Basics of Size Reduction

Hosokawa Micron Powder Systems

Hosokawa Polymer Systems

Hosokawa Presenters

Jeff Gunderson is the Area Sales Manager for Hosokawa Micron Powder Systems (HMPS) and resides in Nashville, TN. HMPS is an industry leader in Size Reduction and related Solids Processing Technology for the Chemical, Food, and Plastics Industries. Jeff graduated from Rutgers University in 1982 with a degree in Chemical Engineering and worked for several years as a Process and Project Engineer in the polymer industry before joining Hosokawa in 1995. As area Sales manager Jeff is responsible for Sales and Technical Support for our clients in the Southeastern United States and having been employed by Hosokawa for 25 years Jeff is knowledgeable and experienced in all of Hosokawa Solids Processing Technologies.

Hosokawa Presenters

Doug Ort is the Division Manager of Hosokawa Polymer Systems (HPS) where we design and manufacture recycling systems for the plastics, paper, wire and cable industries. Doug graduated from New Jersey Institute of Technology in 1991 with a Degree in Mechanical Engineering. After spending summers interning at Celanese working on their new Celgard film launch, Doug started his career at Hosokawa Micron Powder Systems (HMPS) in 1991. While at HMPS he worked in the Testing/Demonstration Center, Service department, and managed the Aftermarket group before moving to Berlin Connecticut as the Division Manager of Hosokawa Polymer Systems. At HPS Doug is responsible for the development and sales of our Industry Leading line of granulators and shredding equipment and has added Dedusting and Washing line technology to our portfolio. Doug has over 30 years of industrial experience and is well versed in all of Hosokawa Solids Processing Technologies.

Hosokawa's Global Presence

HM Polymer Systems (USA)

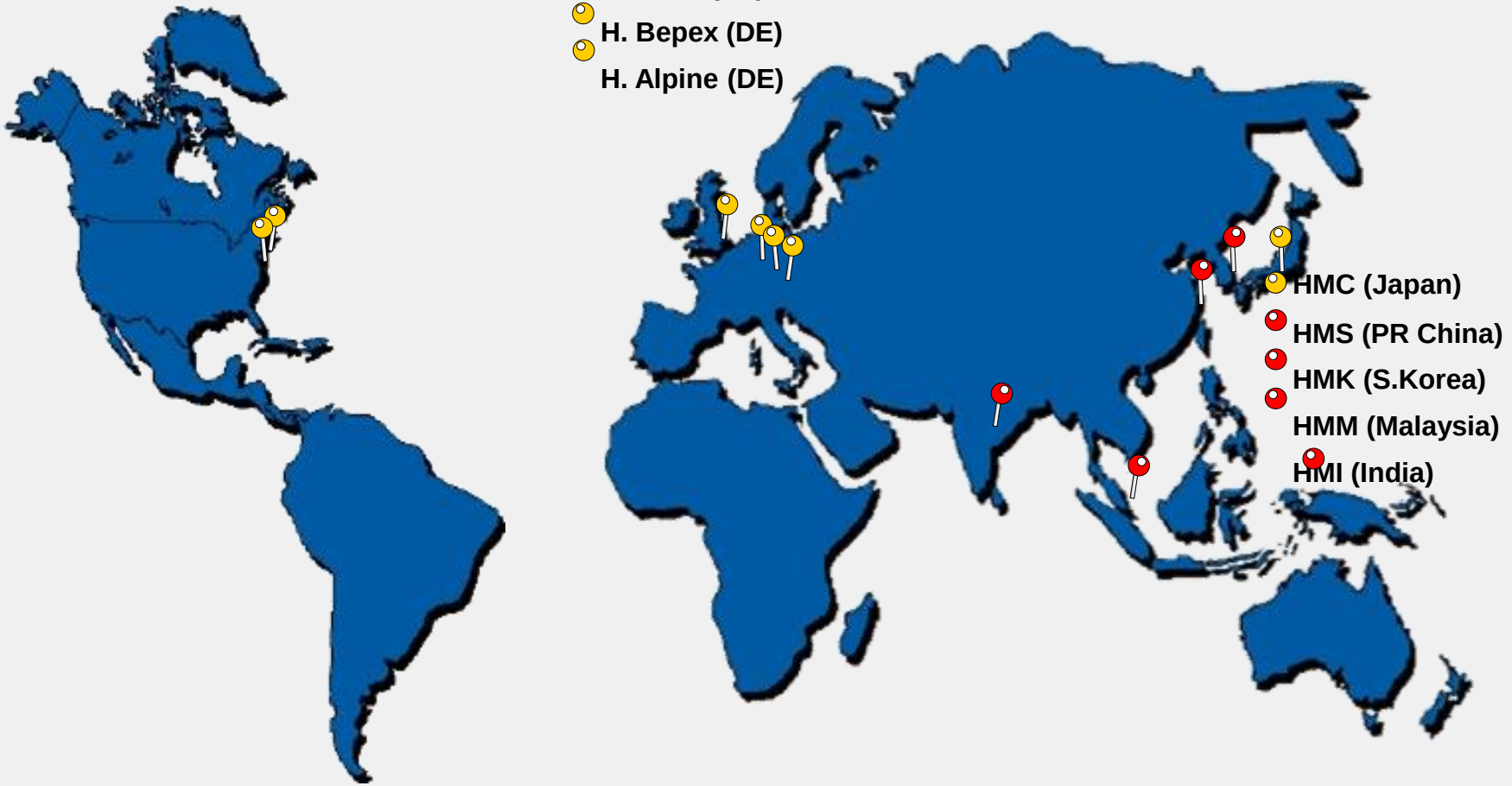
HM Powder Systems (USA)

HM Ltd. (UK)

HM B.V. (NL)

H. Bepex (DE)

H. Alpine (DE)



HMC (Japan)

HMS (PR China)

HMK (S.Korea)

HMM (Malaysia)

HMI (India)

Hosokawa Micron Powder Systems

Summit, NJ

- 1923: The Pulverizing Machinery Company founded (MPS).
- 1923: MPS developed the innovative Mikro-Pulverizer® hammermill .
- 1966: MPS invented the Mikro-ACM air classifier mill.
- 1986: Hosokawa Micron Corp. (Japan) acquired MPS.

- Hosokawa has over 100 years as the leader in powder processing technology
- Over 30 Hosokawa locations worldwide
- Multiple Technical Centers and R&D facilities worldwide

Hosokawa Polymer Systems

Located in Berlin, CT - USA
Foundation: 1961
Member:Hosokawa Group
1998
Over 20,000 Granulators sold

Basics of Size Reduction

- What is size reduction?
- What are the different mechanisms used?
- Types of milling technology
- When do I choose one type of size reduction method over another?
- What type of system is best suited for my application?

Feed Material and Product Specifications

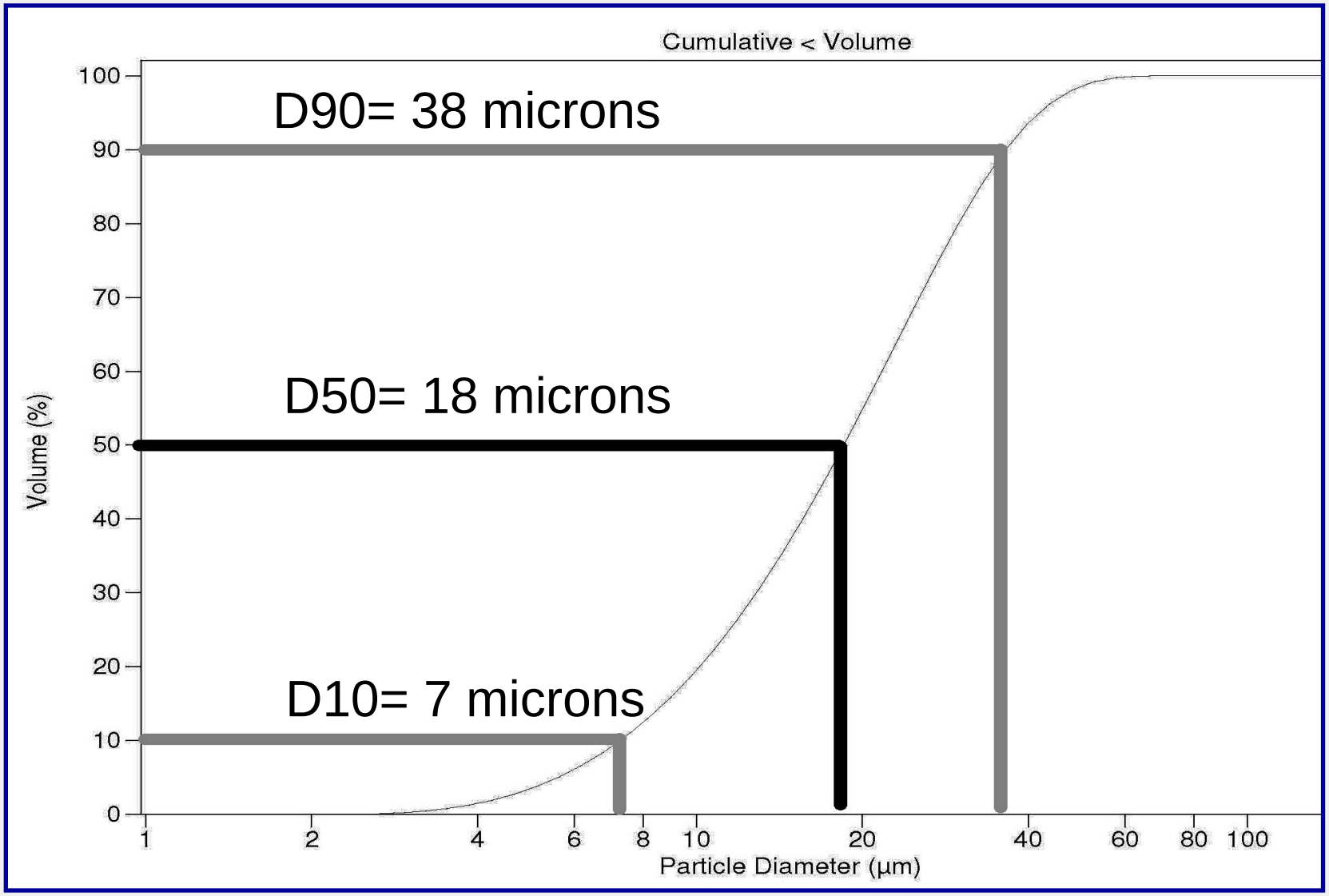
- Feed Size
- Bulk Density
- Cohesiveness (sticky, form agglomerates)
- Softening and Melting Points
  - Moisture, Fat or Wax Contents
- Hardness/Friability
  - Crystalline vs. Fibrous
- Particle Shape/Morphology
- Explosive Properties
- Product Particle Size Distribution (PSD)

Mohs Hardness Scale

Mohs Scale of Hardness for Minerals and Common Objects Test

Hardness Number	Mineral Example	Common Object Test
1	Talc	Can be scratched with fingernail.
2	Gypsum	Can be scratched with fingernail, but not easily.
3	Calcite	Can be scratched with copper penny.
4	Fluorite	Can be scratched with pocketknife. Will not scratch glass.
5	Apatite	Can be scratched with pocketknife, but not easily.
6	Feldspar	Can be scratched with edge of steel file. Cannot be scratched with pocketknife.
7	Quartz	Scratches glass.
8	Topaz	Scratches quartz.
9	Corundum (ruby or sapphire for example)	Scratches all minerals but diamond.
10	Diamond	Scratches all minerals. Can be scratched only by another diamond.

Particle Size Definition

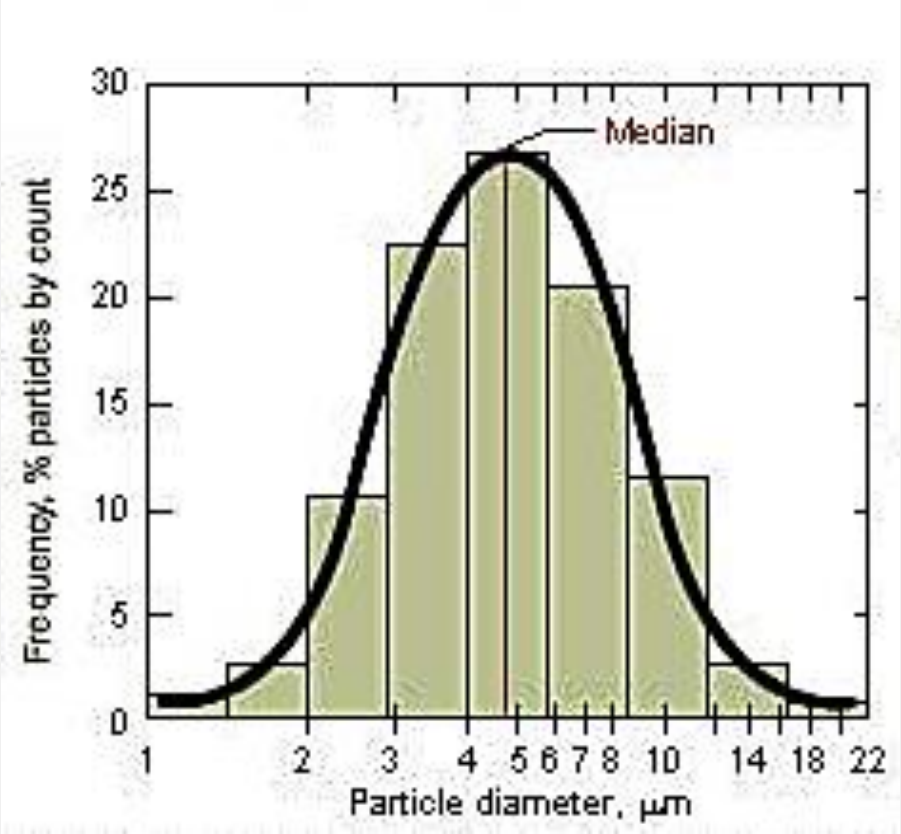


Particle Size Distribution (PSD)

Historgram showing particle size distribution by frequency

Median is defined as the diameter at which 50% of the particles are coarser and 50% are finer

Mean is defined as the average particle size.



