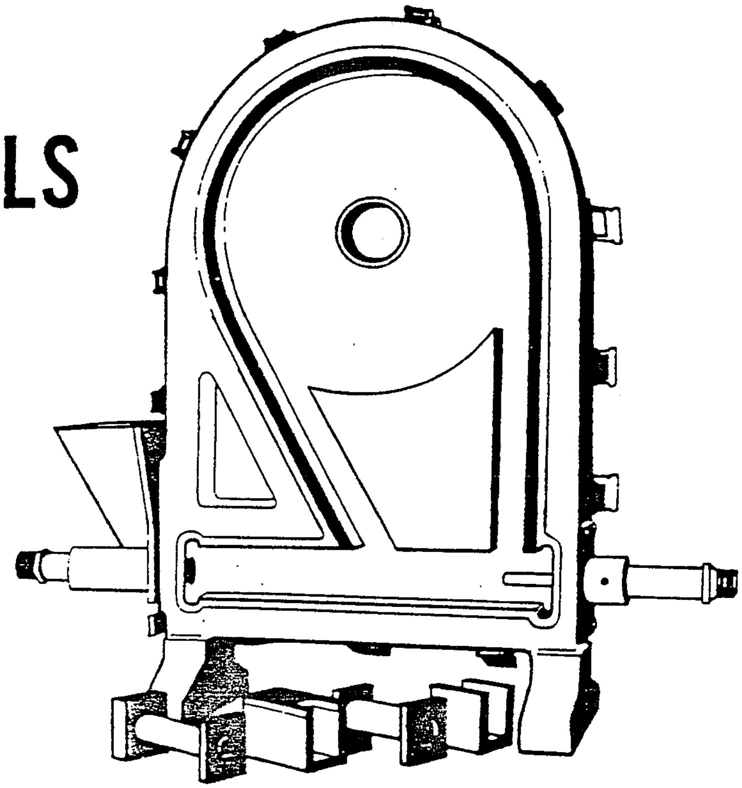
BASIC FLUID ENERGY PULVERIZING PRINCIPLES and MANUAL ON THE OPERATION OF TROST JET MILLS



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BASIC FLUID ENERGY PULVERIZING PRINCIPLES

Fluid energy pulverizing is the generic term for what is often called air or jet milling or pulverizing the reduction of particle size by particle-to-particle collision, the particles being entrained in a gaseous medium made up of high velocity counter flows. Air, of course, is the most commonly used gas, but dry steam and inert gases are also used.

The jet mill designer's task is to use fluid energy to get particles to collide at high impact and to provide a classifying system that draws off the reduced particles of the size required while recirculating the undesired coarse particles for reimpact, and this classifying is done with the same cfm which he requires for pulverizing. While designers have worked on this problem for at least a couple of decades, with gratifying success in a significant number of fields, none have succeeded in making a fluid energy mill that can take any feed material and throw it into a mill of any particular current design and by adjusting feed rate, pressure and jet size (for cfm control), turn out precisely the desired particle size range .... which includes us. The reasons for this are as follows:

When we say any feed material, we imply material of any size and composition; granite of one cubic foot in size lead bullets, rubber balls, caratsized diamonds & walnut shells, for example.

The velocity any particle can attain in a flowing gas stream depends upon how well the gas can grasp and accelerate that particle and that depends upon enough surface on the particle for the gas to contract with its power of thrust, relative to the density of the particle.

The impact of two particles will cause fracture if the particles are fragile or fracturable. Throw one stone against another and one or both are apt to fracture. Throw a rubber ball against another,or even against concrete, and you get bounce, not fracture. Lead bullets colliding in mid-air will surely flatten or distort or even break in two but they are not likely to fly into bits.

The particle size distribution range of the feed effects pulverization in particle-to-particle collision to the extent that the smaller particles fracture more readily than the larger.

One of the product conditions that can result from a feed of a wide particle size distribution is a split into two distinct segments of coarse and fine particles with little in the medium range. If the fines are in the desired range, screening or air classification can be used to scalp off the coarse for return to feed. The more widely separated the coarse and fine segments of the product, the easier a commercial air classifier can scalp off the coarse without digging deeply into the segment of fine particles.

