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Screen Selection and Air Control

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SCREEN SELECTION AND AIR CONTROL

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The air-screen cleaner is the basic machine for seed cleaning operations. This machine utilizes differences in the six of the most common physical characteristics which exist among the seed and their contaminating materials. These physical differences are gross size, length, width, thickness, shape and weight. Only the physical characteristics, surface texture, color, and affinity for liquids are not utilized to a great extent by either the series of screens or the air system(s).

This presentation is divided into three sections, screens, screening and air control, for purposes of convenience. Under operating situations the screening section and the air section, are operated simultaneously to attain the efficiency levels that "management" requires.

Screens

To achieve the desired screening action in an air-screen machine it is necessary to know the screens available.

For over 20 years the major manufacturers of air screen cleaners have listed around 210 screens for sale, each with a different size, shape or orientation to the screen opening. This means there are 21,945 sets of two screens each which could be used in a two screen air-cleaner. The number 21,945 assumes that the screen with the larger openings will be used as a scalping screen and the screen with smaller openings is used as a grading screen. Some where among this large number of screen sets there is only one best set for each seed lot, but fortunately several satisfactory sets.

There are no "new" screens since it has been some time since the need for a different size or shape screen opening has been identified, however if there is need, the screen can be fabricated. Further, there is probably no processor who owns or has a need for a screen of each size opening.

The nomenclature of the screens and the numbering system that is used to identify them is also important. At present, all screens made in the U.S. are identified by the size and/or number of openings per inch. One fabricator also uses the metric system.

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There are five basic shapes of openings in the screens used for seed processing. The shapes are round, oblong, triangular, square, and rectangular. To identify these different shapes and their orientation on the screen, screens are sub-divided into six categories.

Large Round-Hole Perforations: The number used to identify large round-hole perforated screens is the diameter of the perforations measured in 64ths of an inch. This system is used for numbering screens ranging in diameter from 6/64ths up to 80/64ths of an inch. There are 56 different round-hole screens under this numbering system, each identified simply by the numerator of the fraction, i.e., 6, 18½, 36, etc.

Small Round-Hole Perforations: Screens with round-hole perforations smaller than 5½/64th-inch are also identified by the perforation diameter, but as measured in fractions of an inch rather than 64ths. There are 14 screens identified in this manner, the smallest is a 1/25 and the largest is 1/12. By using fractions of an inch, rather than 64ths, screen fabricators are able to provide screens with 14 different size perforations over a range of only 3/64ths-inch.

Large Oblong Perforations: The size perforation of the large oblong perforated screens is identified by two numbers. The first number indicates the width of the perforation in 64th-inch and the second number indicates the length of the perforation in fractions of an inch. Such screens range in size from 5x3/4 up to 24x3/4. There are 22 different widths of large oblong perforated screens where the length of the perforation is parallel to the flow of the seed. Additionally, thirteen of the sizes of the large oblong perforated screens are available with the orientation of the perforation at a right angle to the flow of the seed. Screens perforated in this manner are referred to as cross-slot screens but the numbering designation is the same. Cross-slot perforated screens range in size from 6x3/4 to 11½x3/4.

Small Oblong Perforations: There are 15 screens available which have small oblong perforations. Again the double numbering system is used but the first, indicating the width of the perforation, is given in fractions of an inch in the manner like that used to designate the small round hole screens. The length of the perforation is also expressed as a fraction of an inch and may be 1/4-, 5/16-, 1/2-, or 3/4-inch. The range in width of perforations is from 1/12-inch to as narrow as 1/24-inch. Among the group of small oblong perforated screens there is a 1/22x1/2 diagonal on which the slots are turned at a 45^{o} angle to the seed flow.

Triangular Perforations: Screens with triangular perforations are designated by two methods, although, the perforations sizes available are the same. One fabricator identifies perforation size as the diameter in 64ths-inche of the largest circle that can be inscribed inside the triangle while another designates perforation size by using the length of one side of the equilateral triangle in 64ths-inch. Thus, a screen designated as the 5-tri by the length of size system is a 3½ V by the circle system while the 11-tri has the same size perforations as a 6½ V. Screens with triangular openings can also be obtained with twice the number of openings as the standard triangular perforated screen from at least one supplier.

