

Introduction to Air Classification

I. Definition of Air Classification

Air classification is a process of *approximate* sizing of dry mixtures of different particle sizes into groups or grades at cutpoints ranging from 10 mesh to sub-mesh sizes. Air classifiers complement screens in applications requiring cutpoints below commercial screen sizes and supplement sieves and screens for coarser cuts where the special advantages of air classification warrant it. *Air sizing is the counterpart of water classification.*

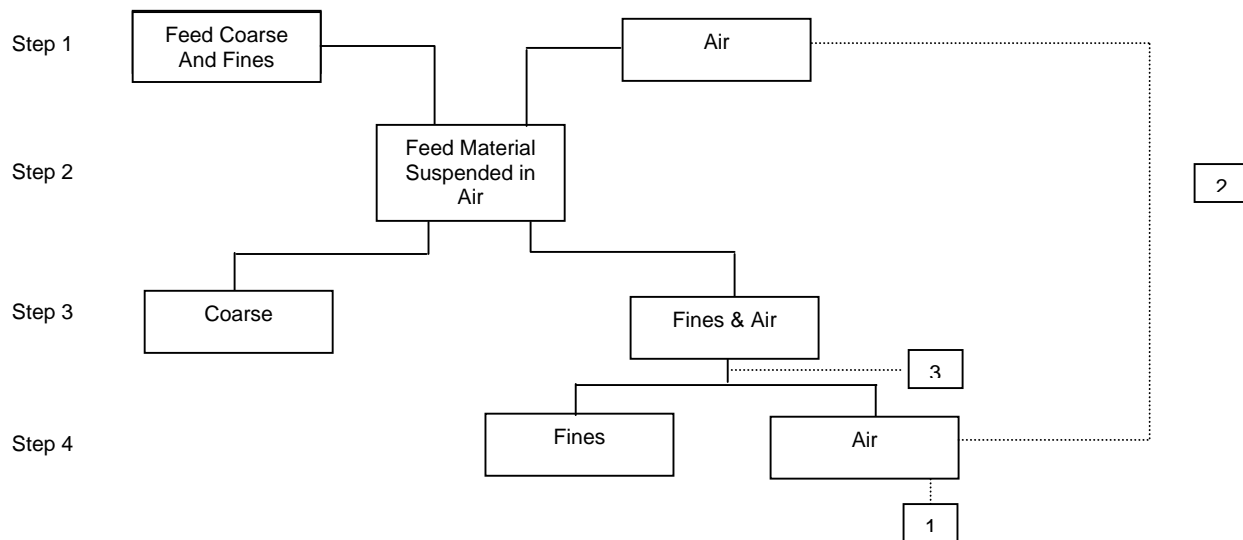
2. Primary Applications

The applications of air classification are many and varied. Some of the more important uses are:

- a. Scalping off of the coarse end from a pulverized product, usually for further milling. This prevents overgrinding and saves power.
- b. The "tailoring" of several size fractions from a heterogeneous mixture of particulate matter. In this application, each fraction has a different particle size distribution meeting commercial specifications or requirements of a dry beneficiation process.
- c. The scalping off of the fine end of the product for "de-dusting," "de-fuming" or changing the flow, apparent density or other physical characteristics of the coarse fraction.
- d. Beneficiation of a mixture by the removal of impurities contained in a narrow particle size range of the mixture or the separation of mixed products having substantial difference in settling velocities in an air stream.

3. Principles of Operation

All air classifying devices employ the process steps shown in Figure 1 below:



Step I - Suspension of the feed material to be classified in an air stream. Step I is sometimes completely separated from the classification process as when the classifier is handling an air-solids stream from an air-swept mill.

Step II - Introduction of the air-solids stream in the classification zone.

Step III - Separation of the coarse fraction from the fine fraction and air stream by opposing the drag force created by the air with gravitational, inertial or centrifugal force or a combination of them. The drag force is proportional to the first power of a particle's diameter. Inertial or centrifugal force is proportional to the cube of the particle's diameter. If the particle is small enough, it will move with the air stream. If the forces are equal, the particle will be held in equilibrium. This equilibrium determines the cutpoint of an ideal classifier. *The cutpoint therefore is equal to the particle size that has a 50-50 chance of ending in the fine fraction or coarse fraction.* In some applications, it is necessary to remove part of the air stream with the coarse fraction to facilitate the removal of the coarse particles.