Size Reduction Techniques

- **Shearing / Cutting**
- **Attrition**
- **Compression / Crushing**
- **Impact**

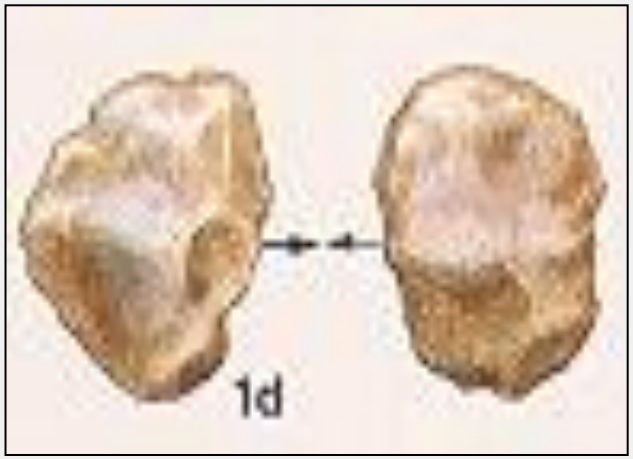
Shearing

Cutting or cleaving action

- Granulators
- Shredders

Attrition

Rubbing action between two particles or a particle and a surface in an opposing parallel motion

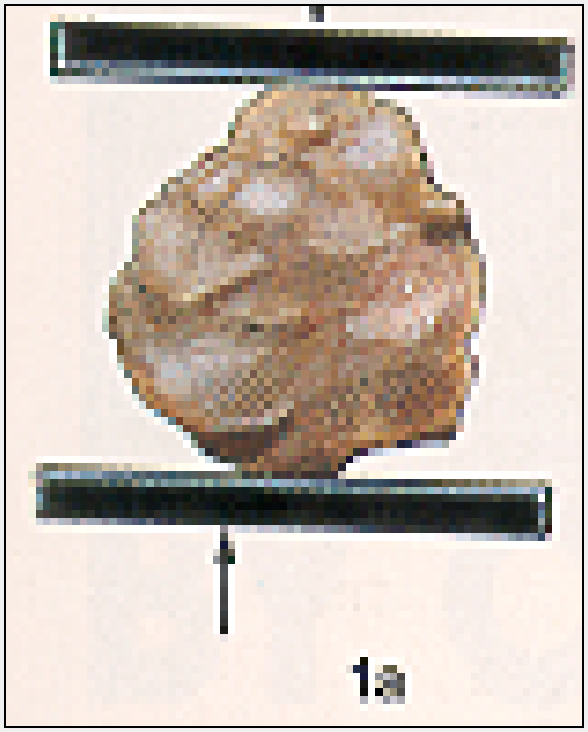


Commonly referred to as autogenous grinding:

- **Attrition Mills**
- **Gap Mills**

Compression

Pressing of a particle between two surfaces



Used primarily for coarse crushing & grinding:

- **Jaw crushers**
- **Cone Mills**
- **Flake Crushers**
- **Roller Mills**
- **Ball Mills**

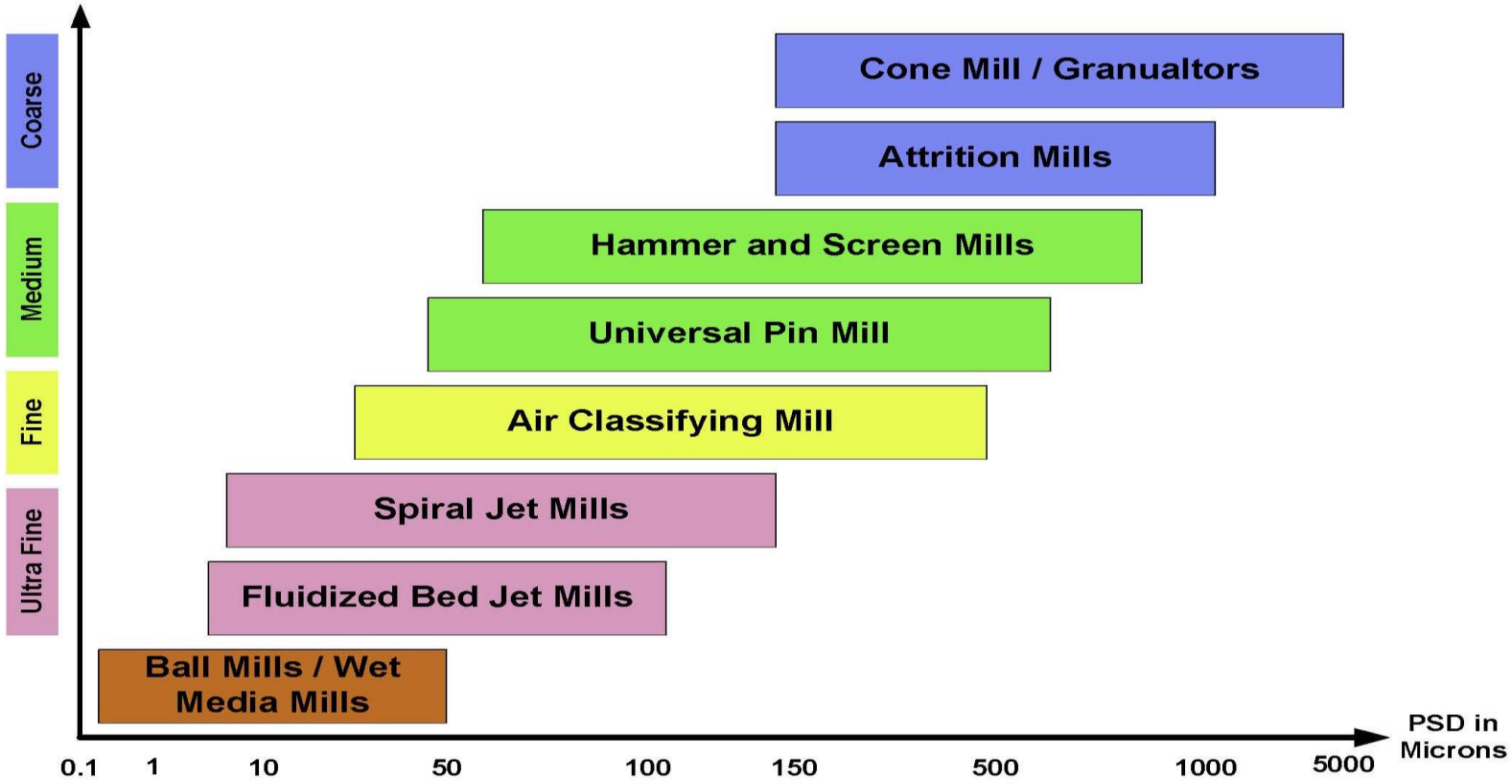
Impact

Sharp instantaneous blow from a moving body striking a particle

Impact Milling:

- Hammer Mills
- Pin Mills
- Air Classifier Mills
- Fluid Energy Jet Mills

Equipment Grinding Range



Hosokawa Polymer Systems

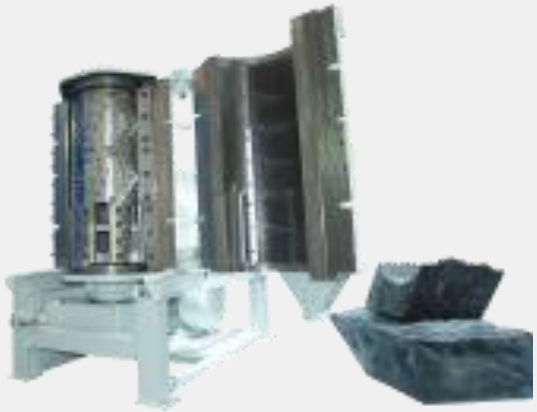
Recycling

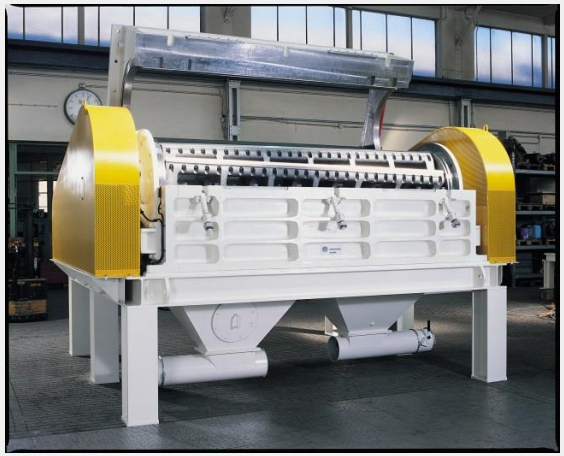
- Chemical
- Food
- Mineral
- Pharma

Shredders/Granulators

- Washing Lines
- Separation/Classifiers
- Attrition MIlls
- Compactors

Products





Granulators

Granulators are cutting (shearing) machines which reduce feed stock to a “REGRIND” via shear of internal knives and a sizing screen usually 4-25 mm

Ideal for: Plastics (rigid and flexible), fibers, rubbers, heat sensitive, soft – elastomeric material

Range: 2- 1000 HP

Capacity: 5-20,000 pph

End size: 3/16” – 1”

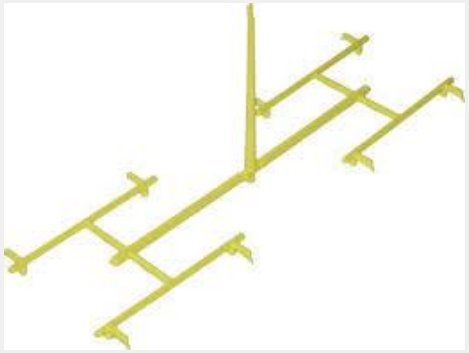
Tight knife gap (0.002”-0.012”)

RPM 250-1000

Gravity feed, airflow (5000-6000 fpm)

Granulators Applications

Injection molding – Parts, runners
Blow molding – Flash, bad parts
Extrusion - Trim, line breaks, reject pipe, profile
Recyclers – post industrial



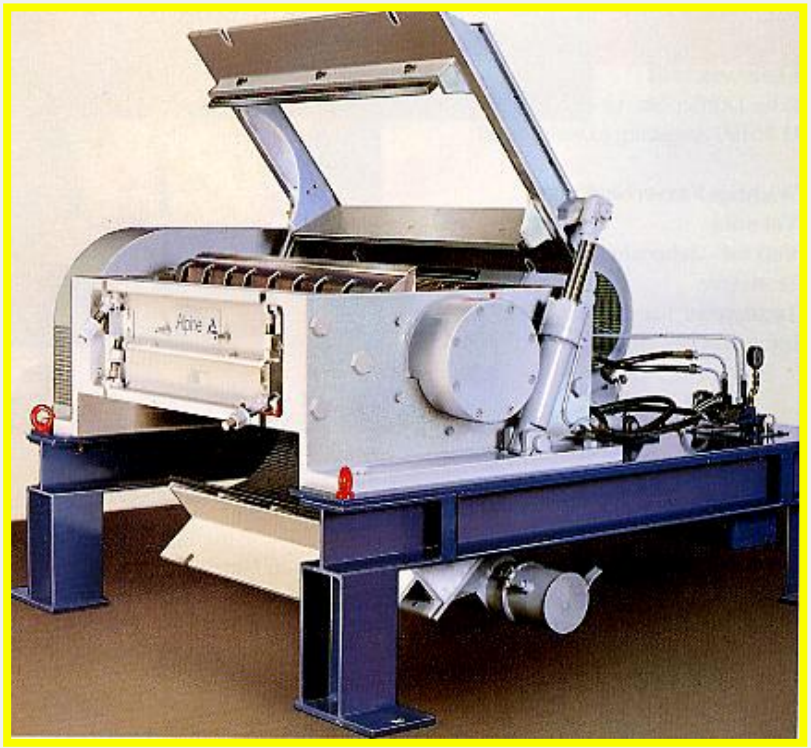
Post consumer recycling:

PET, HDPE bales
Film bales, rolls
Feed for Chemical and Pyrolysis recycling

Granulators

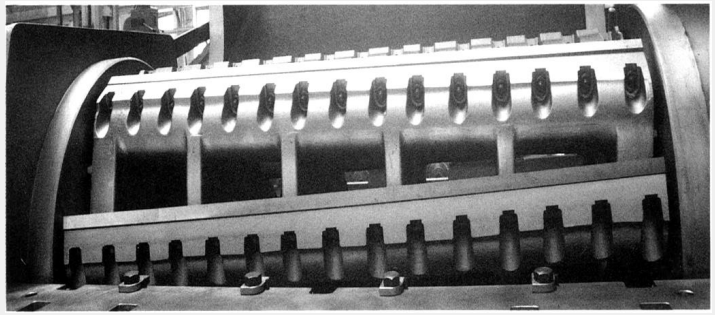
- Slow Speed 2 - 7.5 Hp
- Press-Side 5 - 25 Hp
- Low Line 5 - 20 Hp
- Auger 5 - 15 Hp
- Hot Melt HMG 5- 50 Hp
- Rollfeed 10 -100 Hp
- Large Part 20 - 40 Hp
- Premium Shurfeed 20 - 40 Hp
- Shurfeed 50 -100 Hp
- DGH 50- 250 Hp
- DGP – Profile 30-150 Hp
- DGF 50-200 Hp
- Heavy Duty 50 -200 Hp
- Rotoplex 50 -600 Hp
- CL 75 -400 Hp

Over 100 models to meet any need



Knife Geometry

Double Angle Cut

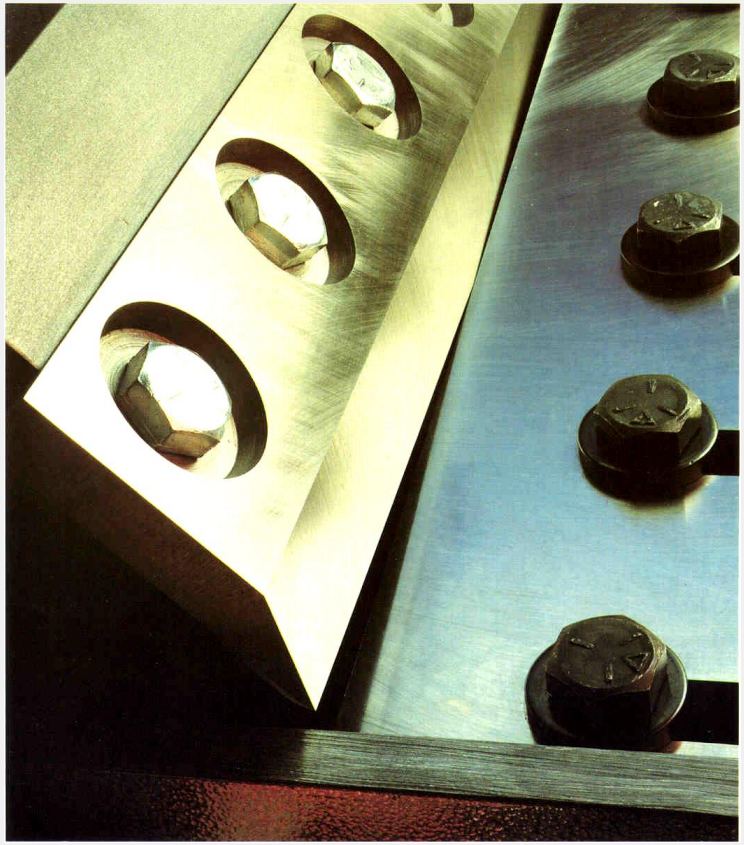


Cross Scissor Cut

Chevron Cut

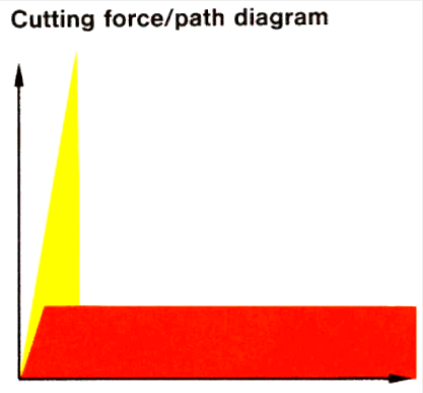
Double Angle Cut™

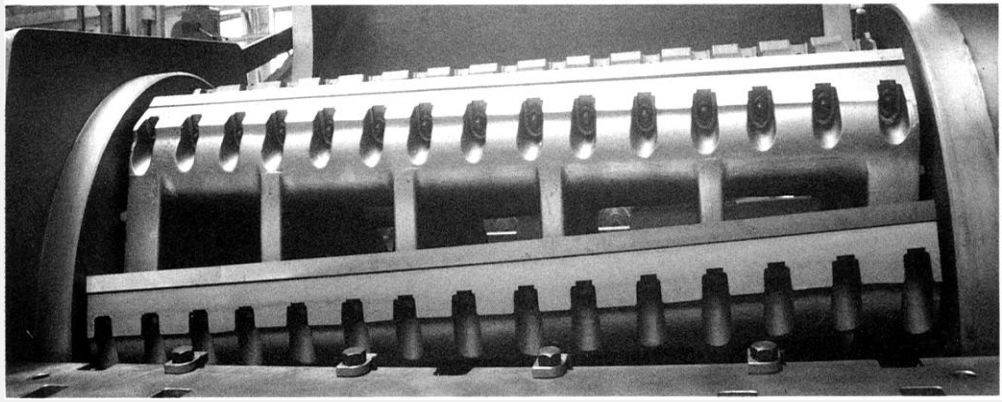
- Revolutionized granulator cutting action
  - Both knives are angled
  - Produces consistent tight knife gap
  - This means more cutting, less tearing
  - Concentrates all forces at one point
  - Maximizes efficient power use
  - Smooth grinding increases bearing life