Wire Mesh Screens: All wire mesh screens are identified by a dual numbering system. However, unlike the oblong perforations, the first number indicates the number of openings per inch vertically and the second number the number of openings per inch horizontally. Thus, a 2 x 8 screen has two openings per inch in the direction of seed flow and eight openings per inch across the direction of seed flow.

The surface of wire mesh screens is rough because of their woven nature. As a result, the seed mass is constantly mixed as it moves down the screen in a action similar to placing screen dams on perforated screens.

The openings in wire mesh screens are either rectangular or square.

a) Rectangular openings: There are 50 different screens available with rectangular openings. These range size from the 2 x 8 down to the 6 x 60. In a 6 x 60 screen, the length of the opening is the width of the wire less than 1/6th-inch and the width slightly less than 1/60th-inch.

b) Square openings: Twenty-six wire mesh screens with square openings are generally available. These range from the large openings in a 3 x 3 screen to the smallest openings used in seed cleaning, the 60 x 60.

The question most often asked by beginning seed processors is, "what combination of screens is best for cleaning ---?" There is an answer for every seed lot but the only way to determine the best combination is to determine the specific physical characteristics of each lot, know the quality standard that must be met and then match these factors with the screens available. This is the "Science of selecting screens.

Screening Principles

As previously stated, the two most important factors for successful seed cleaning is to know the composition and characteristics of the various components of the seed lot and to know the performance required. The compositon can only be determined by examination of a representative sample of the seed lot. The major factors which should be determined are:

a) Differences in physical characteristics between good seed and all other materials.

b) Frequency of occurrence and kind of contaminants

c) Size variation of the good seed and the contaminants

d) Flowability - flow characteristics of the seed mass

e) Need for pre-conditioning, scalping, drying, scarifying, debearding

f) Damaged seed

The second factor, which the less discriminating processors only briefly consider, is a defined set of performance requirements. Performance requirements for screen cleaning are dependent upon two criteria: (a) the cutpoint and (b) screen deficiency. The cutpoint refers to the size opening in the screen which largely determines the quantity of oversize and undersize contaminating material that can be removed from the clean seed. Screen efficiency is the percentage of undersize material in the lot that actually passes through the screen in question.

Screen efficiency is determined by completing the formula below and is expressed as a percent.

$$\text{Screen Efficiency (SE)} = \frac{\text{Weight of material passing through screen}}{\text{Total weight of undersize material}} \times 100$$

An example of how screen efficiency is determined should help gain a better understanding of the term "screening efficiency" which will be discussed in greater detail later. A physical analysis of a seed lot, based upon size and shape, revealed the lot was composed of 2% material larger than the good seed, 88% good seed and 10% of the lot was materials smaller than the good seed. To remove all of the materials larger than the good seed, 98% of the total lot must pass through the scalping screen. Applying the formula, if 98% is undersize and 98% passes through the screen, then screening efficiency is 100%.

Now assume that the defined performance requirement or quality control permits 1% undersize material to remain in the clean seed. Considering only at the grading screen, 90% of the lot is oversize and 10% is undersize. Because 1% of the undersize material is permitted then a screeing efficiency of only 90% is required to meet the performance requirements.

Even though the air-screen cleaner is a continuous flow machine, each seed and/or contaminant either passes over or through each screen, one screen at a time regardless of the total number of screens in the machine!

Thus, when a useful screen is chosen the seed mass is divided into oversize and undersize fractions. The term "scalping" is used when the mass of good seed pass through the screen. The term grading is used when the mass of good seed pass over the screen.

Engineers who work on industrial screening problems ranging from flour milling through coal grading have made some determinations that have significance to seed processors. Let's briefly consider some of these "screening precepts." 2/

1. The most dificult, therefore, the most expensive separation is encountered with near-size particles. Near-size particles are defined as those less than 1½ times as large but more than ½ as large as the screen openings.