Step IV - Separation and collection of the fine fraction from the air stream. The air is either released to atmosphere (1) to form an "open air system" or recirculated (2) to form a "closed air system." Step IV is sometimes eliminated with the fines and air mixture going to another process (3) such as another classifier or a direct-fired, pulverized coal burner, etc.

A theoretically perfect air classifier would combine the above four steps in such a way as to assure that all particles are perfectly diffused in the air stream as discrete particles. Each particle must then be subjected to the same air velocities to induce a drag force proportional to their size. This drag force, in turn, must be opposed by a gravitational, inertial or centrifugal force or combination thereof, acting equally on each particle so that they must be only proportional to the particle's mass. Means must then be found to collect the coarse particles without their colliding with the fine particles which are traveling in the opposite direction. The fine fraction must then be 100% collected from the air stream. In addition, the classifier must not be subject to abrasion, have surfaces on which material can build up to spoil the classification nor subject particles to too violent action which might cause attrition. Above all, the classifier must be inexpensive and economical to operate. It is therefore no wonder that hundreds of classifying devices have been invented over the past 100 years, none of them achieving perfection. Some devices are more successful than others. Since the design of a classifier entails compromises, it is natural that the classifier must be designed around the job it is to perform if maximum efficiency is to be achieved.

3.1 Basic Classifier Details

Classifiers employing gravitational forces only are limited to the coarsest cuts. Their range is normally 10 mesh to 65 mesh, although the range can be extended to 200 mesh. A 200 mesh spherical particle with a specific gravity of 2 has a terminal velocity in standard air of 1 foot per second. The air volume required to effect the classification is proportional to the amount of material to be classified. This air volume must move at 1 foot per second. To classify even relatively small amounts of material necessitates very large, cumbersome equipment. Imparting an inertial force on the particulate material to be classified proportionally increases the drag force required to counteract the inertial force on the cutpoint particle. Air velocities can therefore be increased and the classification equipment required to handle a particular tonnage correspondingly decreases. Classifiers employing inertial force are usually employed for cutpoints from 40 mesh to 270 mesh.

Centrifugal force is employed in classification for the same reasons that inertial forces are employed. Centrifuging is a practical method of imparting a force on a particle 500 to 2,000 times greater than is feasible by the gravitational method. Classifiers employing centrifugal principles have a range of 150 mesh to five microns.

Particle size is normally expressed in mesh or sieve size for particles 40 microns and larger, i.e., the particle that would just pass through an opening formed between the strands of woven wire cloth. For example, a 10 mesh particle is a particle that would barely pass through the spaces formed between wire cloth with 10 openings to the inch. The particle would have a diameter approximately 0.08 inches or 2,000 microns. A 100 mesh particle would barely pass through the spaces between a wire cloth with

100 openings to the inch. The particle would have a diameter of approximately 0.006 inches or 150 microns.

4. Factors Affecting Efficiency

The fractionalization results obtained by air classifying devices on pulverized materials are controlled by the physical characteristics of the material to be classified.

4.1 Cutpoint and Particle Size Distribution

By far, the most important factor is the particle size distribution of the product to be classified with respect to the cutpoint required. A good understanding of this subject matter is essential to grasping the fundamentals of air classification.

First, we must elaborate on the term "cutpoint" briefly described for Step III in Figure 1. At that time, we stated that the cutpoint is established by equilibrium condition of the drag force acting against the gravitational, inertial or centrifugal force which can only hold true for a particular size particle. This is the particle that has a 50-50 chance of being found in the fines or in the coarse. As it will be seen shortly, this is the only acceptable definition of the term; however, it is of no commercial interest. *The user of classifier equipment is only interested in a top size or minimum size value for which there are no commercially-recognized definitions.* A 200 mesh cutpoint might mean anything from a product 100.00% passing through a calibrated mesh sieve to 99%, 98% and 80%, even 70% minus 200 mesh. This also holds true when the user is thinking in terms of coarse fraction devoid of fine material. At that time, a 200 mesh cutpoint would signify a coarse product of 98% plus 200 mesh, etc.

