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How the size of the starting material directly affects the size reduction energy.
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This is a study of how the size of the starting material can influence the processing rate, tightness of the particle size distribution, and energy costs associated with particle size reduction.

There are many reasons to pursue jet milling as part of your size reduction plan. These advantages include: purity of product, continuous processing, dry processing, and the finest and narrowest particle size distribution (PSD). Jet mills are generally capable of reducing large feed stock of ½" [1] down to below an average particle size of 5μm. The size of the feed stock is limited to what the feed funnel of the mill will accept as a free flowing material.

It may not be well known, but there are three (3) physical law's that describe the energy required for size reduction. They are the Bond's Law, Rittinger's Law, and Kick's Law. These laws provide a relative approach to looking at the materials being reduced and do not include equipment efficiency or material friability characteristics.

BOND'S LAW — The work required to form particles from very large feed is proportional to the square root of the surface-to-volume ratio.

$$E = K_B f_c [(1/L_2)^{1/2} - (1/L_1)^{1/2}]$$

RITTINGER'S LAW — The energy required for reduction in particle size of a solid is directly proportional to the increase in surface area.

$$E = K_R f_c (1/L_2 - 1/L_1)$$

KICK'S LAW — The amount of energy required to crush a given quantity of material to a specified fraction of its original size is the same, regardless of the original size.

$$E = K_K f_c \log_e(L_1/L_2)$$

There is no physical law for the efficient use of energy and therefore it is incumbent upon the processing engineer to find the most applicable and cost effective method to get from here (L_1) to there (L_2). As noted by Ehmer, there is an inverse relationship between size and strength of particles; as particles get smaller, their strength increases.[2] Therefore, it takes a large amount of energy to produce ultra-fine particle sizes. However, the opposite is also true--when pursuing a coarser finished particle size, a lower-energy method may be utilized. The total processing train may include jaw crushing, roller milling, hammer milling, and media milling before utilizing high energy jet milling.

Knowing that a jet mill can be quite costly to operate, every care should be taken to run them as efficiently as possible. While a jet mill is capable of reducing a particle population's average size by a factor of 1,000, it takes a lot of energy to get there. As long as the application allows for it, other size reduction methods should be used to initially reduce the particle size as much as possible, and the jet mill should be used for the final size reduction phase.

Focusing on jet milling technologies, there are other factors that can influence efficiency such as the condition of the compressed gas (temperature, pressure, and humidity), product quality (uniformity and moisture content), and the size of mill.

For this study, we used an activated carbon designed for emissions applications such as mercury removal from flue gases. Activated carbon continues to become a more important product within the power generation market. We feel that understanding ways to optimize the process train is very relevant at this time and therefore became the focus of our study.

We selected two(2) different size starting materials. We had a 3.0 mm coarse feed stock (CFS) top size and a 1.2 mm fine feed stock (FFS) top size starting materials and had ample supply of material to ensure continuous steady state performance. The test mill was a spiral jet style 20" Micron-Master® type Bottom Side Feed (BSF) powered by dry compressed air at 110 PSIG. The BSF style jet mill has a predistribution chamber under the grinding chamber that provides a more uniform injection of material into the grinding chamber. We started with the CFS to establish a maximum rate that would produce the desired fineness. After several iterations and satisfied that we reached a steady-state condition, we cleaned up the system and made it ready for the FFS. We worked through the same maximum rate approach until we reached the desired fineness and steady-state conditions.

Results: As anticipated, the FFS starting material processed faster (2.3x faster) than the CFS material and produced a tighter distribution at 3.7μ Std.Dev. vs 5.0μ Std.Dev. The apparent energy saving was approximately 56%. The FFS and CFS processed at 0.124 Kw/pound and 0.285 Kw/pound respectively. This energy calculation excludes any ancillary processing equipment such as feeder, collector, and controls.

Conclusion:
There are numerous equipment offerings and combinations that can convert a coarse particle it into a super-fine particle. Understanding how each piece of equipment exerts force on the particle and within what range it is the most efficient is essential to selecting the right process train. It is clear that providing a jet mill with finer feed stock will save time and energy. Further research is required to determine which pre-crushing options and combinations provide the most cost effective and efficient work within the desired target particle ranges.

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1 Up to ½ inch in diameter for a larger jet mill.
2 Ehmer, Alex. Micronization of Proteins by Jet Milling. Diss. Universität Regensburg, 2009.