Figure 1 shows the size distribution of a lot of combine run soybeans. Assume a 10 x 3/4 oblong perforated grading screen is used as the cutpoint. Application of the above precept indicates difficulty can be expected in screening due to that portion of the lot which falls in the range from 5/64 to 15/64ths-inch. As can be determined, this range included 98% of this seed lot. This is the reason the term "precision cleaning" is used when considering cleaning seed.

Some might question the reason for including seed larger than the 10/64-inch cutpoint. The reason for including these seed is that although they will not pass through the screen, they will fill the screen opening sufficiently to prevent undersize material from passing through. Thus, the greater the percentage of near-size seed the more difficult the screening job.

2. A second screening precept is, "when scalping, the minimum size screen opening is limited only by the cutpoint at which good seed pass over the screen. "Seed processors should give more thought to the implications of this precept. How often have you observed good seed traveling more than half the length of any scalping screen? Use of scalping screens with smaller openings will reduce the work load of the grading screen. This is true because when placed on a vibrating screen the smaller, heavier materials will be the first to pass through the openings. Thus, the last material through a scalping screen will almost always be too large to pass through the grading screen.

3. A third rule of screening is, "when grading, the highest screening efficiency results when the cutpoint intersects the steepest slope of the size distribution curve." To apply this precept an 11 x 3/4 grading screen should have been selected for this lot since it intersects the steepest slope on the size distribution curve (Figure 1).

What results would be obtained when this precept is applied to a lot of soybeans? To make the determination, several samples of combine run soybean seed were sized using a series of hand screens with oblong perforations. The screen with the largest openings was placed on top and the width of the perforations of each screen decreased by 1/64-inch. The screens were shaken until all material had an opportunity to pass

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2/ Sullivan, J.F. 1975. Screening Technology Handbook. Triple/S Dynamics, Dallas, TX.

