types of cyclones versus particle size which is plotted on the horizontal axis of the graph from zero to 100 microns. Consider the curve labeled "Ordinary Cyclone." The graph shows that approximately 80% of the 30-micron particles will be captured by the cyclone. If you recall, Figure 1 showed the particle analysis of a typical dust sample, the major portion of which was about 10 microns. It is not hard to understand, then, why many states have arbitrarily said that cyclones will not be approved as collectors in dust control sys-
Figure 3. High efficiency cyclone (Day 'HV').
tems. Yet, high efficiency cyclones will do a more effective job than ordinary cyclones in capturing small particles. The curve marked "HV" represents a high efficiency cyclone. In this cyclone, a particle 30 microns in diameter will be collected with 96% efficiency, and a particle 10 microns in diameter will be collected with approximately 85% efficiency.

The reason for this higher efficiency is that the unit is long and slender in order to allow more turns or settling out of small particles. It is smaller in diameter than ordinary cyclones, so the settling forces are very large. This unit is good, but still not good enough to meet the codes when used on very fine dust.

Fabric filters are not in wide use as a replacement for the less efficient cyclones. Most of these filters have a collection efficiency in the range of 99.9+%. They are constructed by suspending a felted or woven cloth in a dusty air stream to filter out dust particles and allow the clean air to pass through.

The problem resides in keeping the media cleaned so that the filter can operate continuously. If cleaning is not accomplished, the cake of collected dust will build up to the point where the resistance to air flow would be so great that it would cease or be drastically reduced. Thus, your hoods would no longer have enough air flow to capture airborne dust.

Years ago, bag houses, as they were called, operated at air to cloth ratios of 1 or 2 CFM per sq. ft. of cloth in the filter. Today, normal air to cloth ratios are 10 or 15 to 1 and improved cleaning of the media is necessary. Thus, the modern filter has become more and more compact; and, in order to maintain continuous operation, better and more frequent cleaning is required.

Shaking, vibrating, reverse jet, and reverse flow collapse are used to remove the bulk of the dust cake from the individual filter tube. Reverse jet is the most common, and we will concentrate on this method.

Fabrics used vary widely depending on temperature, corrosiveness of the air, and the dust. The two most common materials used on grain dust are Dacron and wool felt. The RJ filter shown in Figure 5 consists of a cylindrical body which spins out heavy particles. The filter is divided into two parts by a tube sheet which separates the clean air section from the dust laden air section. Attached to the bottom of the tube sheet are filter media envelopes made from felt or woven material. Cleaned air passes through the openings in the tube sheet, after having first passed through the filter media. The filter media is in the shape of envelopes that are opened at one end and are prevented from collapsing by rigid wire frames mounted inside the bag.

To clean the RJ media, a reverse air manifold is provided that
Figure 4. Typical dust recovery curves.

Figure 5. RJ dust filter.
rotates slowly around the top of the tube sheet. This manifold is supplied with air from a blower at a pressure of about 16" water gauge and is equipped with a butterfly valve and trip mechanism, such that cleaning air is confined within the manifold until it comes into alignment with the hold in the tube sheet over the bag to be cleaned. The butterfly valve at that time is opened suddenly to inject high velocity reverse air into the bag. The high velocity air snaps the bag, breaks up the dust cake on the outside of the bag, and the filtered dust particles drop into the hopper.

The Dynamic Module Filter is a rectangular filter made up of 2' wide panels. The media is composed of round tubes 4½" in diameter and up to 8' long, which are mounted on the top tube sheet (Figure 6). Each 2' x 6' section of the filter encompasses 24 bags which are arranged in rows of 8 each. Protruding into the top of each bag is a small pipe extending from an injector tube that runs across each row. The end of the injector tube is closed in a valve chest on the side of the filter by a quick opening diaphragm valve, similar to a power brake diaphragm which is caused to suddenly open when a small, solenoid valve is activated by a solid state control system. This opens the end of the injector tube to a reservoir of air at about 15 lbs. per square inch. The sudden reverse jet blows off the dust cake that has accumulated on the outside of the bags.

The bags can be cleaned in any frequency that is desired, the duration of the cleaning pulse can be controlled, and you can regulate the amount of reverse air. Another advantage of the filter is that all moving parts are outside of the filter. Also, its modular design allows for construction in virtually any size and the additions of more sections in the future as your air volume requirements change.

Proper hood design and the volume of air to be collected by each hood, has evolved over the years mainly by trial and error. Let's look at a particular example. Suppose we have a room with several people in it. One person is smoking a cigar, and we want to remove the smoke being produced. One approach would be to place a fan in a window pointing outward and provide adequate openings into the room to replace the air removed. This, in essence, is ventilation as opposed to control. Smoke is still in the room but is gradually being removed. Now, suppose we want to control the smoke from only the one person, the cigar smoker. We would supply a separate duct from the fan over to him, put a hood over or around him in such a way that we could control the smoke and draw it into the hood rather than let it escape into the room. We will have then provided spot control and would therefore use less CFM and less horsepower.

Now applying this principle to dust control in your plant, let's take one source of dust, such as a loader beneath a bin which is dumping onto a belt. In this case, when the seed or grain hits the belt, dust is generated and will cloud the immediate area unless a properly
Figure 6. Dynamic Module Dust Filter.