Patented Cross-Scissor-Cut

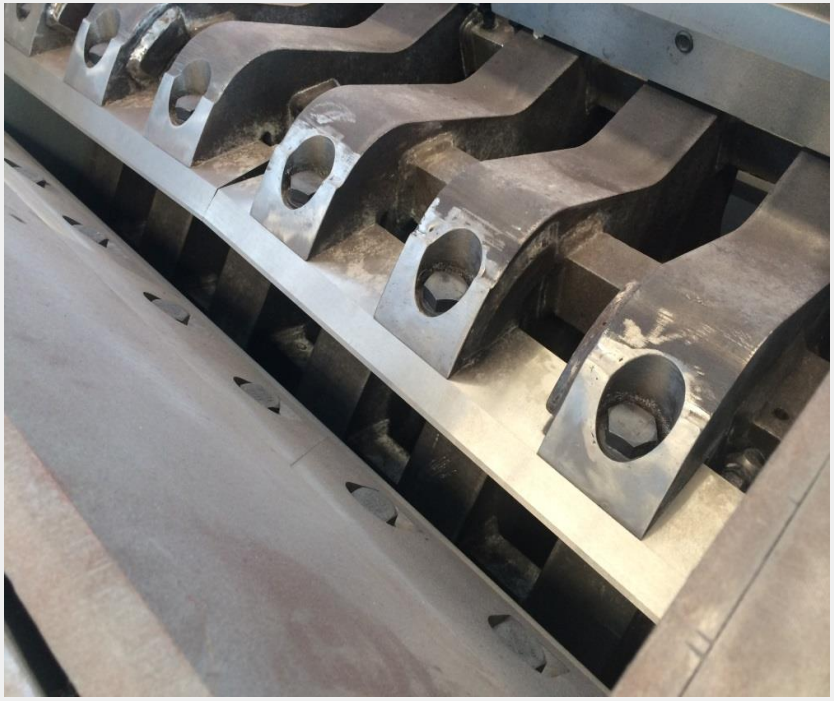
- Patented technology
- Helical rotor knife rows
- Produces consistent knife gap
- Alternate rotor angle direction
- for even material distribution
- Concentrates all forces at one point-maximum tip force
- Maximizes efficient power use





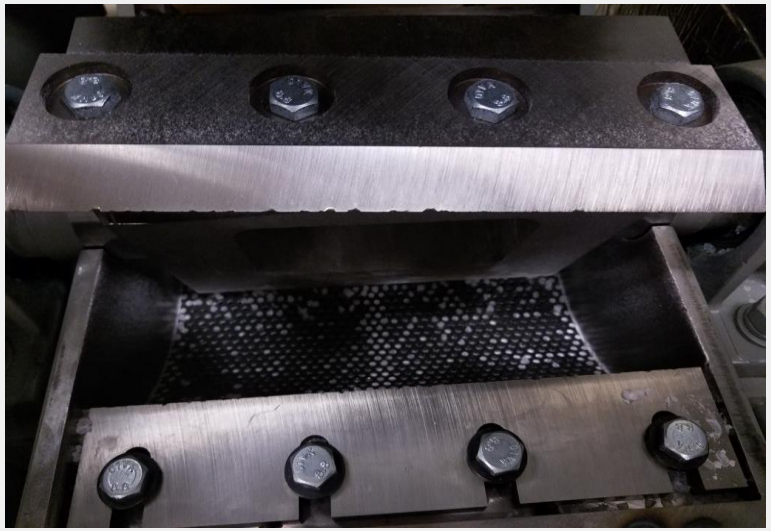
Chrevron Cut

- Similar to a double angle cut (DAC)
  - Twin rotor angles
  - Produces consistent tight knife gap
  - This means more cutting, less tearing
  - Concentrates all forces at one point
  - Maximizes efficient power use
  - Smooth grinding increases bearing life



Shearing, Cutting Action

- Granulator
- Temperature – cooling
- Smearing - anglehair
- Knife style
- Gap, Wear, Damage
- Screen area
- % open area, overall area
- Holes cleaned
- Evacuation
- Cooling, velocity, elbows
- Cyclones – vacuum
- paper under fine charged
- Deionizer only…
- Conveying
- Distance, velocity
- Travel by rail long way.



Granulator Chamber Geometry

Top feed

The rotor is positioned in the center of the chamber and the feed drops in on top of the rotor.

Tangential

This type of chamber has the rotor offset from the chamber top opening. The material enters into the tangential "bellows" and falls into the down stoke of the rotor circle. (The circle made by the rotor knife tip)

Semi - Tangential

A moderation of the Tangential. Tilting of top feed chamber, offset hopper on top feed…

Profile

Given the name "profile" because if can take long parts "profiles". This is more a hopper change and the chamber is still one fo the above.

Feed Roll

Using one of the above, adding a feed foll to automatically take film, sheet, fibers.. In a controlled manor into the cutting chamber.

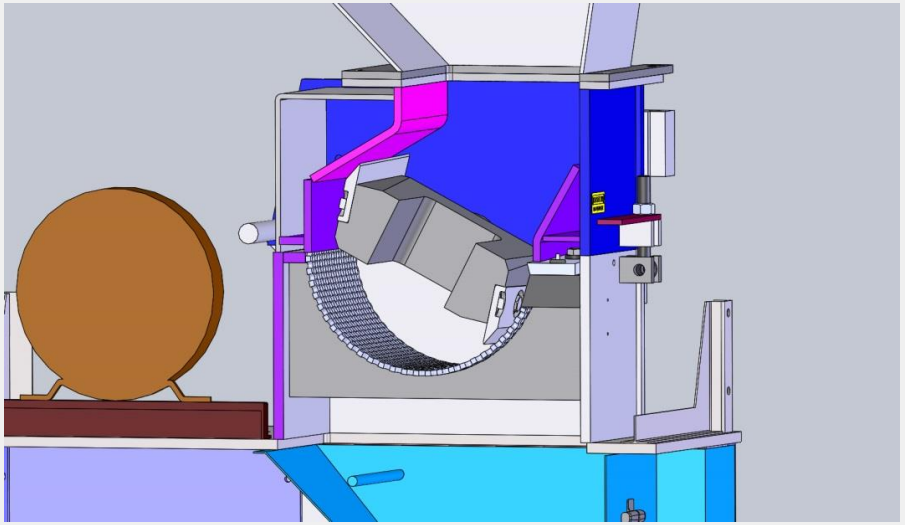
Granulator Chamber Geometry

Top feed

The rotor is positioned in the center of the chamber and the feed drops in on top of the rotor.

Multipurpose
Best for parts, runner < ½ Diameter
Using gravity
Allows larger screen area
- **material evacuated faster – less fines**
- **runs cooler**
- **higher capacity**

Not ideal for larger, volumous parts
- **Can bounce**



Granulator Chamber Geometry

Tangential

This type of chamber has the rotor offset from the chamber top opening. The material enters into the tangential "bellows" and falls into the down stoke of the rotor circle. (The circle made by the rotor knife tip)

Ideal for volumous parts

Buckets, bottles, bumpers

Parts fall into the down stroke of the rotor knife

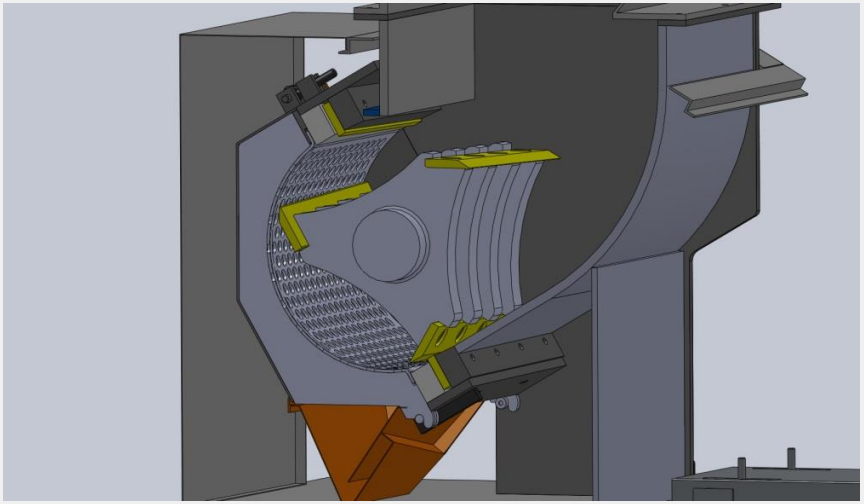
Uses centrifugal forces

Usually have less screen area

Fights gravity

Genate a little more dust

Terrable for purgings



Granulator Chamber Geometry

Semi – Tangential

A moderation of the Tangential.
Tilting of top feed chamber, offset hopper on top feed…

Partial benefits of top and tangential
Gas tanks, large cans, bumpers…
Still has large screen area
Can take heavier parts

Granulator Chamber Geometry

Profile

Given the name "profile" because if can take long parts "profiles". This is more a hopper change and the chamber is still one of the above, usually – top feed.

There are many types of profile configurations

They all should have the material enter on the down stroke of the knives

Hoppers and also allow for profile grinding on general purpose granulators

Granulator Chamber Geometry

Feed Roll

Using one of the above, adding a feed roll to automatically take film, sheet, fibers.. In a controlled manor into the cutting chamber.

Used for sheet, film in online or offline recycling
Feeding should be in front of rotor, not over rotor

Over the rotor can lead to tugging


POLYMER SYSTEMS
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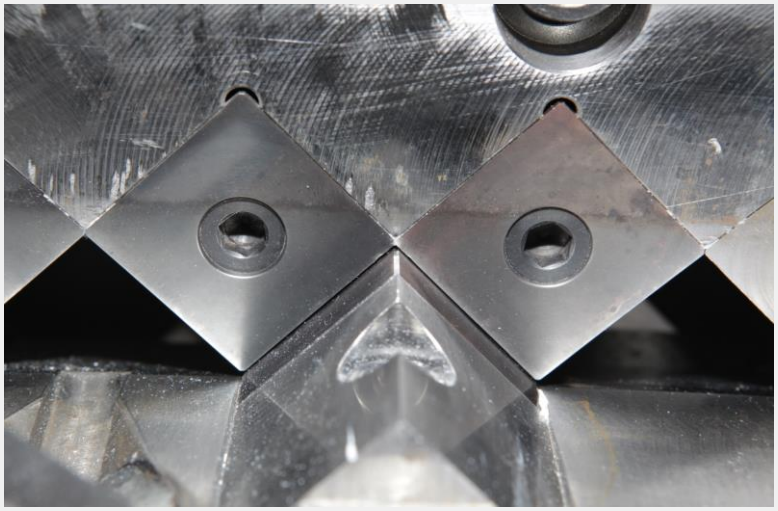
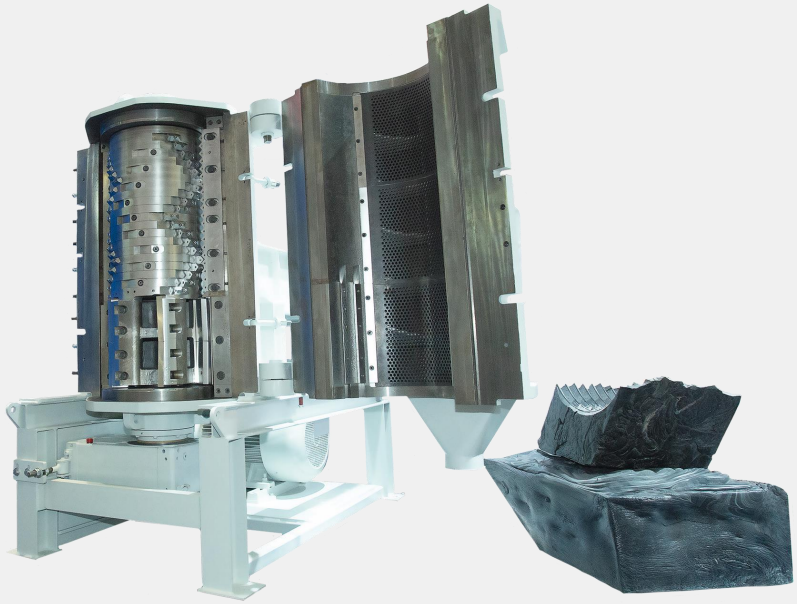
POLYMER SYSTEMS
ALPINE
COMPACT-Lin


POLYMER SYSTEMS

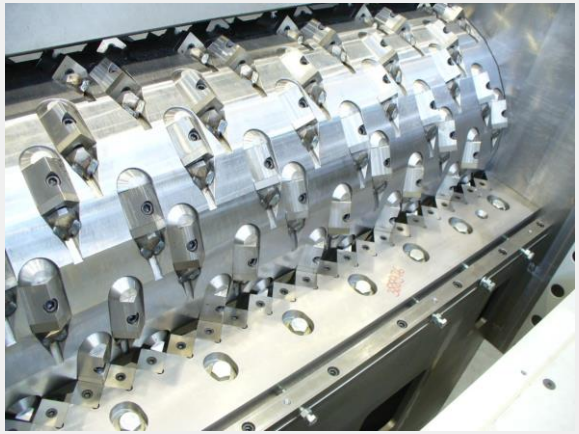

POLYMER SYSTEMS

Shredders





Types of Shredders



Single Shaft

Dual Shaft

Screw

Quad Shaft

Shredders

Shredders are heavy duty cutting machines designed to shear large tough plastics, metals, wood and other feed. Usually a primary step in recycling.