All this indicates is that feed size and make-up are important elements of jet pulverizing success. How small can such a feed size be? The largest size for a particular mill is usually listed as much smaller than any aperture the feed must pass on its way to collision. Clusters of medium-sized feed can block, though perhaps temporarily, the flow of energy and upset the pneumatic balance by which a mill operates. There may be blow back at the hopper. Caked or agglomerated feed held loosely together can be fed more coarsely than discrete particles but even this should not be overdone. The best answer to the question of feed size is that the feed should be reduced to the smallest size by mechanical means than can be done economically without undesirable contamination.

One more point on feed ..... There is a size for every material that in a given system is too small to attain velocity of sufficient mass to have adequate impact power. At that point, the increase in power necessary to fracture further goes up steeply. The mass velocity force may be too low for sonicspeed fracture where fluid energy mills are designed to operate. This point can be summarized as follows: There is a time when repeated passes through a fluid energy mill will not significantly reduce the particles further.

There are other basic principles in a fluid energy pulverizing system. A great part of every designer's thinking is the attainment of high velocity for impact. He, therefore, thinks in terms of pressures and volume of the energy medium. In straight line thinking, the more the psig and the more the cfm, the greater the energy, the greater the fracture and the finer the product. Such straight line application of energy, however, works out best in sand blasting. Where energy is of necessity channelled in a vessel and combines fracture and classification chores. The excessive use of energy bottles it up instead of using it. Good fluid energy mill design is based upon channelling the energy, not impeding it. As this is true of the pulverizing equipment, then it is also true of the collection system. This basic factor is commonly overlooked by air mill manufacturers, dust collector sales engineers and operators. A dust collector system, whether a simple cloth bag that filters the pulverized product from the spent fluid or a series of many cloth bags in a bag housing with automatically timed air pulsation of the bags to clean their pores and prevent clogging, must be operated so that energy is not bottled up. Once restriction of energy release becomes higher than about 3" of water positive pressure on the clean side of the collection system (the final exhaust of spent energy), there can be too much positive pressure in the system between this final gas outlet and the fluid energy pulverizer itself. The result of pressure substantially above 10" of water at the discharge end of the fluid energy mill is summarized by two effects: less pulverizing and lower production.

Since pulverizing without classification is useless for most product requirements, some principles of classification, as they apply to this discussion, must be understood. As indicated above, feed size and particle size distribution play an important part in fracture to a smaller size and the resulting particle size distribution. Feed fracture characteristics affect classification, too.

Here are types of feed that require different results from classification system:

1) Agglomerates of fine particles are often jet milled. Breaking of particle-to-particle bond is desired rather than the fracture of the undivided particle. Fracture by collision and prompt exit is here more required than any subsequent classification. Titanium dioxide and ferrites are typical examples of this type of feed.

2) Some already fine heavy metals of irregular particle shape (and which may also be partially agglomerated) attain a more spherical form, useful for a denser packing for electronic uses or powder metallurgy. Jet milling of nearly all heavy metals - at least

with our experience in the Trost design - increases in bulk density. The general rule in particle size reduction is a decrease in bulk density..... the finer product always occupies more space. The finer, heavy metals, however, when jet milled occupy less space. This is achieved by crowded feeding and medium energy input with scant concern for classification as such.

3) Minerals and natural inorganic mixtures, as well as materials such as calcined alumina, often break up into components of differing fracture characteristics. They remain difficult to get down to a grade of an absolute 100% passing of a 200 or 325 mesh screen or, say a 20 micron top size. In one exhaustive test on natural limestone that had a silica inclusion, we found it possible to separate the silica from the calcium carbonate and keep on recycling the silica so that the product had a different specific gravity than the feed.