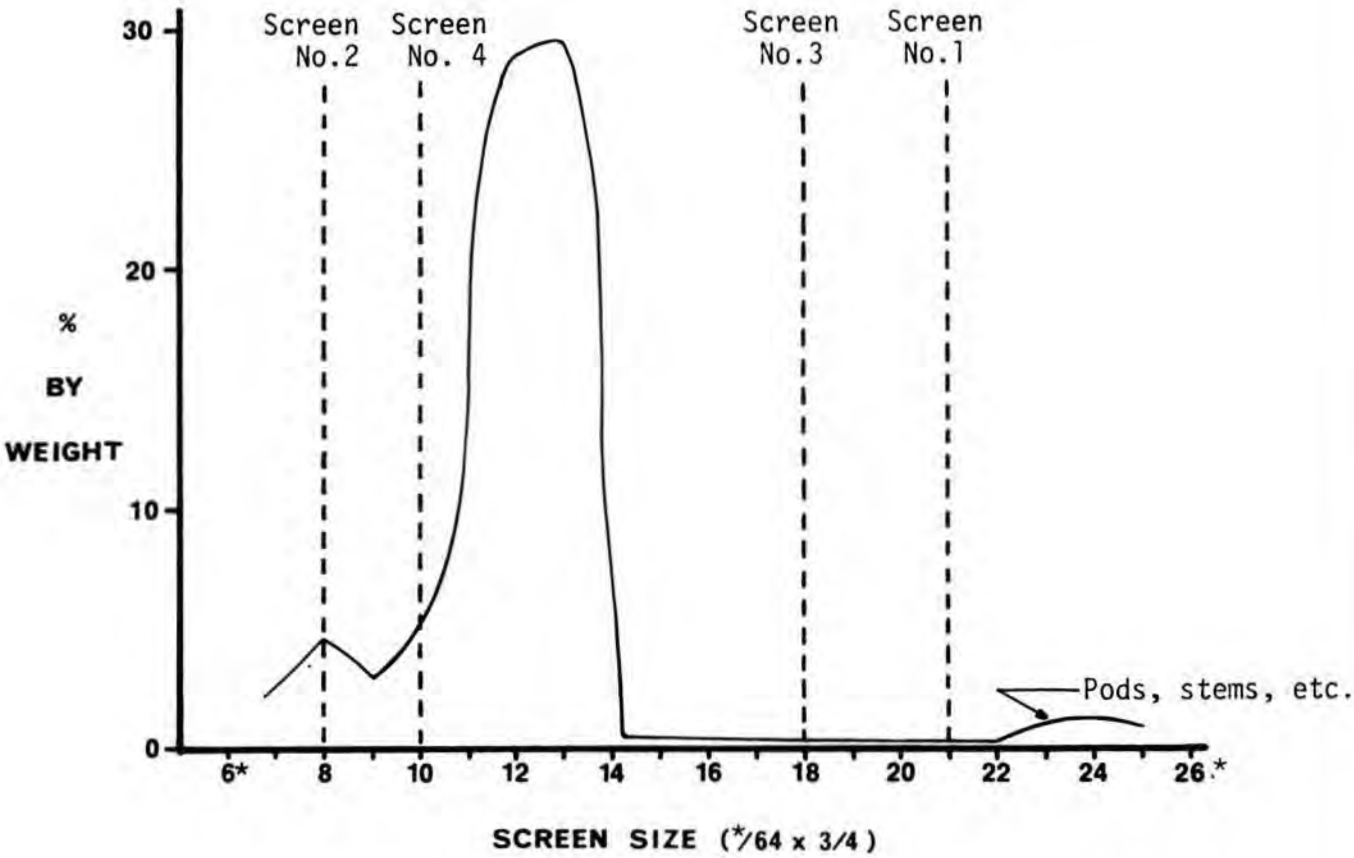


Figure 1. Size distribution of one lot of Lee 68 soybean seed.

TABLE 1. Size Distribution Lee 68 Soybeans[1/]

Screen Size*	Large Inert (%)	Seed (%)	Weeds + Inert (%)	Total Lot (%)
6			1.50	1.50
7			2.50	2.50
8		.63	3.90	4.53
9		1.31	1.50	2.81
10		4.14	.40	4.54
11		17.27	.20	17.47
12		28.93		28.93
13		29.38		29.38
14		7.34		7.34
15	T			T
16	T			T
17	T			T
18	T			T
19	T			T
20	T			T
21	T			T
22	T			T
23	.50			.50
24	1.00			1.00
25	.50			.50
26	T			T

1/ % of 1000g sample remaining on top of hand screen

* /64 x 3/4 perforation

through each screen. This gave a screening efficiency of 100%. The whole seed were separated by hand from the splits and other inert matter on each screen. The results of this physical separation are shown in Table 1. Note that the percentage shown opposite each screen size is the percentage of material that did not pass through the screen.

If a 10 x 3/4 screen is selected and screening efficiency is 100%, 11.34% of the total lot will be removed. If an 11 x 3/4 screen is selected then the total loss would be 15.88%. Of major concern is the fact that most of the apparent 4.5% increase in weight loss would be good seed, therefore, it appears logical to select the 10 x 3/4 screen. Unfortunately, proper screen selection is not that simple.

The information available from the screening engineers indicates that the actual screening efficiency for that portion of the seed lot within 1/64-inch of the cutpoint is only about 50% not 100%. When this reduced screening efficiency is combined with a defined performance requirement of a maximum of 1% inert matter in the clean seed, as would be the case in actual operation, the results change as discussed below.

Operating at a constant rate of feed and removing only 50% of the material within 1/64-inch smaller than the cutpoint, the total loss through the 10 x 3/4 screen decreases to 9.74% and that through an 11 x 3/4 screen to 13.61% a difference of only 3.9%. Futhermore, since a screen does not distinguish between materials, only differences in physical characteristics, the inert matter remaining in the good seed will be only 0.4% when the 11 x 3/4 is used but an unacceptable 1.35% when the 10 x 3/4 screen is used. It is now apparent that the 11 x 3/4 screen must be used to meet the performance requirement.