Ideal for: Plastics (rigid and flexible), wood, rubbers,

Range: 20- 1000 HP

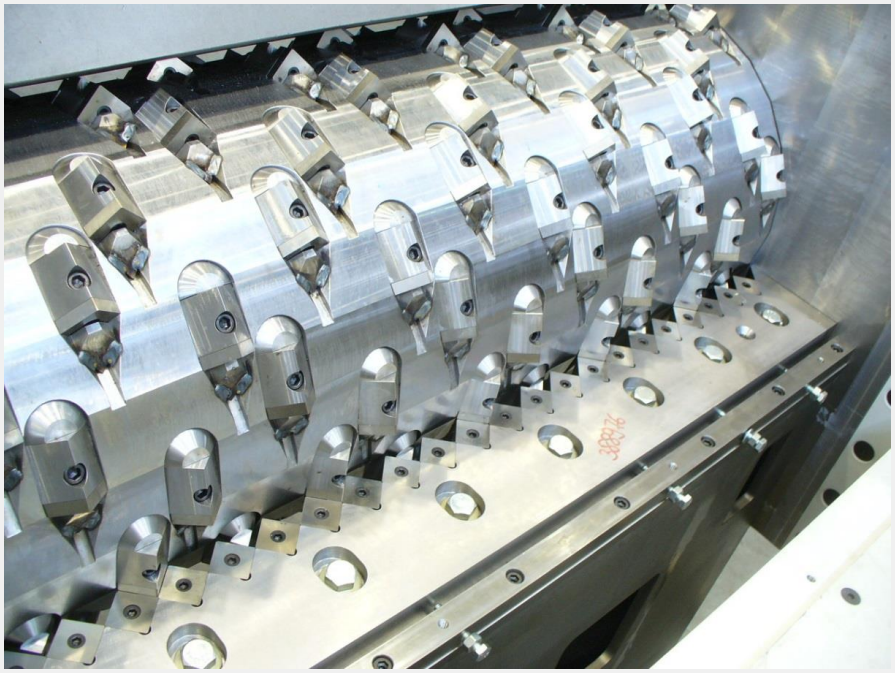
Capacity: 5-20,000 pph or more

End size: 2”-4” Sometimes less

Tight knife gap (0.015”-0.125”)

RPM 50-150

Gravity feed, forece ram feed, gravity discharge or screw or conveyor



Shredder Applications

Injection molding – Parts, runners
Blow molding – Purge, large parts
Extrusion – Film bales, rolls, reject pipe, WPC
Recyclers – post industrial

Post consumer recycling:

PET, HDPE bales
Film bales, rolls
Feed for Chemical and Pyrolysis recycling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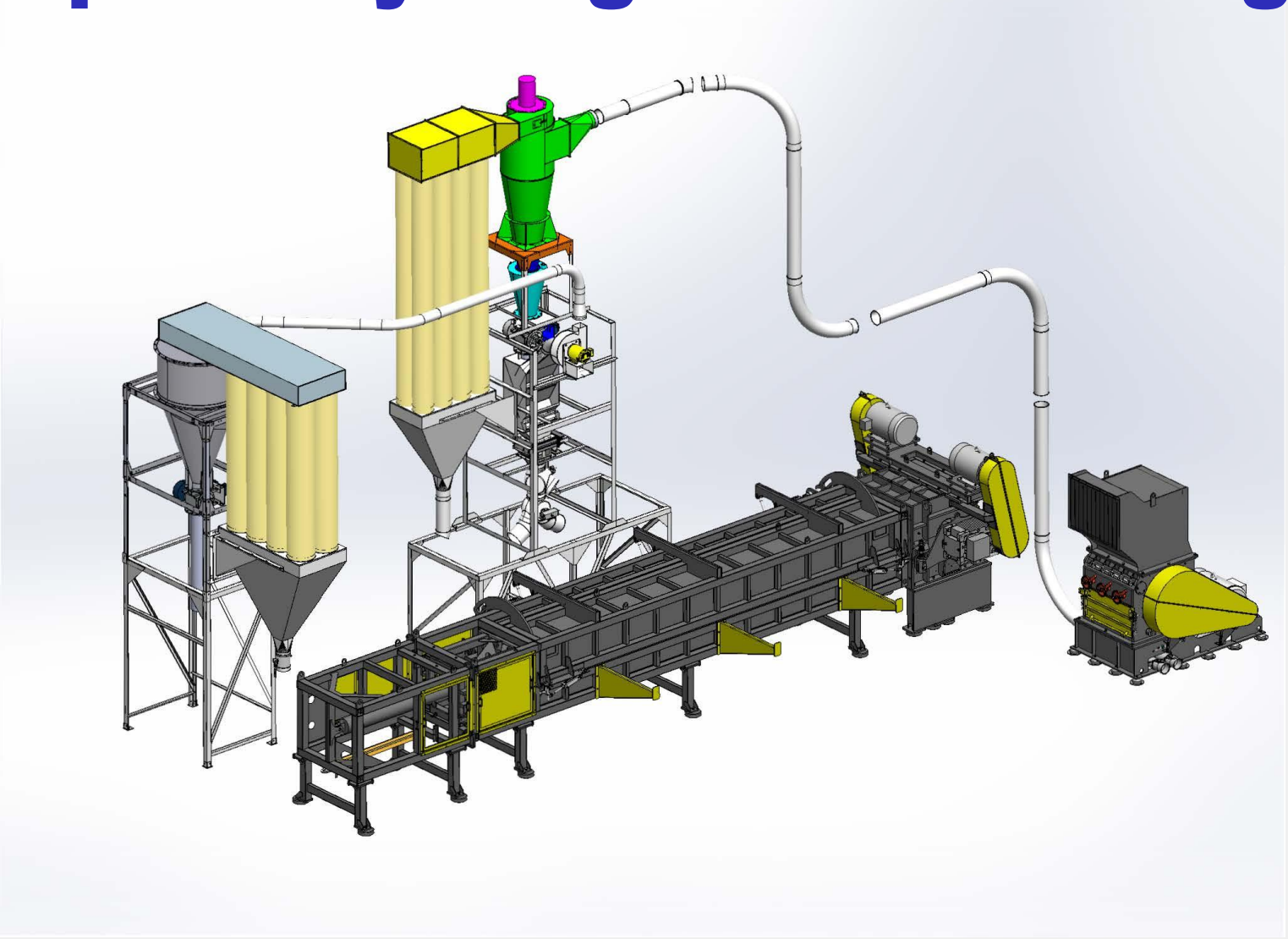
Pipe Shredders

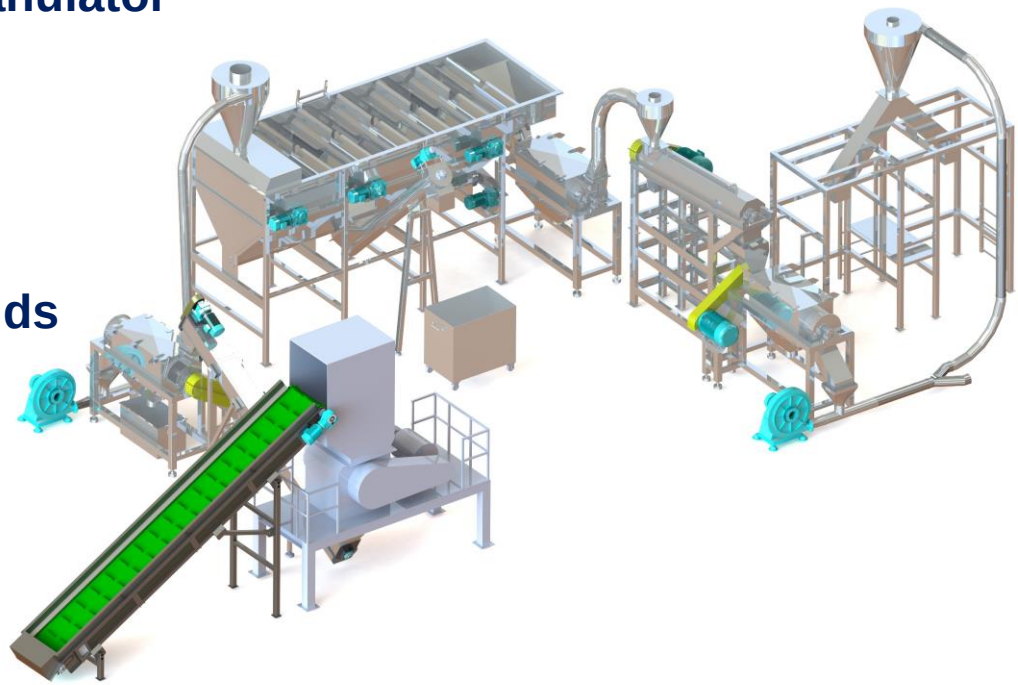
Pipe Recycling and dedusting



Polyplex – All in One

Washing lines

- Shredder, Wet Granulator
- Friction Washer
- Sink Float Tanks
- Delablers
- Debalers
- Spinner – film, rigids
- Dedusting
- Film Squeezer
- Hot Tanks



Washing lines

Function

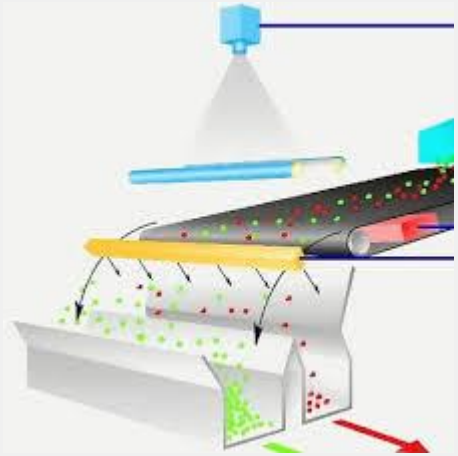
To transform dirty plastics to Clean useable regrind or pellets

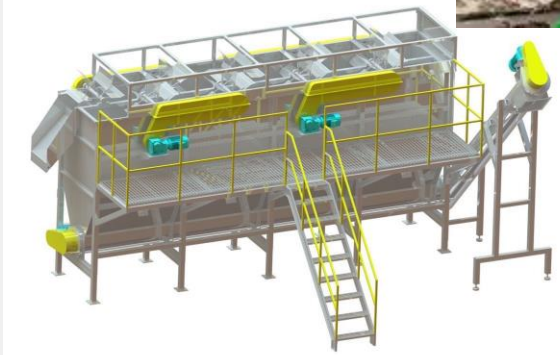
Separation

End product

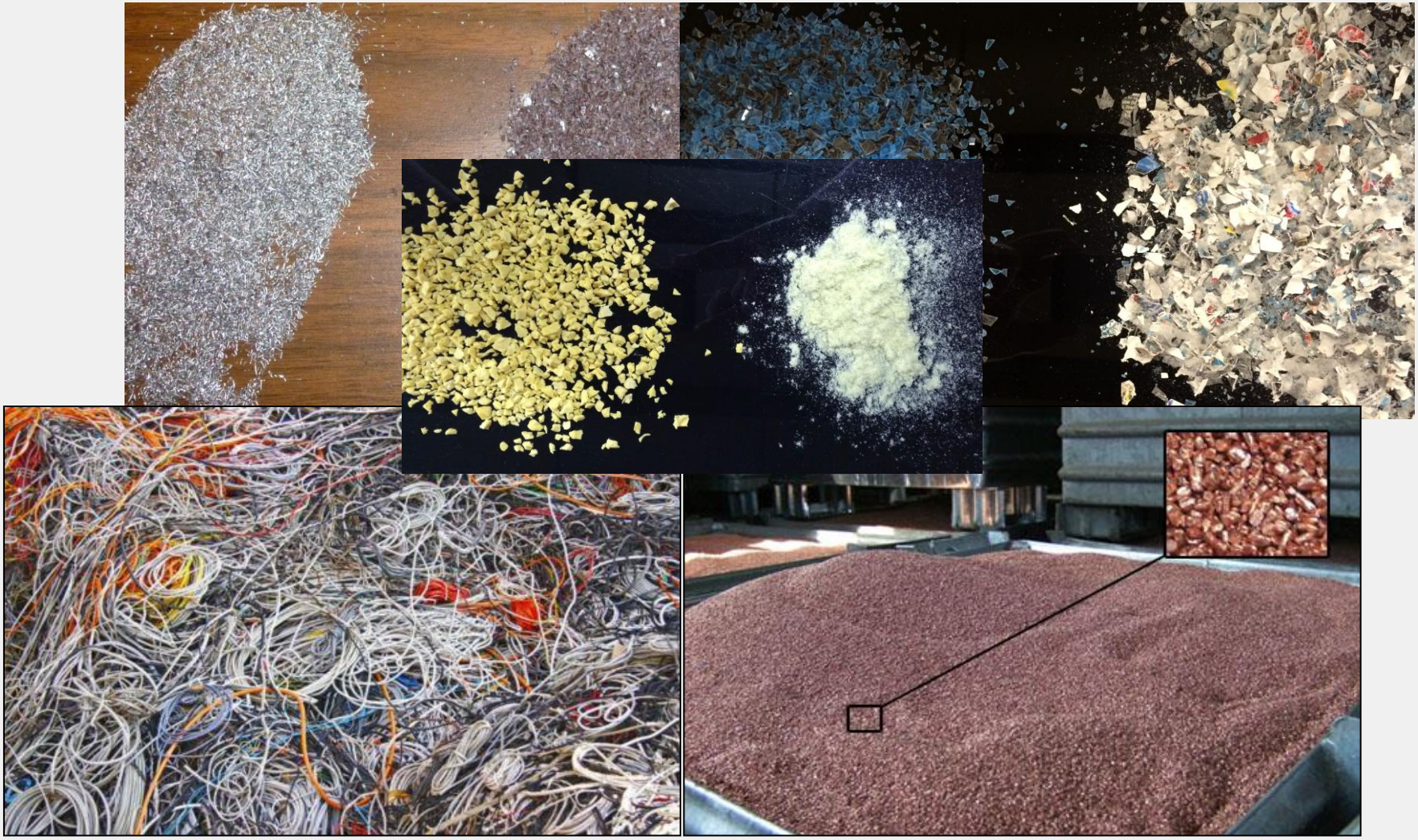
Dedusting, Screening, sep tables, sink float tank, electrostatic sep, eddy current

