DENSE PHASE MILL

The terminology "DENSE PHASE" was selected as being a more descriptive term of this fluid energy milling process than fluidized bed. The principles involved relating to particle acceleration and breakage in the milling process are no different than those used in other types of *free jet* pulverizers, the only difference being the degree of solids loading in the comminution zone, hence dense phase. The primary benefit of this version is the increased probability of collision due to the high solids loading. The incorporation of a forced vortex classifier within the milling chamber allows utilization of the high degree of particle dispersion for improved separation. This combination results in narrow product distributions with close top size control at lower specific energy levels in comparison to other fluid energy milling concepts.

Fluidized bed (Dense phase) micronization utilizes turbulent free jets in combination with a high efficiency centrifugal classifier in a common housing as shown in Figure 1. Feed is introduced into the common housing through either a double flapper valve or injector. Flooding the pulverizing zone to a level above the grinding nozzles forms the mill load. Turbulent free jets are used to accelerate the particles for impact and breakage. After impact the fluid and size reduced particles leave the bed and travel upwards to the centrifugal classifier where rotor speed will define what size will continue with the fluid through the rotor and which will be rejected back to the particle bed for further size reduction. The high degree of particle dispersion leaving the pulverizing zone aids in the efficient removal of fine particles by the classifier. Operating parameters of rotor speed, nozzle pressure, and bed level allows for optimizing productivity, product size, and distribution shape (slope). A low-pressure air purge is used to seal the gap between the rotor and the outlet plenum eliminating particles bypassing the rotor and allowing for close top size control.

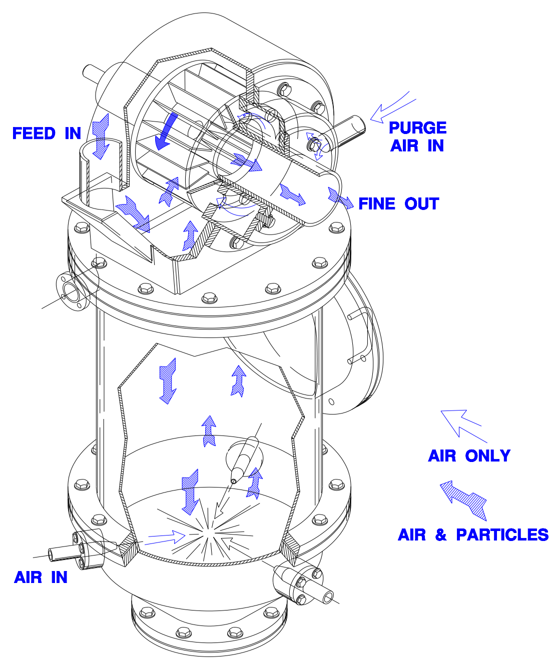

Figure 1 Dense Phase Mill

Philosophy of Fluid Bed Mill Operation

Product Top Size Control: The high efficiency classifier incorporated into the fluid bed allows for prediction of product size using the general theory for particle separation in a centrifugal field.

$$D_{50} = \frac{3k}{\pi D_0 N}\sqrt{\frac{\mu Q}{\pi H \rho_p}}$$

Where D_{50} is the "cut size", k is a constant dependent on the flow pattern (determined experimentally). D_o is the diameter of the separation zone, H is the height of the separation zone, μ is fluid viscosity, Q is volumetric airflow rate, N is rotor rotational speed and ρ_p is true particle density.

The above expression defines the effects of the operating parameters on product size. Given a unit size and feed material, an empirical definition of this relationship can be derived for product size prediction.

For example, assuming the classifier cut size is equivalent to the 95 percentile of the product size distribution, Figure 2 shows the comparison of theoretical and actual, using the DPM-2 processing silica.