In the same group of difficult -to-classify material (a usual attendant of material hard or relatively hard to fracture) are inorganic pigments. Here the requirement of a quality manufacturer is the elimination of particles above 20 microns. This is so difficult a task that our approach is the use of increased velocity to the impact area without increasing recirculation in the classifier area, the reasoning being that higher impact will produce the greatest number of fine particles and not crowd the recycling area. When material is recycled for reimpact, a considerable percentage of the original feed remains within the mill; clogging results and, therefore, classification control is lost. The standard practice of reducing the feed rate is, of course, helpful but a higher energy input may or may not be helpful depending on the design of the mill. One thing is certain; when recycling and/or velocity must be increased, part of the work goes into wear of the mill and not just particle size reduction.

4) The real difficulty of classification within the confines of a jet mill is a product specification of a narrow range of particle size distribution, say, 4 to 20 microns, or 100 to 200 mesh. The latter specification would be coarse for a jet mill but may be requested because mechanical or attrition mills that could pulverize substantially in that range produce unwanted metallic contamination. The former is impossible since no control of individual particle impact can be made to insure no break-off of a particle less than 4 microns. The best that can be done is to lower the impact so that few particles smaller than desired are created. While there will then be particles coarser than desired, an external classifier can be used to scalp off the coarse particles. Some classifiers can be placed in the line between the jet mill and collection system.

It is to be remembered, nevertheless, that all air classifiers have limitations in cut-off of size. To make certain all top size particles are scalped from the product, the cut must be made fairly deep into a segment of particles of the proper size. Classification by air does not select particles by size alone but by shape as well.

"Ideal" pulverizing and classification to a strict top or bottom size specification will come dearly. An instance is a test grind made of a mixture of clays and other components for a cast and fired inorganic structure. At 25 pounds per hour, the product was 100% minus a certain mesh; at 60 pounds per hour, it was 99.9% minus; at 140 pounds per hour, it was 99.5% minus and at 240 pounds per hour, it was 99.0% minus. The average particle size of the first was, of course, considerably higher than the last but was not part of the specification.

Cases of this kind can often be solved by an insertion of a cyclone in the jet mill discharge line, with a container at its outlet, and a continuation of the discharge to the dust collector from its gas outlet. A cyclone is essentially a device for separating the dust in an air or gas stream from the gas itself, the dust dropping downward and the gas going upward. An efficient cyclone, designed for the cfm and the dust it is to handle, will drop nearly all of the dust through its outlet into a container below, but in a case such as this the cyclone must be inefficient and carry 90% or more of the mill product out its gas outlet.

A simple cyclone "collector", which has a container to collect the product below it and an air relief bag to allow gas to be vented into the atmosphere, is ideal in itself for long runs on small jet mills but this equipment can act as a classifier by itself. The finer dust in a product will travel the longest distance with air so there will be a percentage of a product usually varying from 5% to 10% of the total that will wind up in the air relief bag instead of the container. What percentage winds up in the air relief bag depends upon the percentage of very fine particles in the product and their density.

MANUAL ON THE OPERATION OF TROST JET MILLS

In order to understand the effect of the jets position, pressure and cfm changes, the following basic operational pattern is illustrated in Figure 1.

P JET - The "pusher" jet

This creates a vacuum pull on feed material (up to 14" of water) and entrains the feed in a stream of fluid energy. The closer this jet is laced to the "P" tube the greater a vacuum is created to pull material into the "P" tube. This also limits the size of feed that can clear the gap between the jet and the entrance to the "P" tube.

P TUBE

This passage is designed to give velocity to the feed for impact in the impact chamber. The velocity attained is dependent upon at least three factors.

1) The efficient channeling of the flow of gas into the "P" tube.

If the end of the "P" jet is too far away from the "P" tube the compressed gas in the jet expands fan wise and must be re-directed into the "P" tube.

2) The size of the feed particle in relation to its weight. This is also expressed as the ratio of surface area to the density of the particle. For instance, a 1" cube of 6 sq. inches of surface attains better than 76,000 sq. inches of surface if broken into 2 micron particles.

3) The internal diameter of the tube.