Feed
Optical sort
Robotic sort
Manual sort



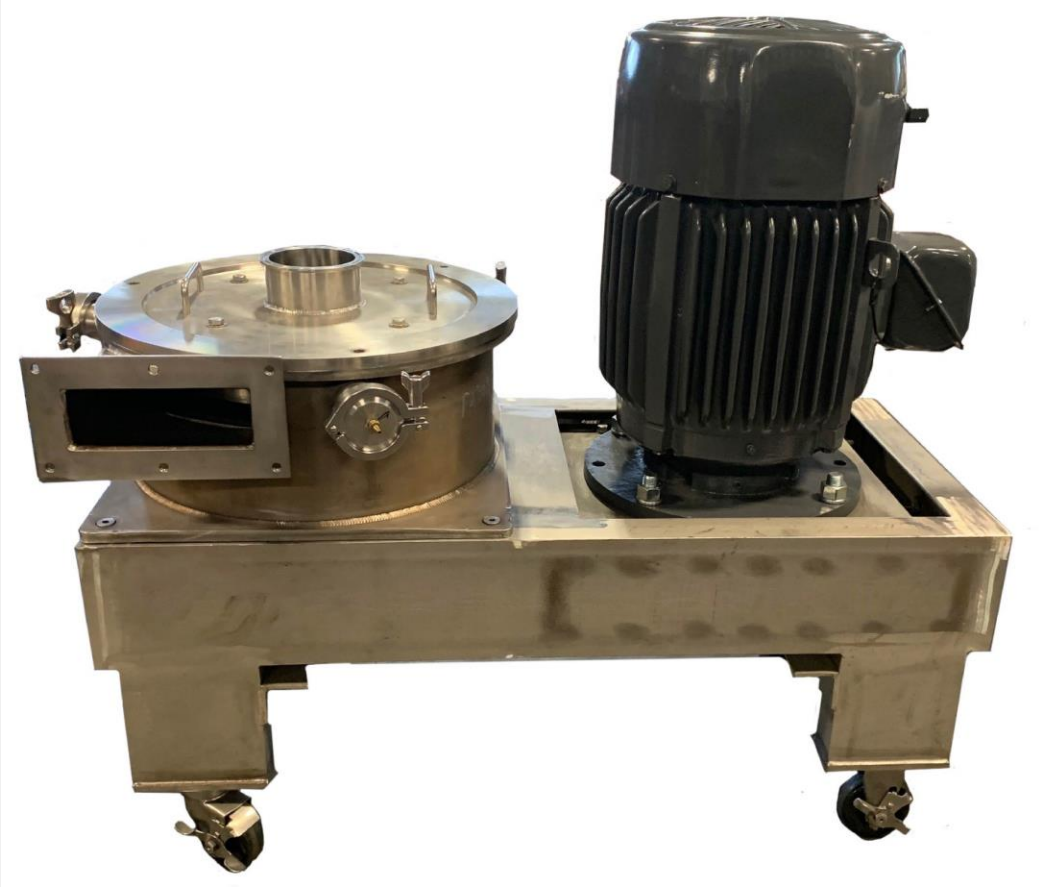


Fine Grinding of Polymers



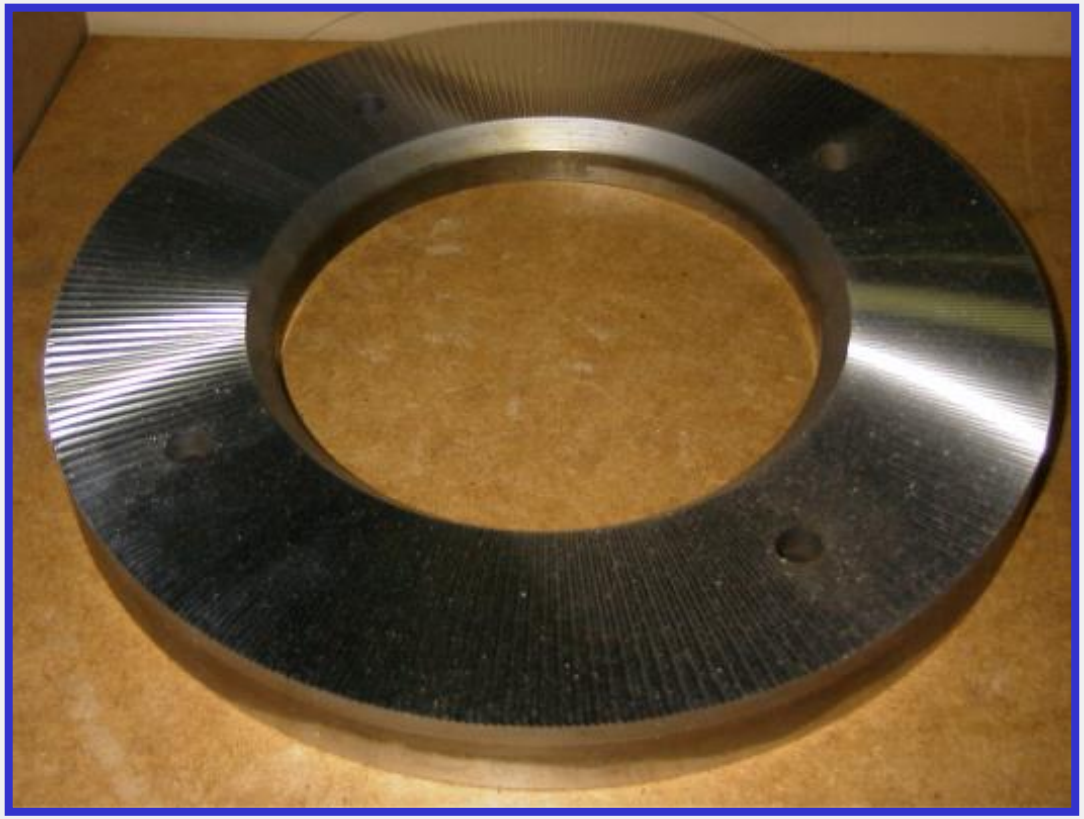
Attrition Milling

- Milling Mechanism: Shear
- Plastics / Polymers
- Advantages: High capacity, low heat,
- Easy to clean
- Cryogenic compatible



Attrition Milling

Serrated Discs



Attrition Mill Applications

Main Application

PVC-Fine Grinding - Inhouse Recycling

Typical fineness: between 600 - 1200 µm

- **window profiles, electrical channels (precut scrap material)**
- **pipes (precut scrap material)**

Production of PE- Powder for Rotation Moulding Application

Feed material: mainly original PE granule material

Typical fineness: approx. d_{50} < 300 microns, max. 700 microns

Other Applications:

Generally all other types of plastics, also softer materials or even foamed plastics, like expanded polystyrene.

Requirement: The feed material must be free of impurities, specifically no metalic parts.

Attrition Milling

V-UMP Mill Brochure

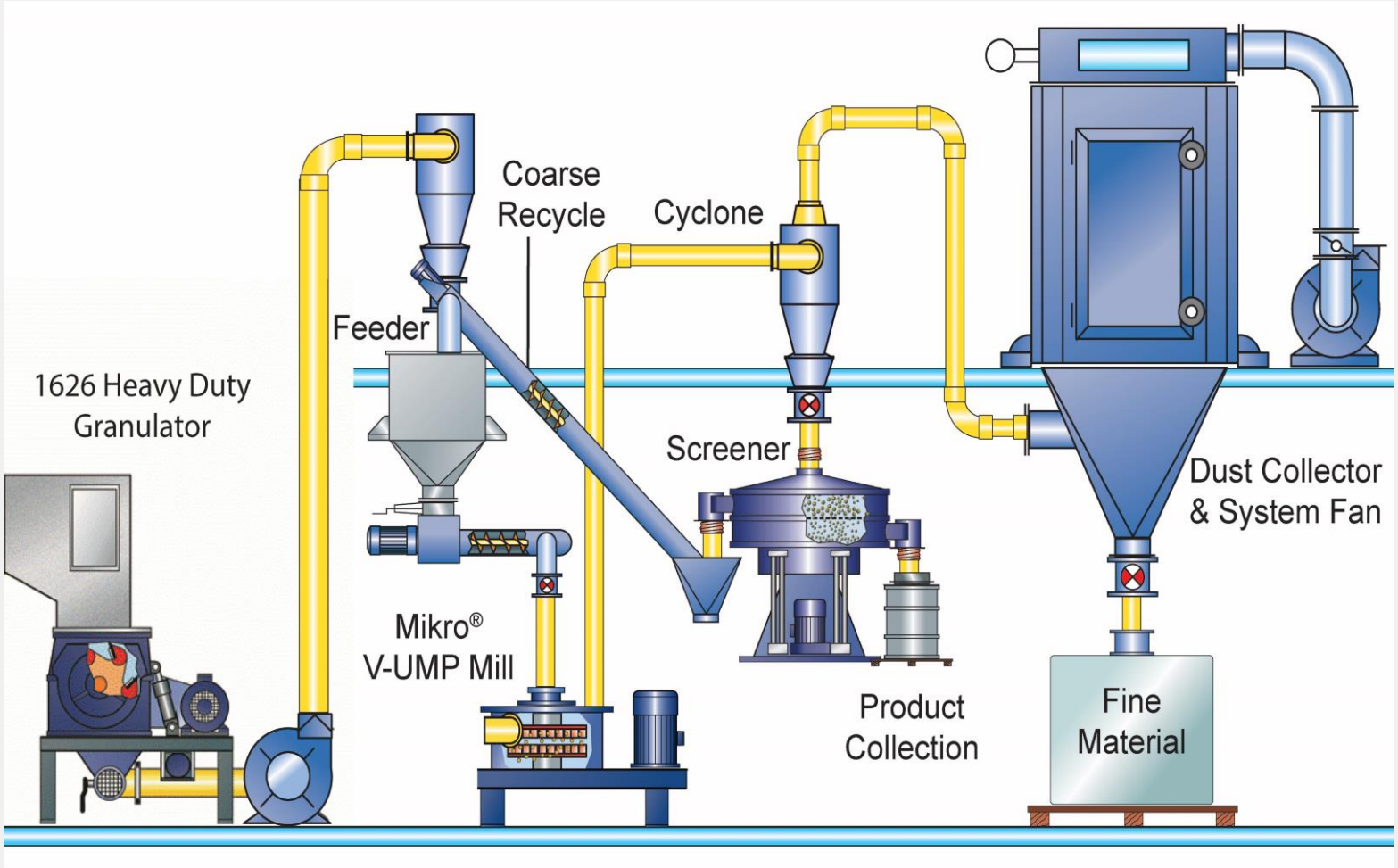
Common Materials Processed	Industries Served
High Density Polyesthylene (HDPE)	Medical
Low Density Polyethylene (LDPE)	Automotive
Polycarbonate (PC)	Airline & Aerospace
Polypheylene Sulfide (PES)	Marine
Polyetherketoneketone (PEKK)	Electrical & Electronics
Polyetheretherketone (PEEK)	Industrial Coatings
Polyvinylidene Fluoride (PVDF)	Sports Equipment
Liquid Crystal Polymer (LCP)	Building Materials
Polyetherimides (Nylon)	Recycling
Polypropylene (PP)	Packaging
Polystyrene (PS)	Appliances
Polyvinyl Alcohol (PVOH)	Textiles
Polyethylene Teraphthalate (PET)	Consumer Products
Acrylonitrile Butadiene Styrene (ABS)	Food
Polyvinyl Chloride (PVC)	3D Printing
Ethylene Vinyl Acetate (EVA)	Rotational Molding
Nitrile Rubber (NBR)	Compression Molding
Ethylene Propylene Diene Monomer Rubber (EPDM)	Chemical Recycling
Thermoplastic Polyurethane (TPU)	Pyrolosis Recycling
Polyurethane (PU)	
And Many Others	

Processing Results

Material	Product
Attrition Plates speeds up to 150 meters/second	
Polypropylene (PP)	97% < 297 µm
Polyethylene (HDPE)	97% < 212 µm
Polycarbonate (PC)	97% < 297 µm
Polyvinyl Chloride (PVC)	97% < 297 µm
Thermoplastic Polyurethane (TPU)	97% < 212 µm
Polyamide (PA) Nylon	97% < 297 µm
Polyetherketone (PEEK)	99% < 74 µm
Liquid Crystal Polymer (LCP)	97% < 106 µm
Ethylene Vinyl Alcohol (EVA)	97% < 250 µm
Acrylonitrile Butadiene Styrene (ABS)	97% < 250 µm
Polystyrene (PS)	97% < 250 µm

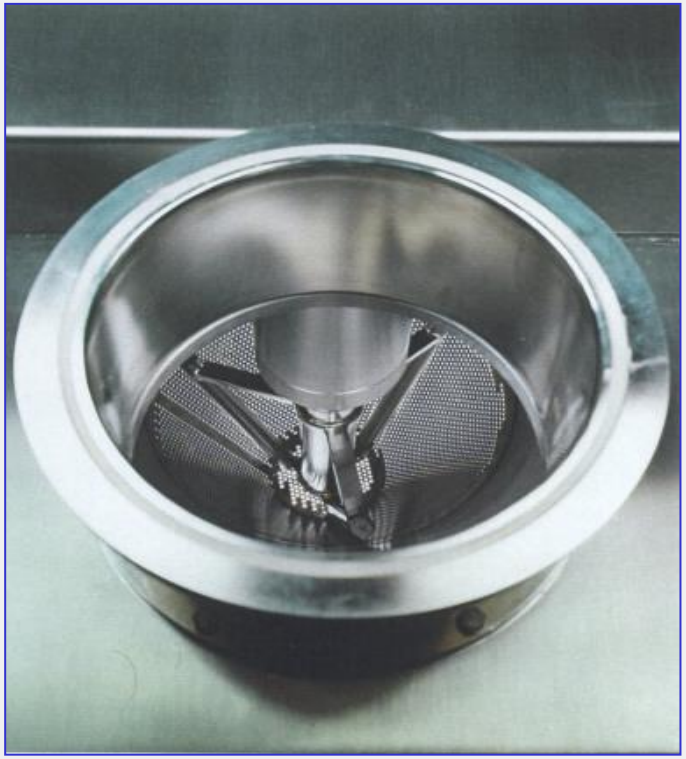
Results based on 4-5 mm pellet feed stock. Capacities & fineness achieved is material & grade specific. Data provided in this chart is a guideline only & does not represent a performance guarantee.

Fine Grinding System



Cone Mill & Flake Crusher

- Particles are compressed against a screen wall by means of a rotating bar or rotor.
- Size reduction is caused by forcing material through a screen or perforated plate and some slight inter-particle collisions.
- Generally low to medium tip speeds.
- Narrow PSD, between 5mm-150 micron with minimal generation of fines.



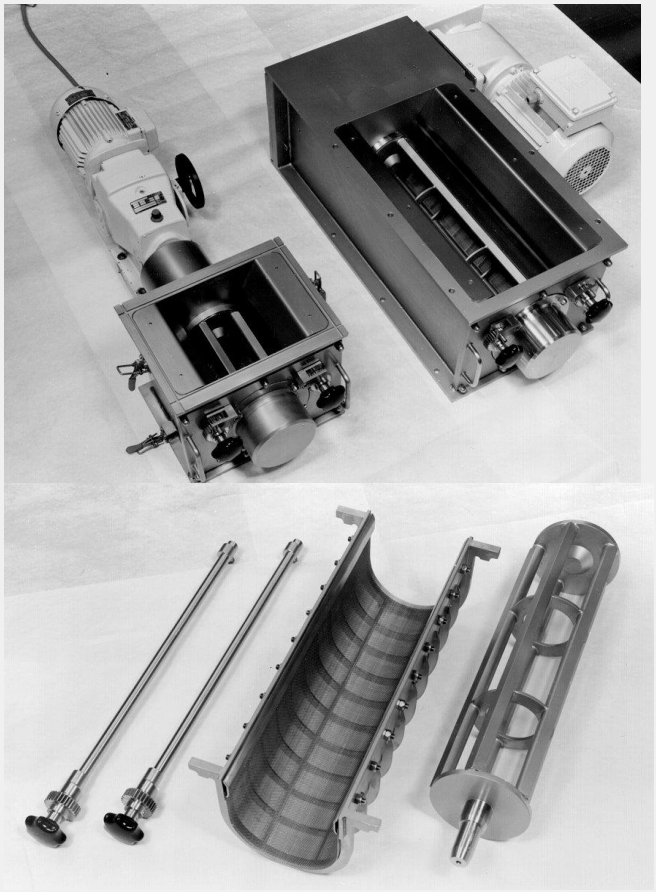
Cone Mill

Cone Mill & Flake Crusher

- Suitable for heat-sensitive materials
- Suitable for friable and soft materials (up to Moh's Hardness of 4)
- Particle size is controlled by screen size, rotor shape and rotor speed and gap
- Compression Principle

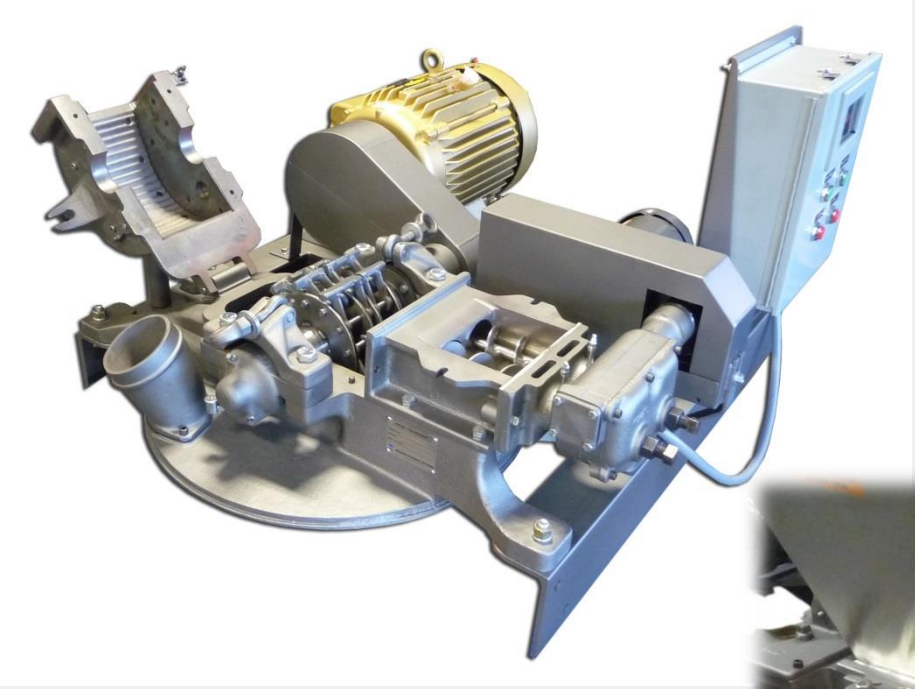
Cone Mills & Flake Crushers

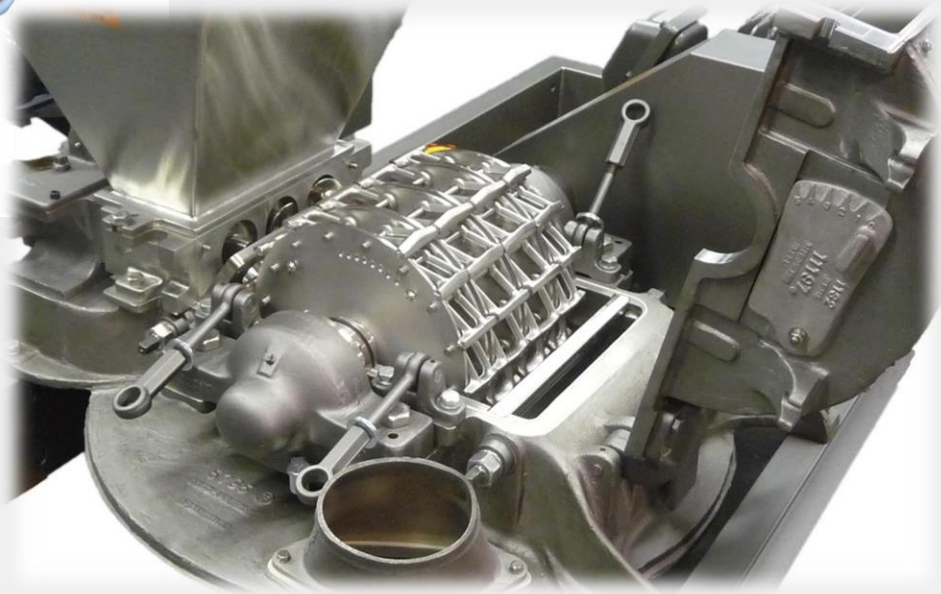
- Particles are compressed against a screen wall by means of a rotating bar or rotor
- Particle size is controlled by Screen size, type and rotor speed.
- Produces narrow PSD
- Granular end products to 200 um
- Typically used in conjunction with roller compactors
- Compression principle