In the continual search for greater capacity processors may forget - there are only two ways to increase screening efficiency; (a) reduce the rate of feed or (b) increase the screen perforation size. This is true because screen efficiency decreases as the proportion of undersize material decreases when the feed rate remains constant. The following examples will demonstrate the validity of this statement:

Example 1

Lot A	Lot B
oversize = 95%	oversize = 85%
undersize = 5%	undersize= 15%

Performance requirement: remove 80% of the undersize material.

$SE = \frac{4}{5} \times 100 = 80\%$ $SE = \frac{12}{15} \times 100 = 80\%$

Note that Lot A has 5% undersize material and Lot B 15% undersize material. When the performance requirement is to remove 80% of the undersize material then 1% of the undersize material remains in Lot A but 3% in Lot B. This is satisfactory when grading coal or sand but not seed.

Consider a second example using the same seed lots but adding a performance requirement of a maximum of 1% undersize material:

Example 2

Lot A	Lot B
oversize = 95%	oversize = 85%
undersize = 5%	undersize= 15%

Performance requirement: maximum of 1% undersize material in good seed.

$$SE = \frac{4}{5} \times 100 = 80\% \qquad SE = \frac{14}{15} \times 100 = 93\%$$

Note that in Lot A, which has a smaller amount of undersize material, the screening efficiency required remains at 80%. However, in Lot B a screening efficiency of 93% must be attained to meet the performance requirement. Viewed in another manner, using the same grading screen Lot A could be cleaned at a 13% higher feed rate than Lot B, if the size distribution of the two lots was the same.

To summarize the screening technologists' findings concerning grading screens; when selecting a grading screen the maximum size perforation is limited only by the amount of good seed the processor is willing to lose.

There are additional points that the air-screen operator should consider when selecting screens and operating the screen section of the cleaner. First, the rate of passage of undersize material through a screen in determined by:

a) the size distribution of the seed lot;

b) the initial depth of the seed layer;

c) the effectiveness of the screening motion.

Effects of the size distribution and depth of the seed layer have been considered. The third factor listed, screen motion or speed of vibration, is variable within limits on all commercial size models of air-screen cleaners.

Screen vibration determines the effectiveness of the screening motion in two ways; (a) it moves the seed mass across the screen and

(b) it expands the seed mass to permit smaller particles to move to the screen. These two factors affect both the capacity, which is a primary concern of management, and screening efficiency, which is of concern to the operator and quality control personnel. Because each lot differs in composition, shouldn't the speed of screen vibration also vary with each lot?

A last point concerning screening is the effects of screen dams. Screen dams have two major effects upon the seed mass; (a) they increase the time seed remains on the screen, which increases screening efficiency, provided the feed rate is not increased, and (b) dams breakup stratification of the seed mass. Decreasing screen pitch will also increase the time seed are on the screen and thus screening efficiency but has no effect upon stratification.

Air Control

The selection of the proper screens for an air-screen cleaner is a science, however, the operator who properly controls the air systems must be an artist. As with any art form, the judgement concerning the effectiveness can be made only after the "masterpiece" is completed or in our case, some seed are cleaned. The only universal guide to proper air control is, "the air velocity should be sufficient to remove an occasional, good healthy seed." Many interpret this to mean, one good seed in a double handful of the material discharged from the lower air settling chamber.

There are two factors which help in understanding and making the desired air separations. Understanding the principle of terminal velocity helps envision the separation to be made. Secondly, proper installation of the air trunking or ducting from the machine to the dust collection system will eliminate 90% of the air control problems commonly encountered.