Obviously, if 100 cu. ft. of air can be forced through a 1/2" tube, it will have a higher velocity then if the same amount of air goes through a 5/8" tube. The area of a 5/8" tube is 57% more than that of a 1/2" tube. Varying sizes of "P" tubes can be furnished, decreasing or increasing impact velocity according to the fracture characteristics of feed and the need for particle size reduction.

The "O" or opposing Jet

This jet has two functions. It induces the coarse particles that hug the periphery of the classifier area to return via the down-leg and the "O" tube for re-impact in the impact chamber. It also directs particles for a head-on collision with incoming feed for the most efficient impact of particle-to-particle collision. By the laws of momentum two equal masses of equal velocity impact in a head-on collision with a force quadruple that of one of these masses hitting a stationary target.

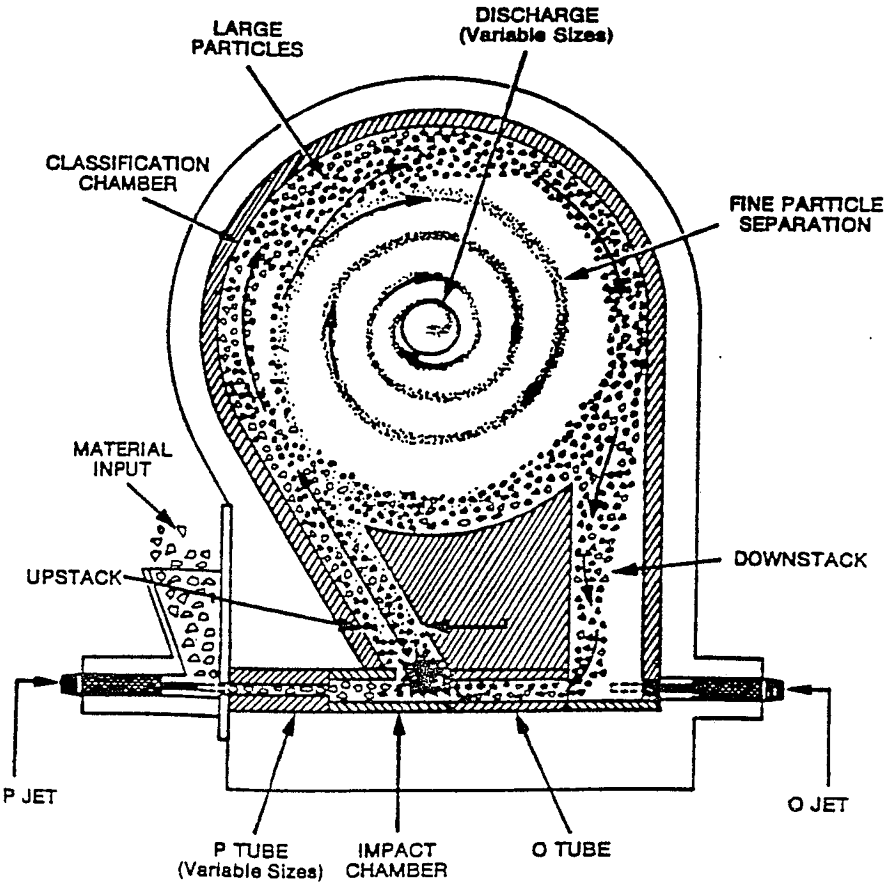

FIG 1

The Positioning of "P" and "O" Jets

In general, the midpoint between the "P" and "O" jets should be about mid-point between the end of the "p" tube (at the right in the illustration) and the upstack to classifier. This is known as the point of impact, although in reality there is a well defined band of impact... it is anything but a point. In a general way there is evidence that the closer the point of impact is to the end of the "P" tube the finer the grind, supported by viewing the impact effect from high speed movies taken of the area. Nevertheless when the "P" tube is decreased in size for higher velocity to the impact chamber it may also be necessary to move the "O" jet back since it in such cases overpowers the "P" jet and impedes flow of feed into the mill.