Flake Crusher

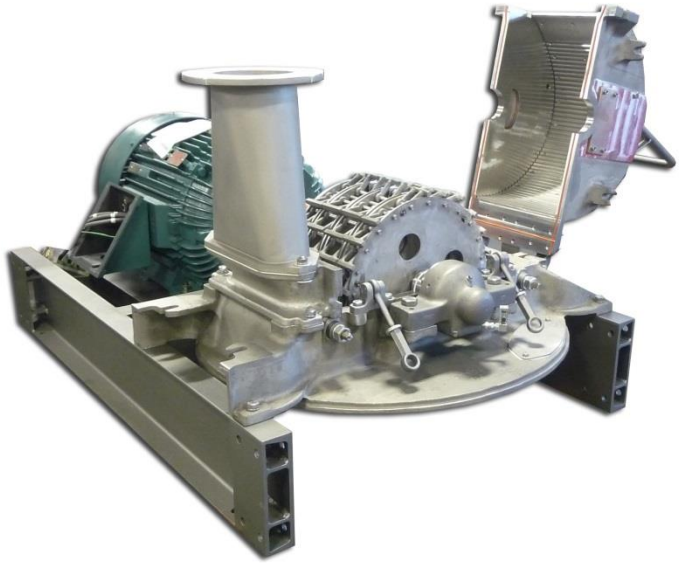
Hammer Mill / Mikropulverizer





Mikropulverizer

- Pre-grinding / De-agglomeration
- Medium to Fine Size Reduction
- Good Top Size and PSD Control
- Multiple Mill Configurations for Flexibility in Many Applications
- Economical / Low Maintenance



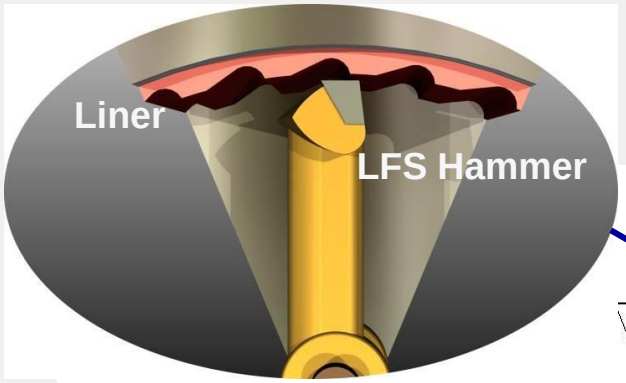
Mikropulverizer

- High tip speed (100 m /sec, 20,000 fpm) produce a high degree of fines.
- High Energy, can have a high temperature rise, not suitable for very heat sensitive material.
- Good top size control due to internal screen but also prone to plugging with oily or waxy materials.
- Not suitable for hard or abrasive materials > 3.5 Mohs and > 0.5% silica.