Regardless of whether the air stream is pulled or pushed through the seed mass the separation made is dependent upon differences in the terminal velocity of the individual particles of the mass. Terminal velocity is simply the velocity of air required to suspend a seed when placed in a rising column of air. Thus, when the air system is in operation and a seed mass is dropped into it, all particles with terminal velocities less than the air velocity will be carried in the air stream until the velocity of the air falls below that required to suspend the individual particles. On the other hand, seed or other particles with terminal velocities greater than the velocity of the air will fall through air stream.

There are five principle physical characteristics which determine terminal velocity of a particle. These are specific gravity (volume weight), shape, surface texture, frontal area and size. These physical characteristics can be demonstrated individually, however, differences in specific gravity and size are the most important for most of the air separations made in seed cleaning. These physical characteristics should be recognized as being the same as those for separations made with gravity tables, aspirators and pneumatic separators. These latter machines simply permit more precise air separations than is practical with the air system of an air-screen cleaner.

All commercial models of air-screen cleaners have excellent air control systems. Therefore, one of the major reasons operators do not obtain the desired air separation is not the air system(s) available but the fact that most operators do not use sufficient air to obtain the desired separation for fear of losing an occasional good seed.

A second major reason for the inability to obtain the desired air separation is attributable to improper installation of the air ducts from the cleaner to the dust collector. Sharp turns, improper junctions, poor connections and/or poor collection equipment all contribute to problems with air control. Sharp turns in the ducting creates back pressure which causes the air to surge through the seed mass making a uniform separation impossible. Air leaks at joints or dents in the ducting cause fluctuations of air pressure within the duct which causes the heavier particles to fall below their terminal velocity, fall to the bottom of the duct and eventually stop the air flow.

A review of five installation principles for air ducting given below followed by correction of any deficiencies in your installation should permit the air separation desired. These five installation principles are:

1) Keep the distance from the machine to the dust collector as short as practical.

2) When the ducting is curved the radius of a 90° elbow should be at least two times the diameter of the duct (Figure 2A).

3) When joining two air ducts, a "duct divider" should be installed, the length of which is equal to at least the sum of the diameters of the ducts jointed (Figure 2B).

4) The duct entering the collector should not cause the air to change direction, in other words, go straight and level into the dust collector (Figure 2C).

5) The direction of air rotation in dust collectors is specified from a top view. When ordering dust collectors use only the terms clockwise or counterclockwise based upon the view from the top (Figure 2D).

In summary, successful screen selection and air control basically depends upon:

a) Knowing the screens available

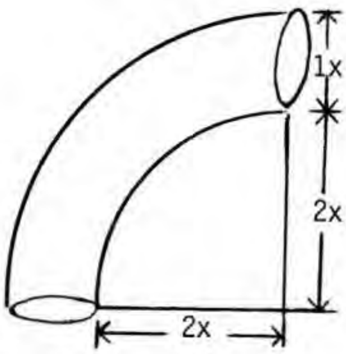
b) Learning the principles of screen selection

c) Determining the composition of each lot

d) Making a screen test

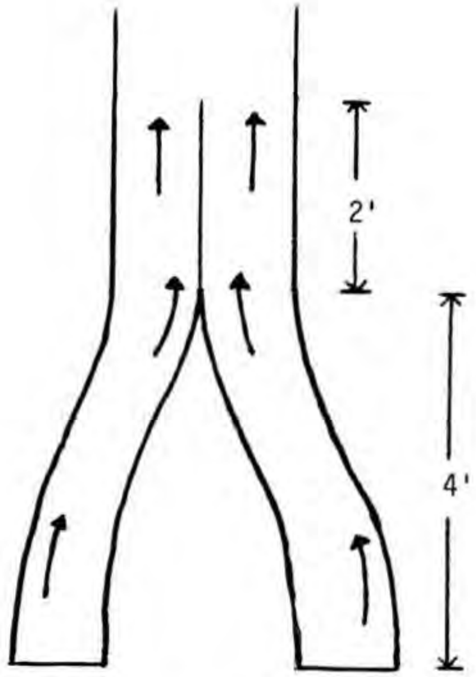
e) Proper installation of air trunking and dust collectors

f) Maintaining your machine.