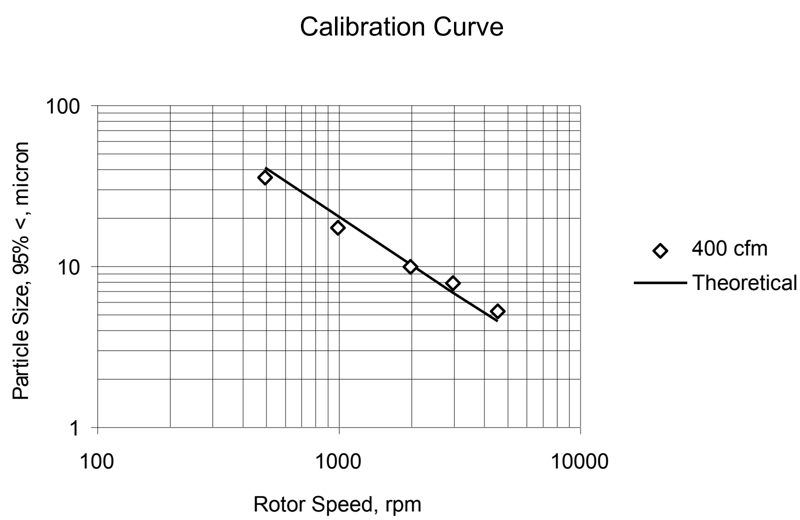

Figure 2

Control operators:

Rotor Speed: Primary product size control, the usual increase/decrease.
Mill load: Mill load will define the maximum throughput. This load will also be the point at which the minimum average particle size will be obtained given the same rotor speed and nozzle pressure. Slope of the distribution maybe steeper at a mill load above or below this optimum.
Nozzle pressure: Airflow rate can be decreased or increased by reducing or increasing pressure accordingly. Slope of the distribution will increase with reduced pressure. (Some data has been published with pressure as low as 45 psig, obviously at the sacrifice of throughput.) Obviously, reduced pressure will allow for finer products.
Nozzle size: Larger nozzles at high pressure extend the particle size range upward in a given unit size (with increased product rate).

Feed size: Reduced feed stock size will have a definite effect on productivity and is feed material dependent.

Unit features and options:

- Mill load controlled through use of load cells to optimize performance at maximum productivity and /or slope of product distribution.
- Choice of introducing feed using an injector or by gravity drop using an airlock or double flapper valve.
- Rotor purge to optimize product top size control.
- Low-pressure purge air is used instead of compressed air.
- Rotor purge air gap is adjustable from the exterior.
- Wear resistant coatings for abrasive applications.
- Pressure resistant designs will be available.

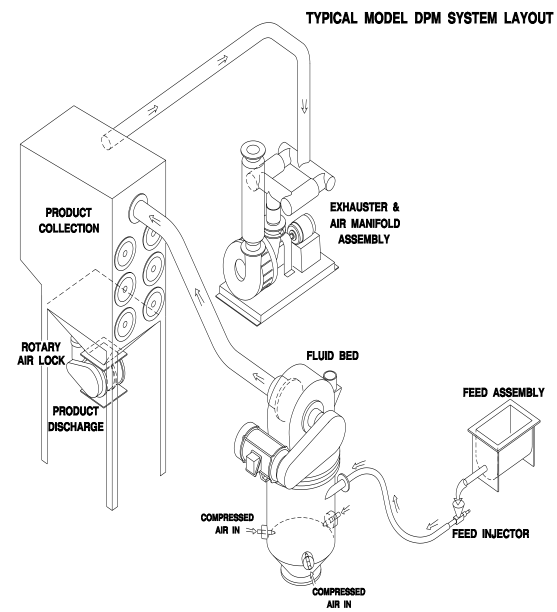

Figure 3

Performance of the fluid bed mill:

Product size range: 95% < 5 μm to 95% < 70μm, assuming 100 psig, at a particle density of 2.6 gm/cc

Product Line Description:

Model No.	DPM-1	DPM-2	DPM-3	DPM-4
Air Flow, scfm*	150-250	300-500	600-1000	1100-1500
No. Nozzles	3	3	3	3
Rotor Speed, rpm	900-9000	500-5000	360-3600	310-3100
Drive, HP	5	10-15	15-20	20-25

* Airflow at 100 psig, dependent on nozzle size selection

System Requirements:

Primary Air, HP	15	30	40	60
Purge Air, HP	1.0	2.0	5.0	7.5

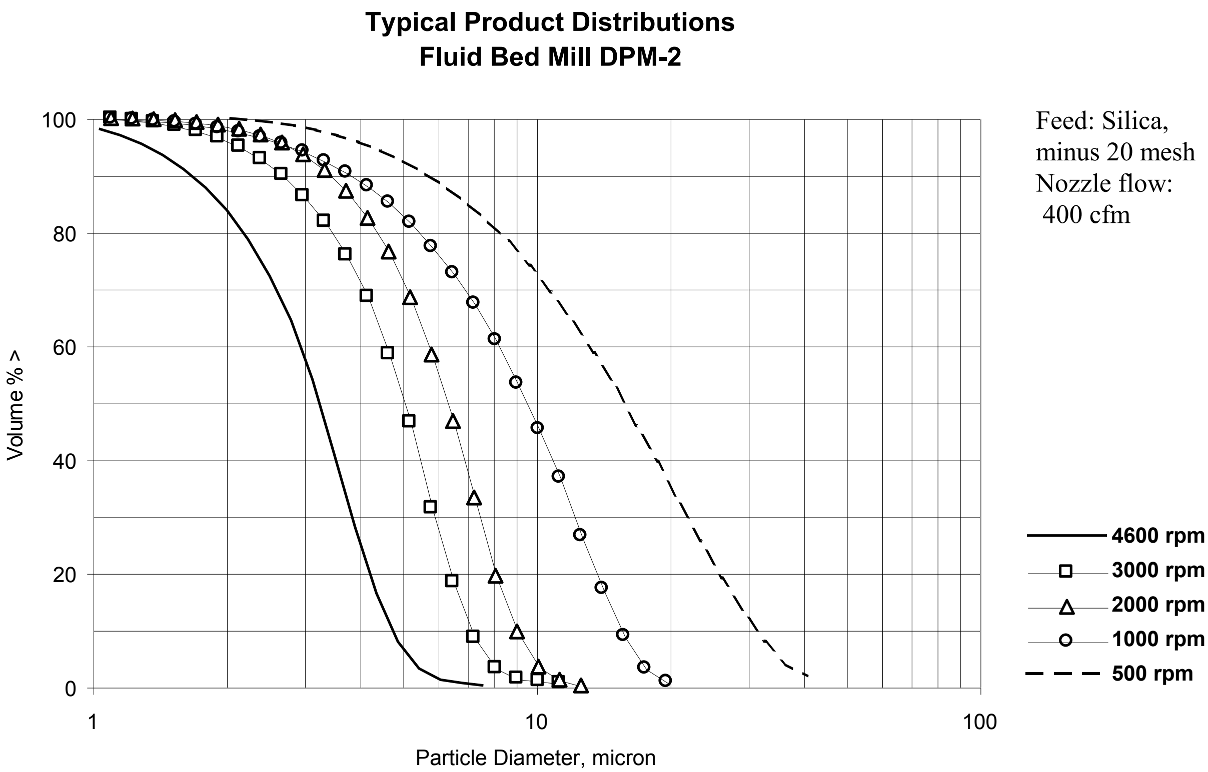
Typical Product Distributions
Fluid Bed Mill DPM-2
Feed: Silica,
minus 20 mesh
Nozzle flow:
400 cfm
Volume % >
100
80
60
40
20
0
1
10
100
Particle Diameter, micron
4600 rpm
3000 rpm
2000 rpm
1000 rpm
500 rpm

Figure 4