Mikro Pulverizer® Hammer & Screen Mill
Model MP #3 in Stainless Steel

Stress Mechanism Approx.
80% Impact, and 20% Shear

How it Works



Feed Hopper

Cover

Air Inlets

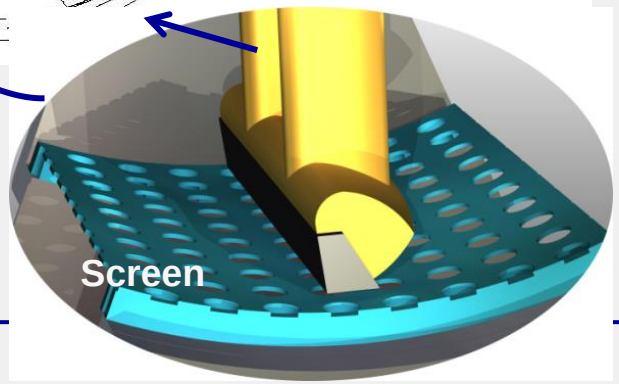
Liner

Main Body

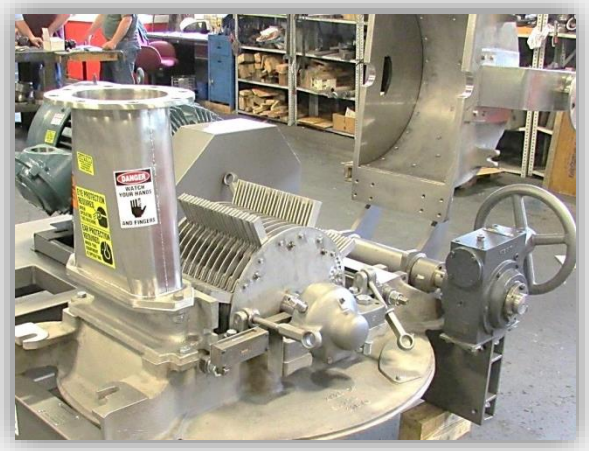
Direction of Rotation

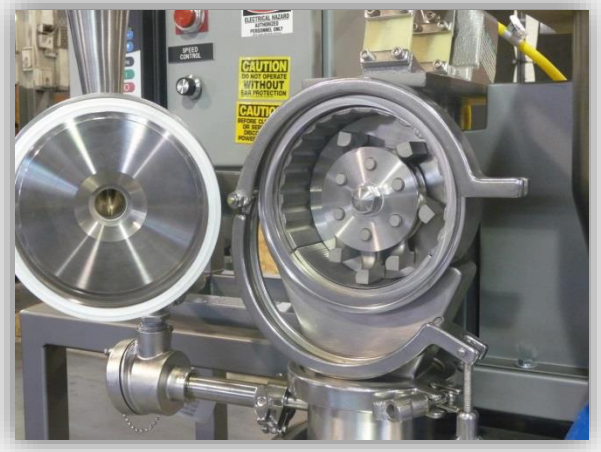
Screen locking cam

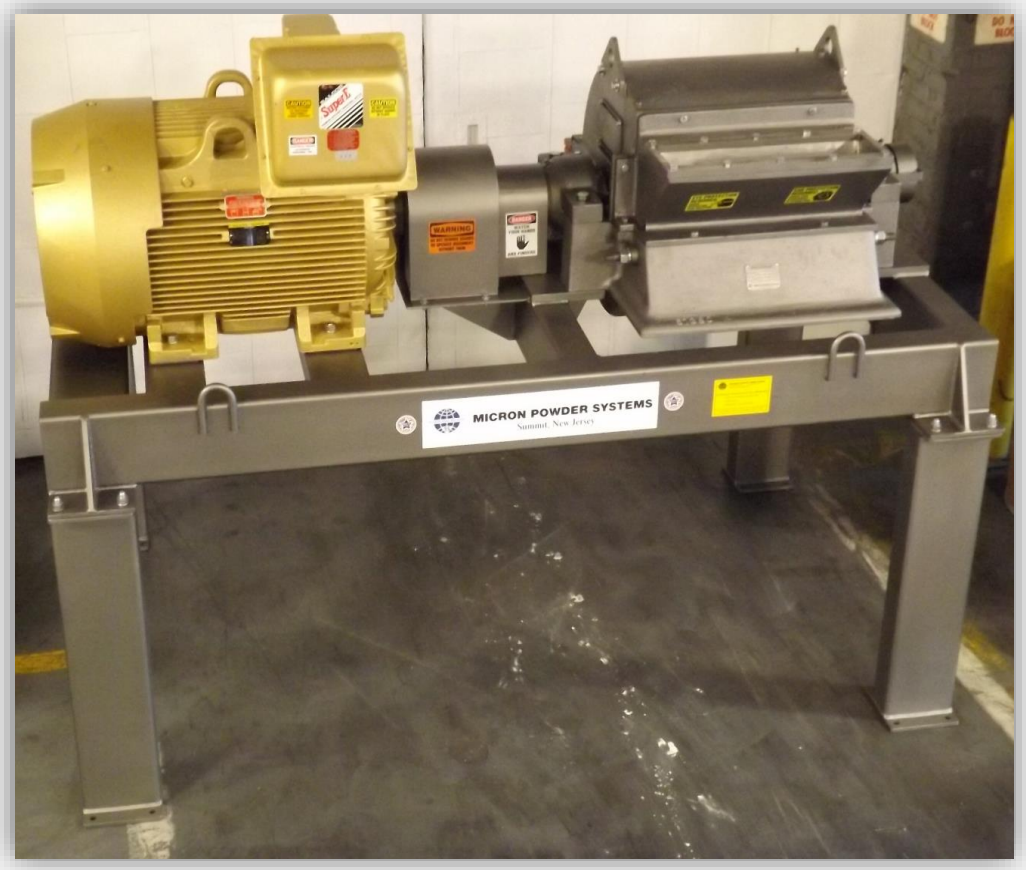
Elevation View



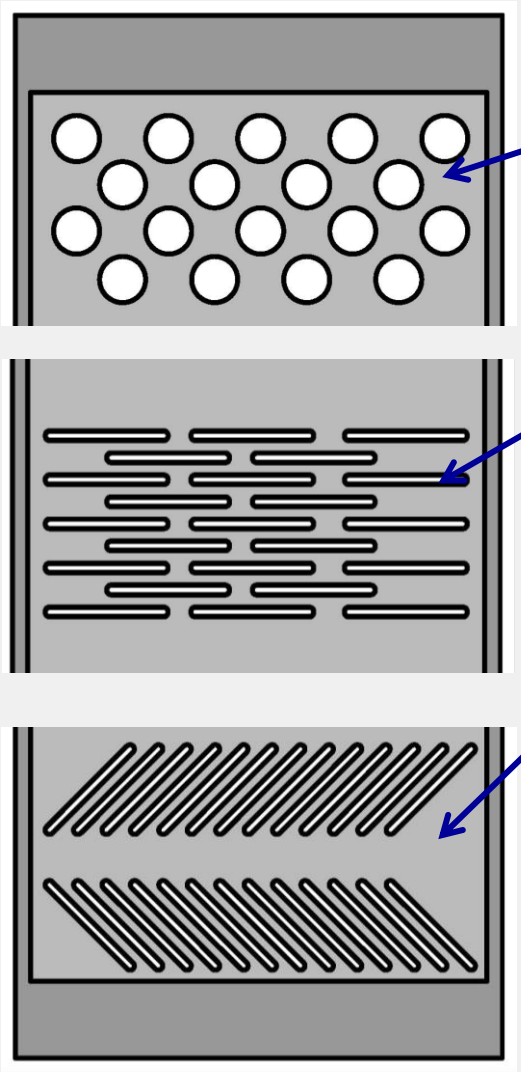
Pilot Scale to Full Production Machines







Screen Types



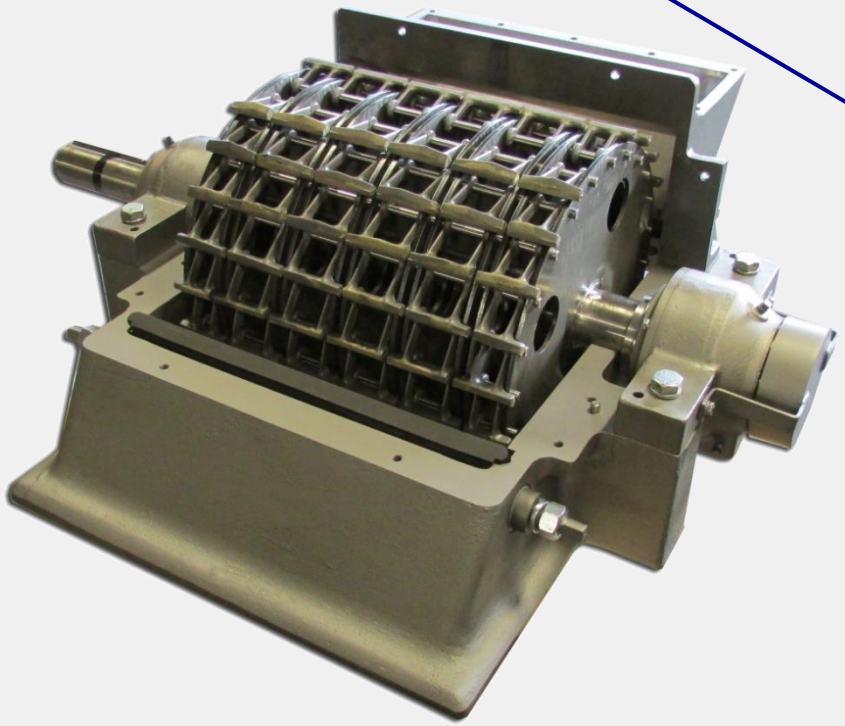
Round Screens

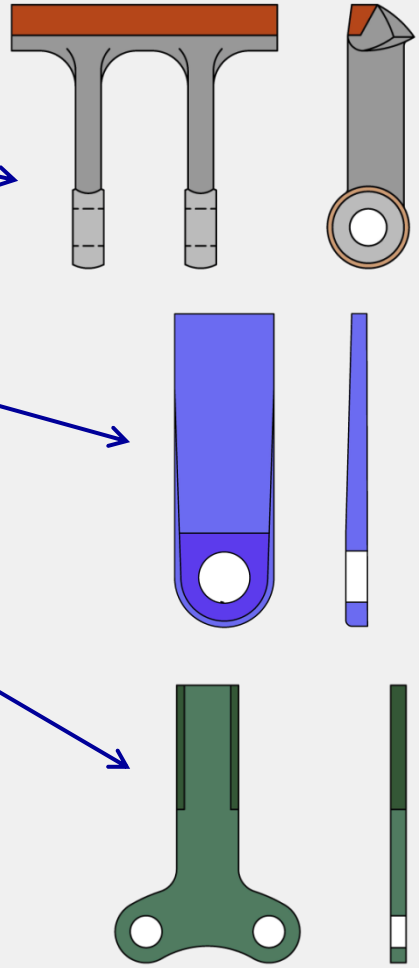
Cross Slot Screens

Herringbone Screens

Hammer Types

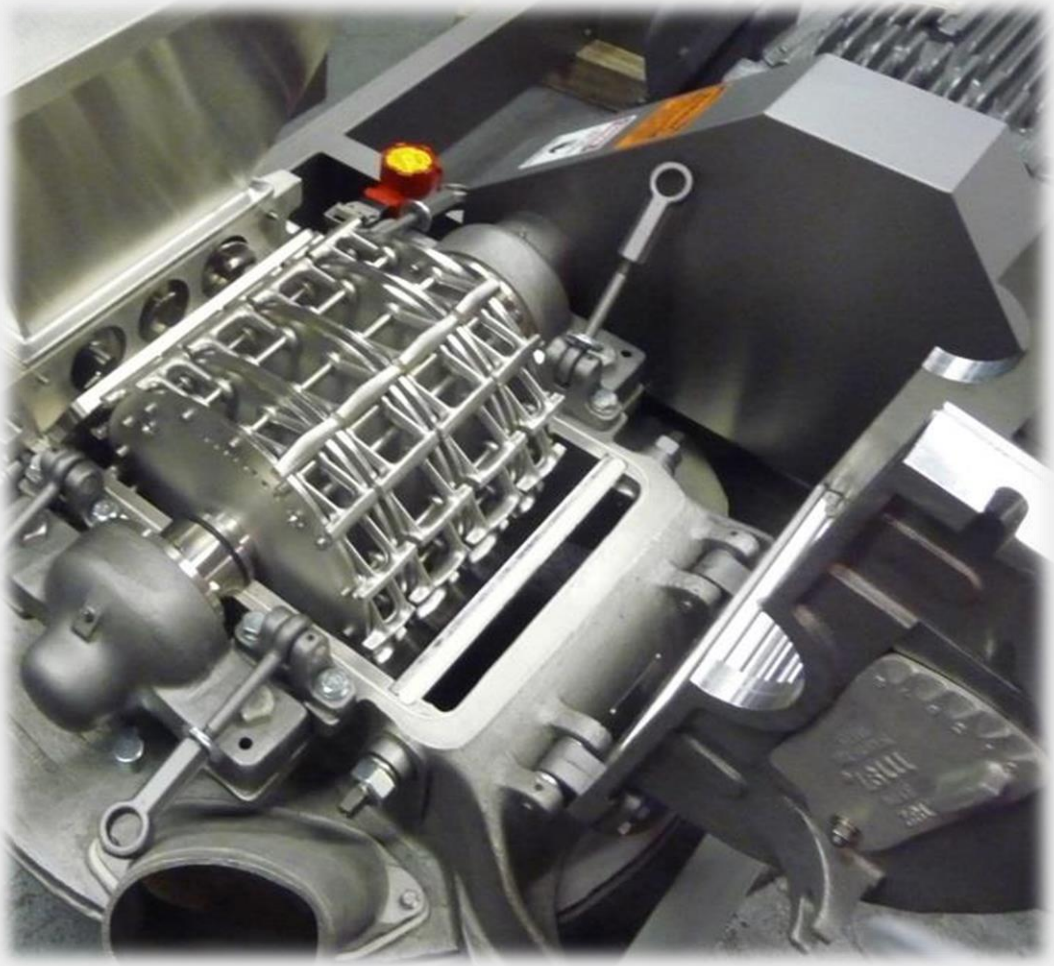
- LFS - Light Forged Stirrup Hammer
- 1/8 x 1 Bar Hammer
- Rigid Bar Hammer



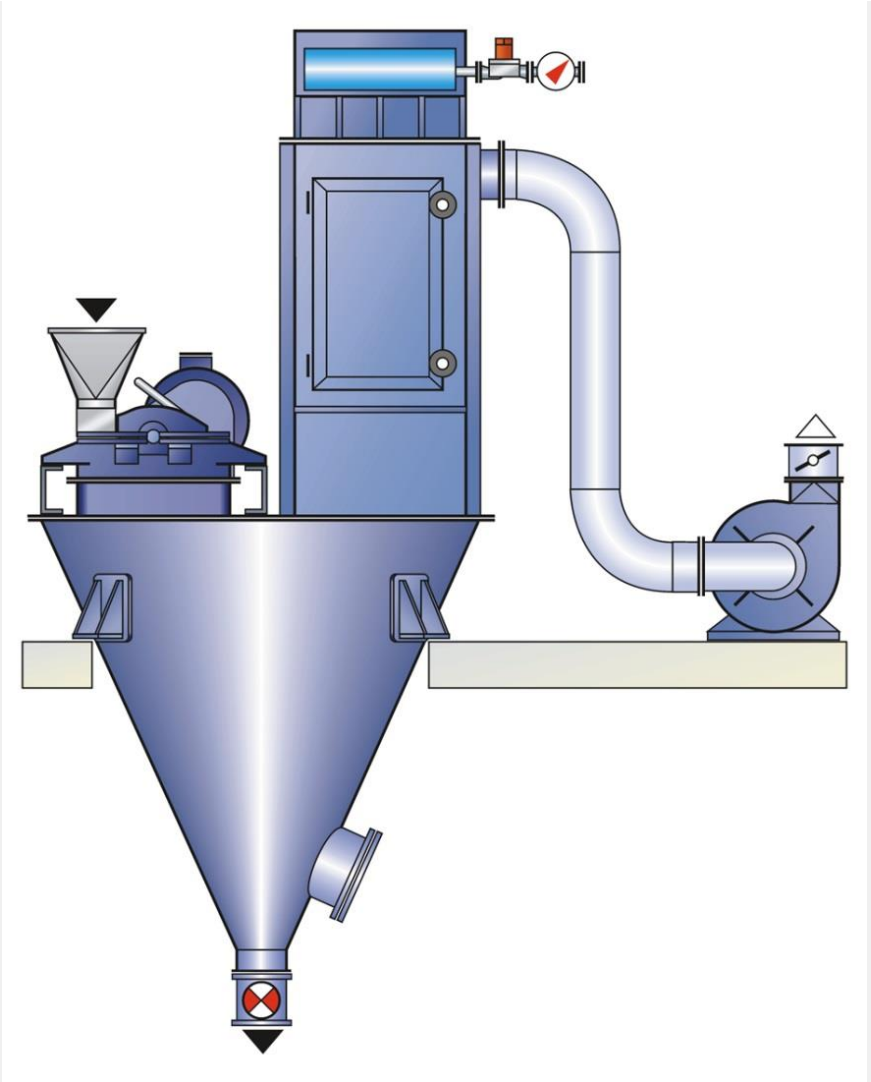


Common Applications

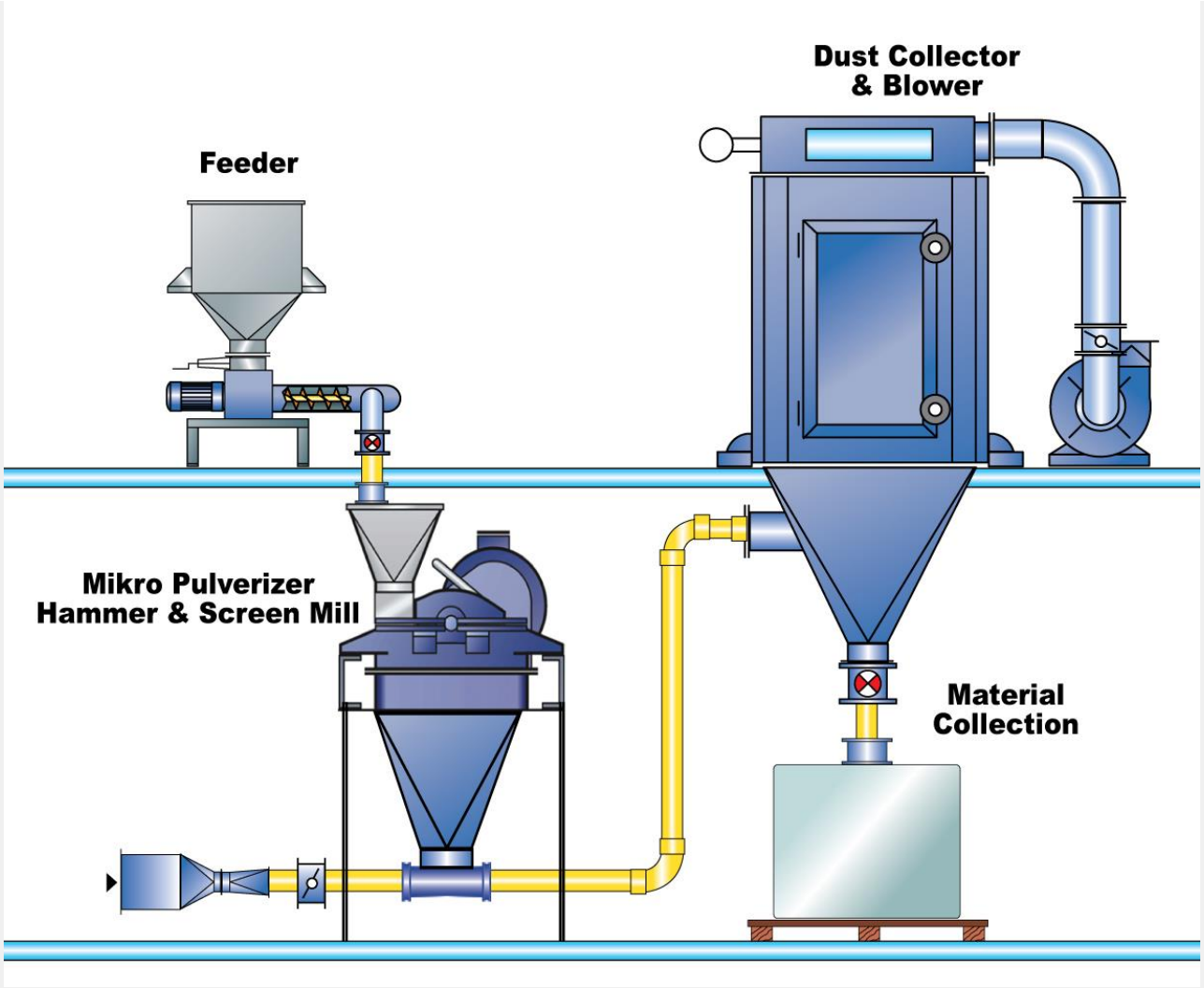
Material	D97_
• Sugar	150 µm
• Corn Starch	75 µm
• Oat Fiber	150 µm
• Melamine	250 µm
• Zinc Oxide	45 µm
• Gypsum	70 µm
• Stearic Acid	150 µm
• Soda Ash	80 µm



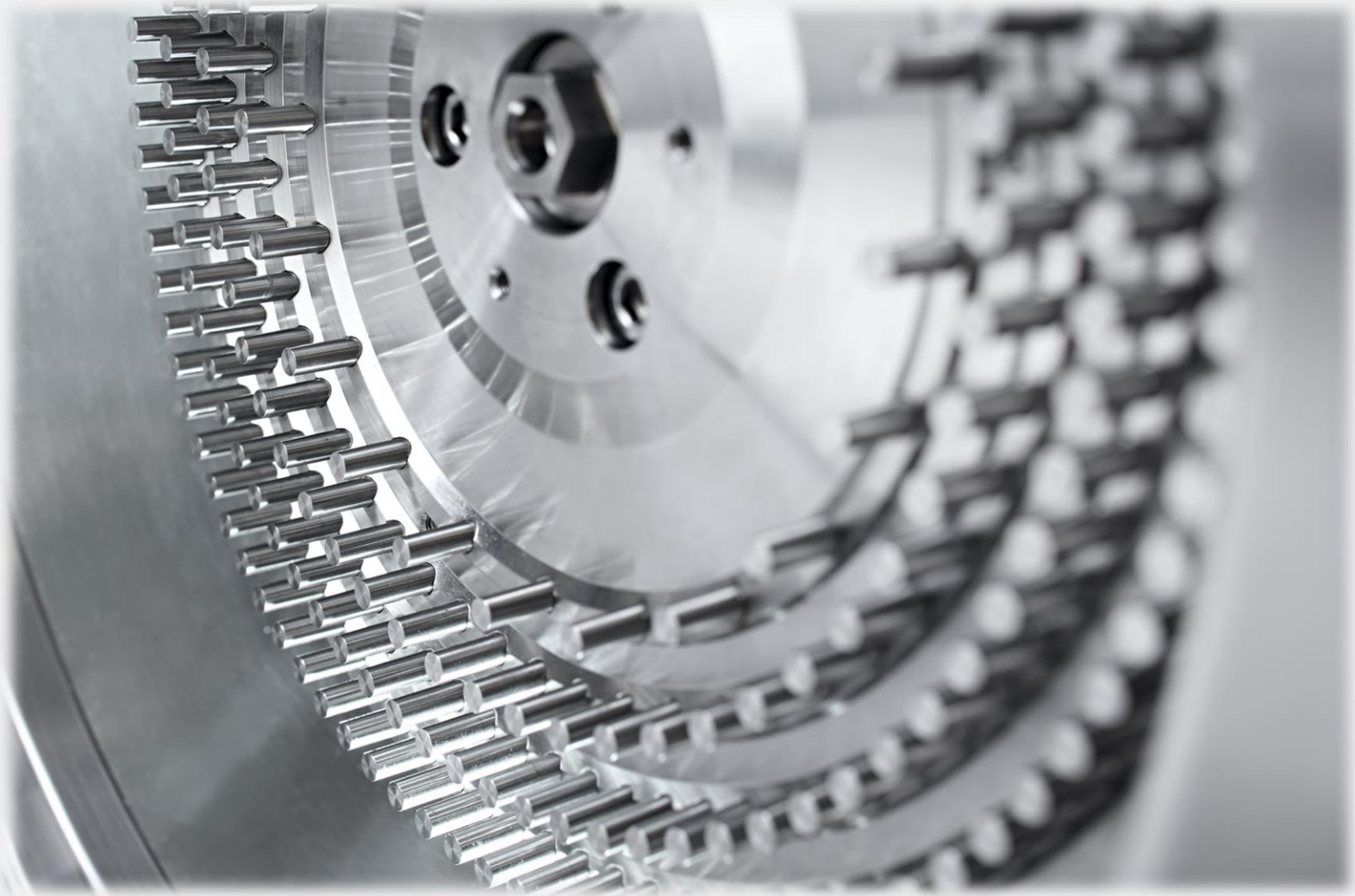
Gravity Discharge



Pneumatically Conveyed

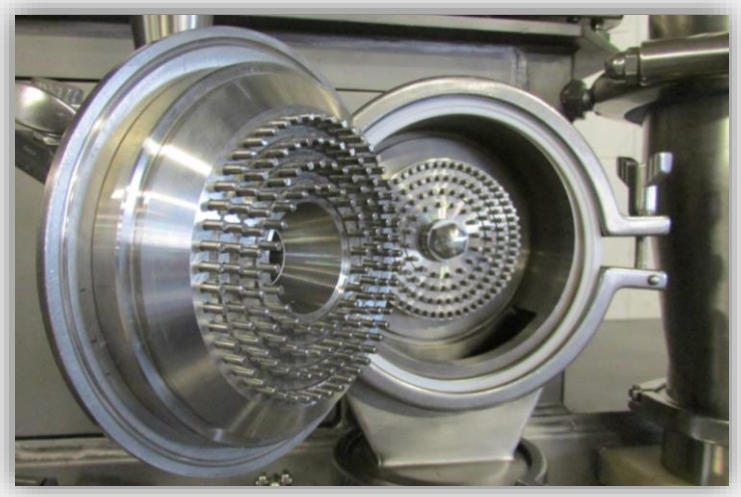


Pin Mill



Pin Mill

- Material impacts against pins and then exits through the labyrinth of pins via centrifugal forces.
- No Screen / blinding
- Variables in pin milling include peripheral speed, feed rate, and air flow.
- Medium to fine size reduction with broad particle size distribution.
- MOH's Hardness up to 3.
- Production of low fines end product with good flow properties.