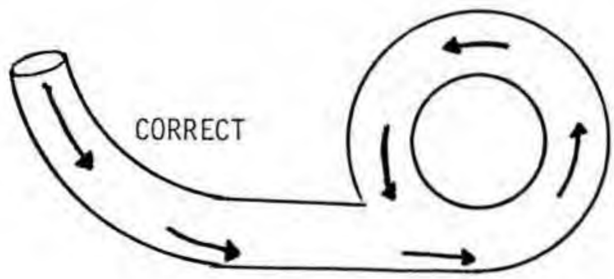
Radius of 90° Elbow
Should be at least
2 times the diameter
of the duct

Figure 2A



Duct Divider
for
Air-Screen Cleaner

Figure 2B



Do Not Change Direction of Air Travel

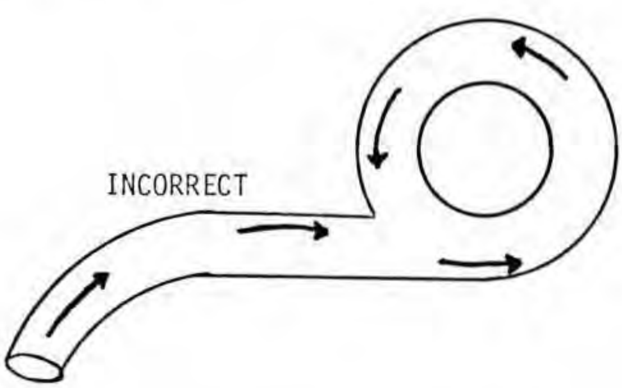


Figure 2C

DUST COLLECTORS

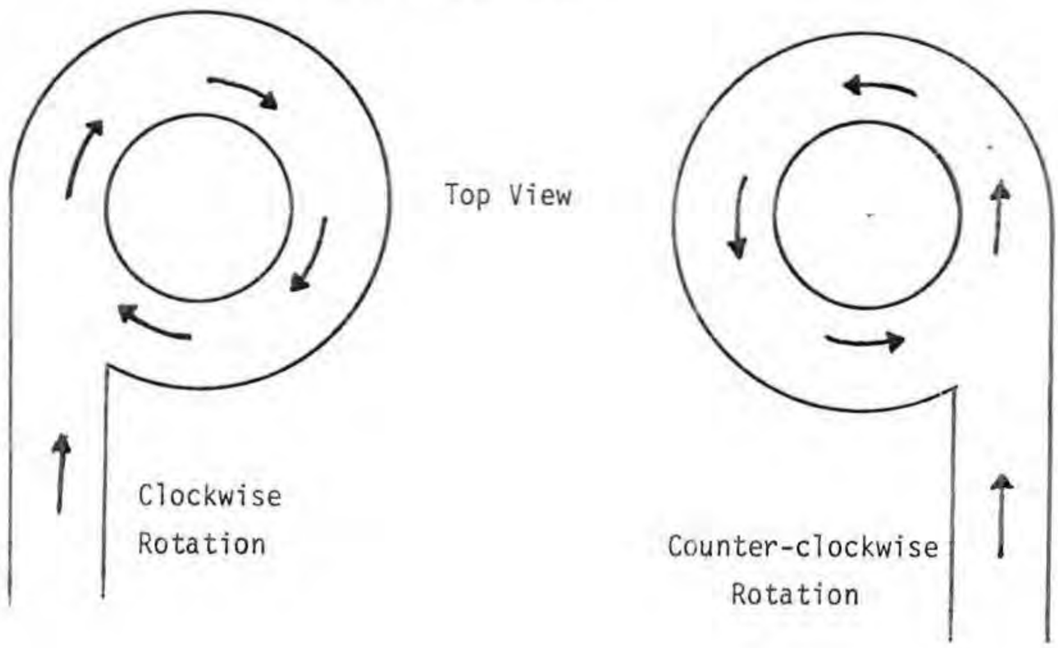


Figure 2D