Figure 7. Dynamic Module Dust Filter installation.
Figure 8. Before (top) and after (bottom) views of an RJ dust filter installation.
Figure 9. Typical RJ dust filter installation.
designed hood with the correct amount of air is applied at this point to capture the dust before it escapes into the atmosphere. The physical size of the hood is determined by a number of factors, including the width and speed of the belt, maximum duct to the grain when the belt is fully loaded, and also the design of the belt loader itself. In some cases, loaders are built so that the grain is released to the belt in a flowing design; in other cases, it is dropped abruptly, which increases the dust load. After determining the physical size of the hood, the next determination is how much air is required, and this is based on past experience, but technically it can be calculated by measuring the open area around the periphery of the hood; that is, the area beneath the hood down to the belt itself, converting this to square feet of open area, then using an air velocity that would be sufficient to overcome any stray air currents in the immediate area, and multiplying these two together which would give us the total air required. Actually, in practice, considerably more air is used than would be arrived at through this formula because, in most cases, there will be more open area after the hood is actually installed than that calculated ahead of time; we provide for this possibility.

This, in essence then, is the basic principle behind designing any hood, such as for belt loaders, belt discharge hoods, or similar unenclosed pieces of equipment. It's based on, first of all, an enclosure that is physically large enough to enclose the area where the dust is being generated and then providing sufficient suction to cause air flow into the hood, or at least prevent the dust from flowing out from underneath the hood.

In sizing hoods or determining the air volume for enclosed areas such as bins or garnerds, where we are not concerned with stray air currents, the problem is to pull enough air from the enclosure to compensate for the rate at which the bin is being filled, plus a safety factor for any entrained air that comes in with the grain stream.

One last area that each of you probably has in your plant is the truck unloading station. This, in many cases, can be the largest single source of dust you have. Where the dump pit is deep enough, connections are placed on either side to draw air down through the top of the grating. Many older pits are shallow and do not allow for any under-grating duct work. In these case, we have designed a unit as shown in Figures 10, 11, and 12.

The truck enters the pit area, and once it is in position, the motorized hood is swung into place. As the dumping takes place, the dust created is drawn into the hood. When the dumping operation is complete, the hood is swung back to its standby position.

No matter how well a truck pit dust control system is designed, its successful operation is dependent upon the pit area being enclosed and a roll-up door installed at one end to prevent cross winds, as no hood can compete with a 10- or 20-mile-per-hour wind.
Figure 10. Dust hood installation for unloading pit. Hood is in not-in-use position.
Figure 11. Dust hood installation for unloading pit. Hood is swung to in-use position.
Figure 12. Dust hood installation for unloading pit. Hood in use.
Now, after we have sized individual hoods and determined the air volume needed for each dust source, the next problem is to combine these various sources into a single duct, which would run to the dust collector. Here again, we try to study the most economical way to bring the various branch pipes together that would result in the lowest amount of fan horsepower, while at the same time keeping in mind that the duct cannot interfere with the plant operation.

Sizing of the duct work required to connect various hoods together is very simply a case of using a velocity of the air stream in the duct that would be sufficient to keep the dust in suspension. Velocity of 3500 to 4000 ft. per minute has always been acceptable, although in recent years, I believe a little higher is used, perhaps in the 4000 ft. per minute rate. A formula used in all air engineering work is: \( Q = VA \). This simply means CFM is equal to velocity times the cross-sectional area in square feet. Let's assume the first hood at the extreme end of our duct requires 1,000 cu. ft. of air. If we want the velocity to be 4,000 ft. per minute in the duct, we divide 1,000 cu. ft. by 4,000 ft. per minute and arrive at a cross-sectional area of the duct of \( \frac{1}{4} \) of a square foot. This area may not be obtainable in a standard pipe size, so we select the diameter to the nearest inch that would give us about this velocity. We then go on to the next hood, add the CFM for the two hoods together, and go through the same formula by dividing the total air volume by approximately 4,000 ft. per minute and again selecting a pipe size to the nearest inch that would give us this velocity.

We proceed in this fashion through the entire system, which could consist, in some cases, of only one hood or it may consist of 30 or 40, and arrive at the final duct size. There is a limitation to the size that we like to use based on the physical size of the duct work that is involved. It becomes very expensive to build and install exceptionally large diameter pipe, so we use discretion in putting a limit on the physical size of any single system. A couple of other factors must also be considered. There is a CFM limitation when using a single filter, and also, it is best to combine hoods that are on equipment that must work together in your plant. It is very wasteful to draw air on equipment that is not in operation.

A few do's and don'ts in duct work are: branch entries should enter into the taper at approximately a 30-degree angle; when two branches are to enter the main duct, they should be a minimum of two pipe diameters apart; duct enlargements and duct contractions should be made by using smooth tapers.

After we have calculated the total air volume of the system, we must then determine the system resistance. The system resistance or losses start at the hood. Here, we normally use 2 to 3" water gauge. This resistance is that which is required to get the air moving to a greater velocity than the surrounding area. Once we have the air inside the duct, then it becomes a matter of using published tables.
to determine the friction loss of moving air at 4,000 ft. per minute through the duct to the filter. To these two figures, that is, the suction required at the hood plus the friction losses through the duct work, we then add the anticipated loss through the collector to be used. Adding these all up gives the total pressure in inches of water to be developed by the fan. Now knowing the total CFM and static pressure, we then select a fan that fits these two requirements. The fan selection chart put out by a manufacturer will then give us the required speed and brake horsepower.

Over the past few years, I'm sure many of you have entered into discussions as to the disadvantage of having to put equipment in to meet the pollution control regulations. I feel it would be interesting to look at the other side of the coin. Bob Hubbard of Cargill, who for years has been a leader in placing modern pollution control systems in plants, has come up with a list of eight definite advantages. Some of these may relate to your operation:

1. Shrinkage of grain weight is, in large part, due to loss of dust to the atmosphere.
2. Employee moral - not having to work with a respirator or mask.
3. Reduction in plant clean-up labor.
4. Increased life of protective coatings.
5. Reduction in contamination of lubricants; dusts, longer machine life.
6. Reduction in fire insurance premiums.
7. Reduction in personnel accidents.
8. Reduction in insect and rodent population and control expenses.