Some materials have very homogeneous particle size distributions. For example, synthetic catalyst for cat crackers where all particles are between 150 and 30 microns with 80% of all particles between 80 and 40 microns. Other products, like crushed limestone, have unlimited extremes with large quantities of coarse particles and very fine minus 10 micron particles.

There are few particles in between. The particle size distribution of the feed is all important in all classifying devices having less than 100% efficiency (none of them does). The less efficient the classifying device, the more effect the feed distribution will have on classifier performance.

Every air classifying device operating at a set stable condition will separate the particles of a mixture into sized fractions according to a probability curve based on the size of the particle. The coarser the particle, the greater the probability of that particle to be found in the coarse fraction and vice versa. For example, a typical MET classifier operated at a 100 micron cutpoint, i.e., all particles exactly 100 microns in diameter in the material feed to the classifier are split evenly between the coarse and fine fraction,

will distribute 200 micron particles twice the cutpoint in the following percentages: 90% in the coarse fraction, 10% in the fines fraction.

At 50 microns (half the cutpoint), the reverse holds true: 10% of the 50 micron particles will be found in the coarse fraction and 90% will be found in the fines fraction. When a heterogeneous material such as limestone is passed through a classifier with the above operating characteristic, the efficiency of the classification is very high as little feed material is found between 200 and 50 microns. With a homogeneous mixture, the efficiency will decrease proportionately to the increase of material between 200 and 50 microns. The above only holds true when efficiency is related to the theoretical cutpoint. From a practical standpoint, classifier efficiency usually is related to the product required by the customer instead of the theoretical cutpoint.

This "actual" efficiency is influenced also by the percentage of the product available in the classifier feed. Example, the following tabulation of "actual" efficiencies for a classifier having the characteristics mentioned above (90% of particles twice the cutpoint are found in the coarse; 90% of particles half the cutpoint are found in the fines) set to produce a fine fraction 98% minus 100 mesh from a heterogeneous mixture 20%, 50% and 80% minus 100 mesh and a homogeneous mixture 20%, 50% and 80% minus 100 mesh would produce the results in Table 1 below.

Table 1

	Heterogeneous Mixture			Homogeneous Mixture		
	20% - 100M	50% - 100M	80% - 100M	20% - 100M	50% - 100M	80% - 100M
Actual Efficiency	37.5%	75%	94%	Not Feasible	2.65%	2.34%
Theoretical Efficiency	96%	90%	90%	Not Feasible	98.0%	82.88%
Theoretical Cutpoint	270 mesh	200 mesh	150 mesh		28 mesh	270 mesh

4.2 Particle Behavior in an Air Stream

A classifier sizes particles according to their settling velocities in the air. The results of a classification test are evaluated; however, against screens which size particles according to the screen's smallest cross-sectional area. The following factors affect particle settling velocities independently of its smallest cross-sectional area.

- a. Specific Gravity which affects the particle's mass and, therefore, its settling velocity in air. For example, a 74 micron particle (200 mesh) with a specific gravity of 2 grs/cc will behave in the same manner as a 53 micron particle (270) mesh with a specific gravity of 4 grs/cc.
- b. Apparent specific gravity of porous or hollow particles such as diatomaceous earth and flyash will have the same affect on their settling velocities as the actual specific gravity of solid particles.
- c. Particle shapes affect the classifier performance when deviating from spherical forms due to their particle changing surface area as the particle tumbles in an air stream producing a variable drag force on it. Particles differing widely from spherical shape are difficult to define size and to measure reliably. For example, a mica flake can have a length and width six times its thickness. If the mean diameter and mass of a particular flake are of a magnitude to have it normally classified as coarse, the particle can still be swept with the fines if the plane in which the flake shows the largest area is perpendicular to the air stream at the moment of its classification.

4.3 Surface Moisture

Free water content of pulverized material when present on the surface of the particles changes the apparent particle size distribution of the classifier feed by forming agglomerates. The free water content tolerated by air classifying devices depends entirely on the nature of the material being classified. Flour, for example, normally contains approximately 18% free water; there is no affect on the classification. However, one percent water in fine limestone will seriously affect the efficiency of the classification.