The best overall advice on jet positioning is that when jets are set and mill is running with air and no feed the suction on the hopper be tested with a paper towel or something similar. If it is sucked downward into the hopper there will be pulverizing action with feed. In any case, **DO NOT** pull the "P" jet back too far, whether the conditions of impact mid point are met or not. Do not bank on getting particles, especially if they are rather big, to drop in front of the jet and be blown into the "P" tube. The particle will be more likely to blow back into anybody's face that is peering into the hopper. Particles should be sucked in. If they can't be sucked in because of their size, they should be kept out of the feed to the hopper. (Aggregates in the form of cake, such as of titanium dioxide or silica gel will break up with the power of suction, so "lumps" of this kind are seldom troublesome).

Classifier Area

This works on the principle of differentials between centrifugal and drag forces. The heavier coarse particles are flung toward the periphery. The drag force is within the spiral flow of gas to the exit in the center of the classifying area. The higher the differential between the peripheral velocity and the exit velocity the sharper the cut-off of the finer particle sizes. With a fixed input of cfm the differential between peripheral and exit velocities can be gradually increased by inserting discharge outlet bushings of increasingly smaller diameter.

Why have any of the larger openings? For two reasons:

One, if the product that exits into the collection system is finer than required a larger opening will provide a coarser grind that may be more in line with what is actually desired while the production rate can be higher. One, but not necessarily an inevitable, result of decreasing the discharge opening is the recycling of more material. As recycling increases, the space for recycling runs out, and the "downleg" from classifier is choked. The feed rate must then be reduced. The reason for not insisting that the recycle rate is increased by each decrease in discharge size is that the resulting sharper cut-off may more efficiently suck off the finer particles (this will depend upon density and shape) so that fewer of the desired particle sizes are recycled. One reason for supplying discharge outlets of varying sizes in small increments is that for a particular product there will be the most efficient classification within a particular peripheral and exit discharge velocity differential.

Two, a material that is easily fractured to a small particle should not be inhibited from being discharged by a small discharge opening, and enlarging the discharge opening will permit an increase in production without any change in energy input.

There is still another reason for the larger opening. It permits a higher energy input. This can maintain a more finely ground product at higher feed rates. There is an increase in velocity all around, but the differential velocity of the periphery and discharge will remain approximately the same. However, the efforts to keep on increasing the energy input must be resisted. The increase in overall velocity can be transmitted into wear of the mill rather than reduction in particular size.

Impact for the reduction of particle size, using a given amount of energy, can be increased by a change length of run. Calculate your true feed rate from the total weight fed vs. the time taken. In working with initial and experimental runs, the conditions that should be charted for each test are: Feed rate, pressure, cfm (or jet size) dimension of "P" tube and dimension of discharge outlet (if these are other than standard and changeable with your particular mill), weight of material discharged or recovered, the particle size and range (by whatever method of measurement you find practical and have available) and such other matters (as change of color, etc.) that may be important to you.

Standard Test Procedure

It takes three runs at three different feed rates to establish enough points on a graph to plot a curve. This is with one operational variable only. Fortunately, even most new products are related in a general way to something that has been pulverized. We publish a list of typical materials and their general grindability, which gives clues to feed rate as low, medium or high. At any rate, a feed rate must be picked and we would advise that for the TX this should begin at 5 to 15 lbs. per hour for a usual medium range, and 15 to 40 lbs. per hour with the T15. Once a medium feed rate is assumed and the mill accepts and discharges it, with no more than 5% retention (loss from feed to product stage) it is well to go below and above the first feed rate in successive runs. The reduction in particle size may rise or fall steadily with the feed rate, or it may show signs of a widening or narrowing split of fine and coarse fractions, but a pattern will develop and tests then should follow the pattern, introducing other variables.

Disassembly, changing liners, replacing parts and cleaning.

The mill casting is normally cleaned out with light pressure from an air hose. The liner parts can be cleaned with soap, detergents or bleach powders. Solvents and proprietory cleaners are often useful. Do not soak urethane in solvents as it will swell and take a long time to shrink to original dimensions.

Extreme care should be used whenever disassembly, handling, and assembly of liner is required.