4.4 Viscosity of Gas Stream

Air classifiers may be operated with heated or refrigerated air or other gases such as nitrogen, having different viscosities from that of standard air. As the drag force acting on particles is directly related to the viscosity of the gas stream, the gravitational, inertial or centrifugal force acting on the particle must be changed proportionally to retain a set cutpoint.

4.5 Electrostatically Charged Particles

These particles will repel each other when they have the same polarity, as is usually the case. The material disperses more readily in an air stream and becomes more difficult to collect by mechanical means. This results in higher classifier cutpoints and lower efficiencies.

4.6 Flow Characteristics

Free flowing materials disperse readily in an air stream and can be distributed evenly without difficulty. Both factors are important prerequisites to good classification. The opposite is true for materials with poor flow characteristics. In addition, materials that have tendencies to build up on classifier surfaces will create flow disturbances or plug the classifier.

4.7 Surface Area

The number of particles per unit volume is an important factor in determining the capacity of any classifying device. The finer the material, the more particles will be held by a given volume unit and the lower the capacity of the classifying device. Due to the heterogeneous mixture of pulverized materials and other technical reasons, particle counts are rarely used and the fineness of a product is expressed in terms of developed surface area, expressed in CM.sq./gr., measured usually by Blaine or Wagner tests. Surface area is sometimes expressed in terms of average particle size. This is an inaccurate method as a slight change in the extremities of the particle size distribution can have a tremendous effect on the surface area developed by a particular sample.

4.8 Particle Hardness

Hard particles besides being abrasive have a tendency to bounce and ricochet inside the classifier chamber when handled at medium to high velocities. This results in abnormal amounts of stray coarse particles in the fine product.

5. Efficiency Formulate

5.1 Actual or Conventional Classifier Efficiency

Actual or conventional classifier efficiency is expressed as the percentage of desired product found in the fines in terms of available product in the classifier feed. For example, 90% efficiency means that 90% of the material considered fines in the classifier feed was classified as fines with the balance, 10%, going into the coarse fraction. As no attention is paid to the particle size distribution of the classifier feed, the formula is valueless when comparing various classifying devices unless they are operated with identical material. The definition of the term "fines" also greatly affects

conventional or actual efficiency as the percentage of coarse material is not taken into consideration in the formula. For example, if the term "fines" is defined as 98% minus 200 mesh, the classifier may have an efficiency of 85% on a particular material. If the standard for the fine product is relaxed and a product 95% minus 200 mesh becomes acceptable, the actual efficiency may become 95% even though the classifier characteristics have not changed. The theoretical cutpoint was raised and more minus 200 mesh material in the classifier feed was found in the desired product. If the standards are increased and the desired product must now be 100% minus 200 mesh, the cutpoint must be decreased, perhaps to 35%.

5.2 Theoretical or Absolute Efficiency

Theoretical or Absolute Efficiency is based on the theoretical cutpoint and is the percentage of material properly classified as coarse and fine. Coarse material is defined as any particle larger than the cutpoint. Since the formula does not take into consideration the particle size distribution of the classifier feed, it is not an effective tool to compare various classifying devices unless operated on identical material. It does, however, eliminate the effects of product requirements on efficiency.

5.3 Fractional Efficiency

Fractional Efficiency, as demonstrated above in the conventional formula, cannot give a satisfactory overall picture of the classification efficiency of a particular classifying device as it is influenced by extraneous factors due to particle size distribution of the material being classified and the selection of the cutpoint. The fractional efficiency method is a piecemeal efficiency. The feed material is divided into several size fractions, usually in the screens selected for the analysis, and in 10 micron increments for the submesh fraction. The percentage of each fraction going into the fine product or coarse product is then calculated. Each percentage thus obtained is actually the efficiency of the classifying device on the corresponding size fractions. Besides being a quantitative measurement, fractional efficiency is also a qualitative measuring device as it shows, as an example, if the 5% plus 200 mesh fraction allowed in a desired fine product is made up of material close to 200 mesh or whether it contains undesirable, very coarse particles.

5.4 Fractional Efficiency Curve

Fractional efficiency is best expressed graphically as it summarizes a whole series of percentages, each one of which must be properly identified, into one simple line. The line is plotted with one axis indicating the percent of material available in the feed that was found in either the fine fraction or coarse fraction for each size fraction. The other axis indicates the average particle size in microns or mesh for each size fraction into which the feed was originally divided.