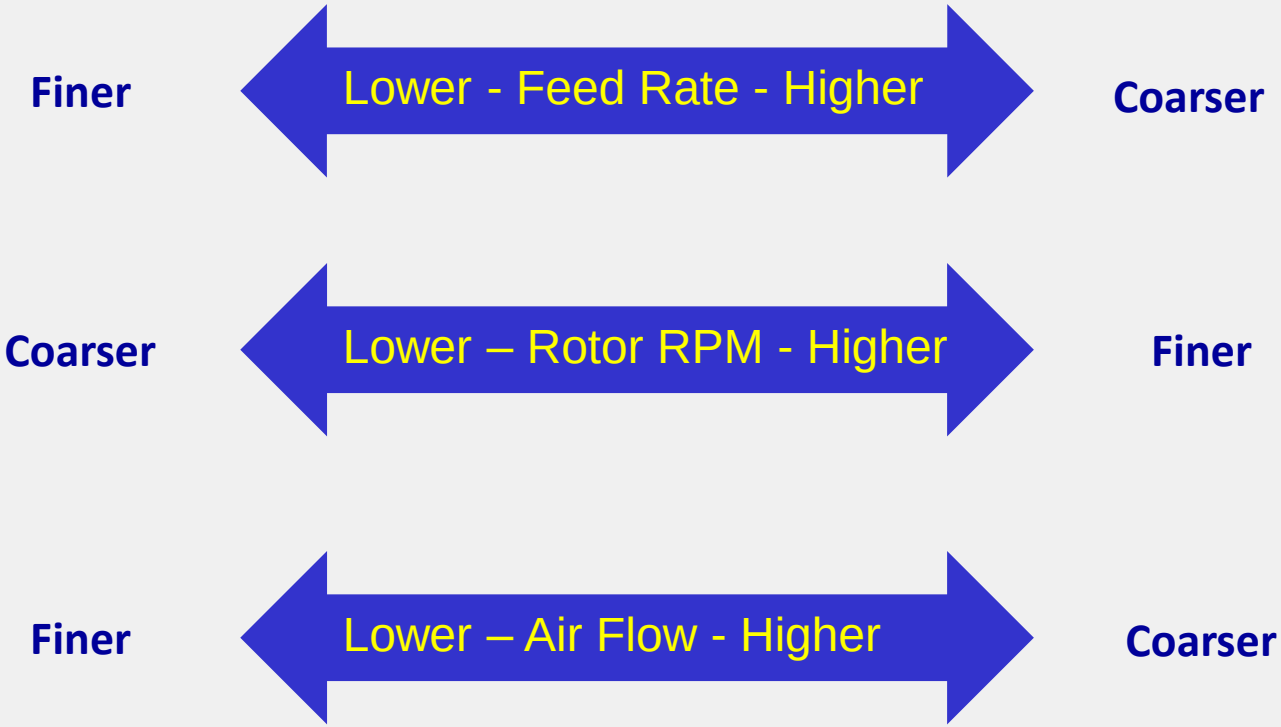
Pin Mill

Pin Mill with Tangential Outlet

Pin Mill - Double Disc Drives with Wide Chamber Design

Counter Rotating Pin Mill with the rotation of both discs

Pin Mill
Single and Double Disc Drives



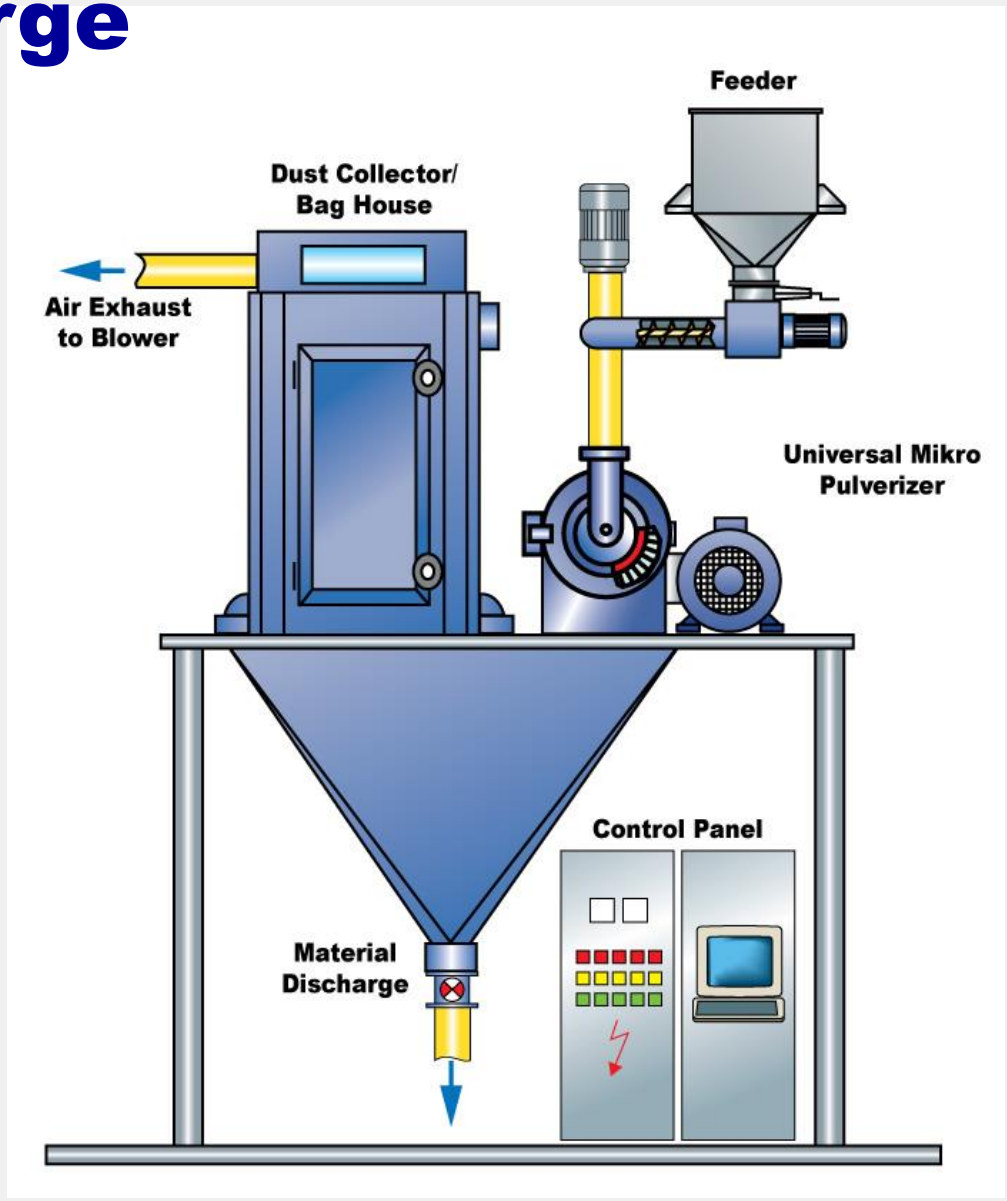
Pin Mill

Common Applications

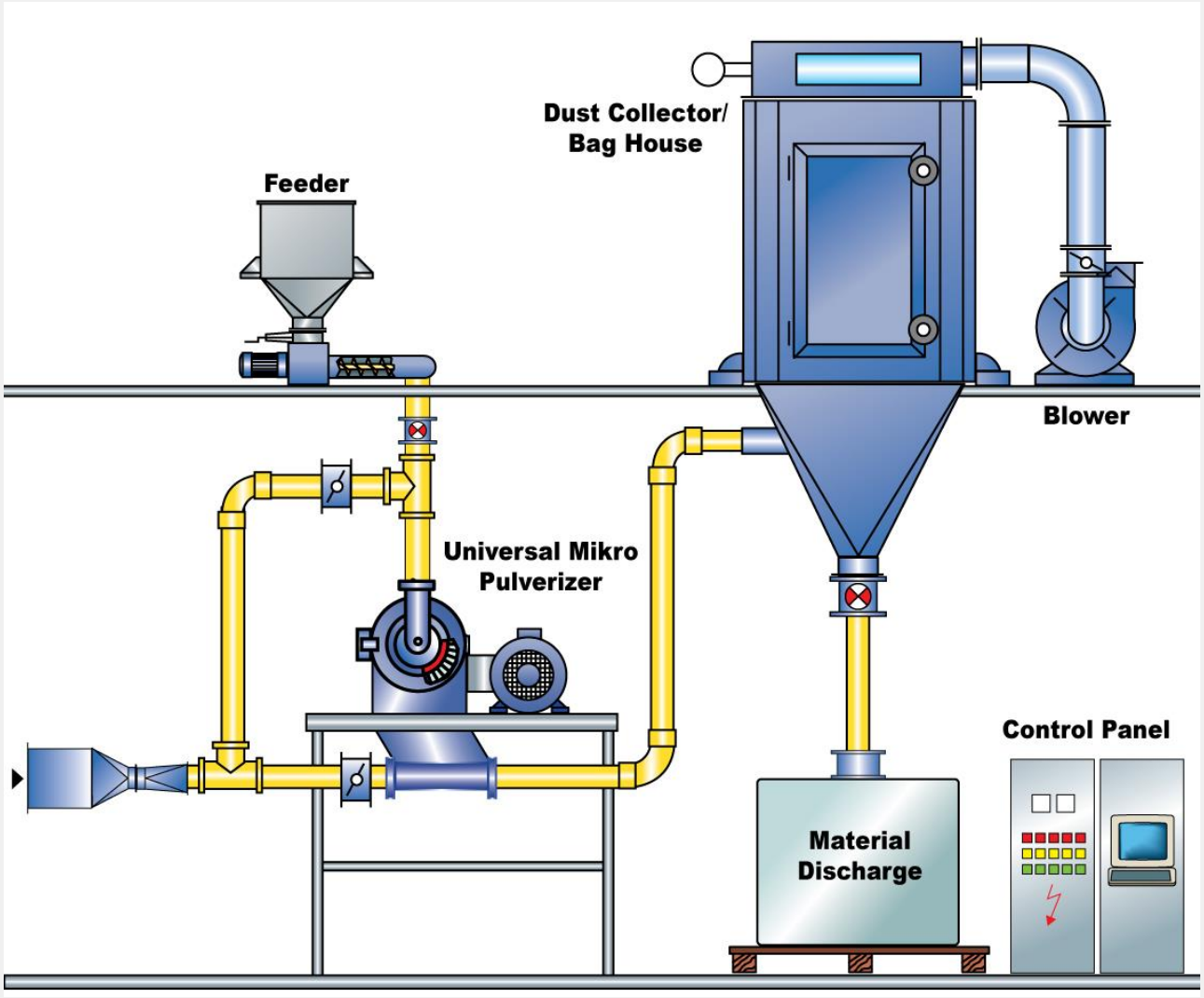
Material		Particle Size
Ascorbic Acid	99%	< 300 um
Boric Acid	98%	< 50 um
Potassium Sulphate	99%	< 150 um
Sodium Chloride	99%	< 60 um
Magnesium Stearate	99%	< 100 um
Sodium Sulphate	97%	< 100 um
Phenolic Resin	99%	< 63 um
Zinc Chromate	99.9%	< 32 um
Chrome Yellow	99.9%	< 10 um

Pin Disc Diameters from 33 mm to 1,400 mm

Gravity Discharge



Pneumatically Conveyed

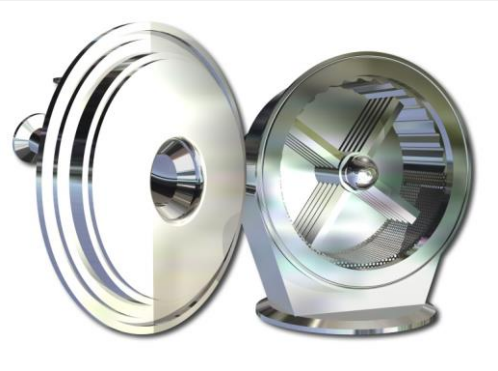


Universal Mikropulverizer (UMP)

Pin Rotor

LFS Hammer Rotor

Knife Rotor

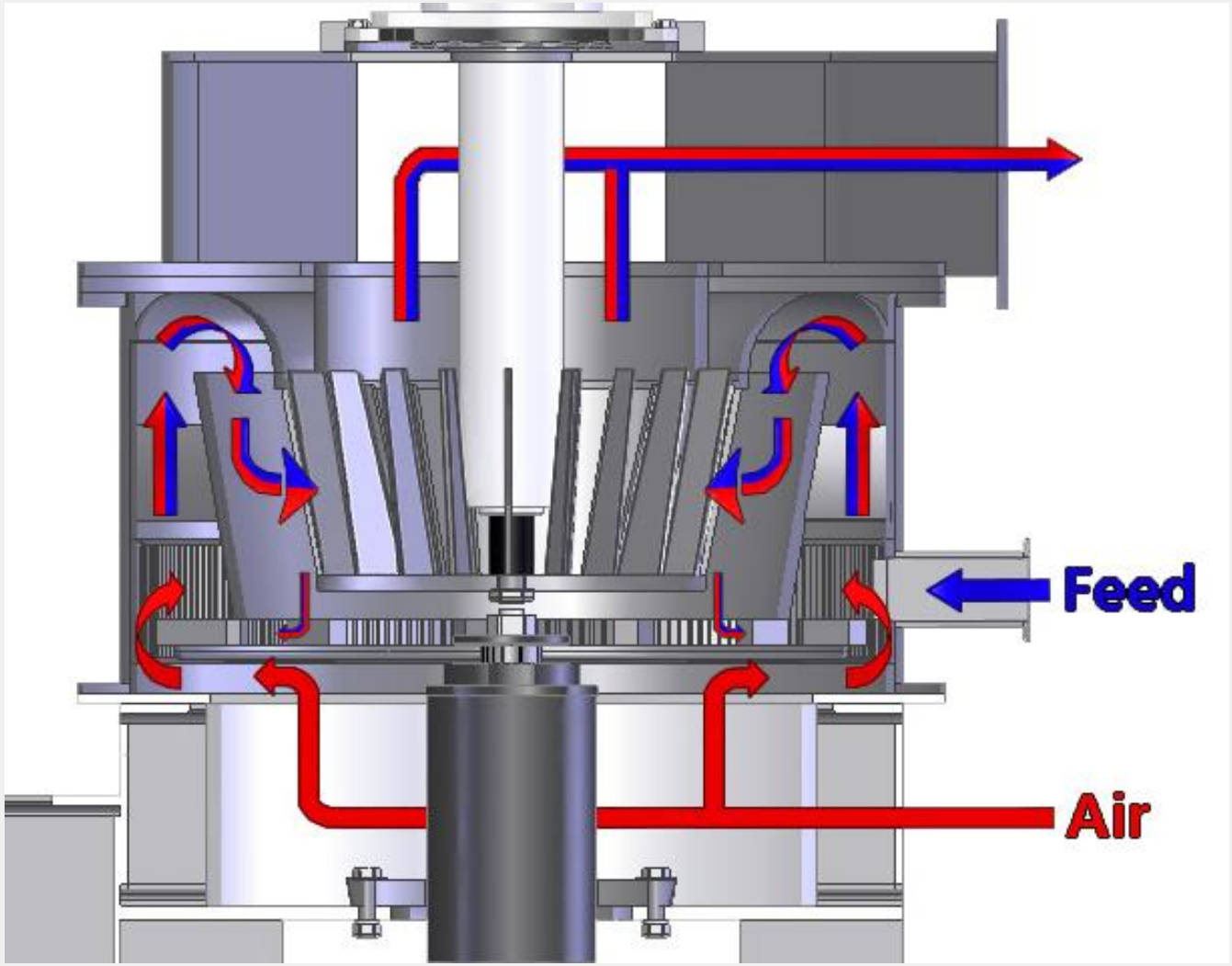


Air Classifier Mills

Air Classifier Mill

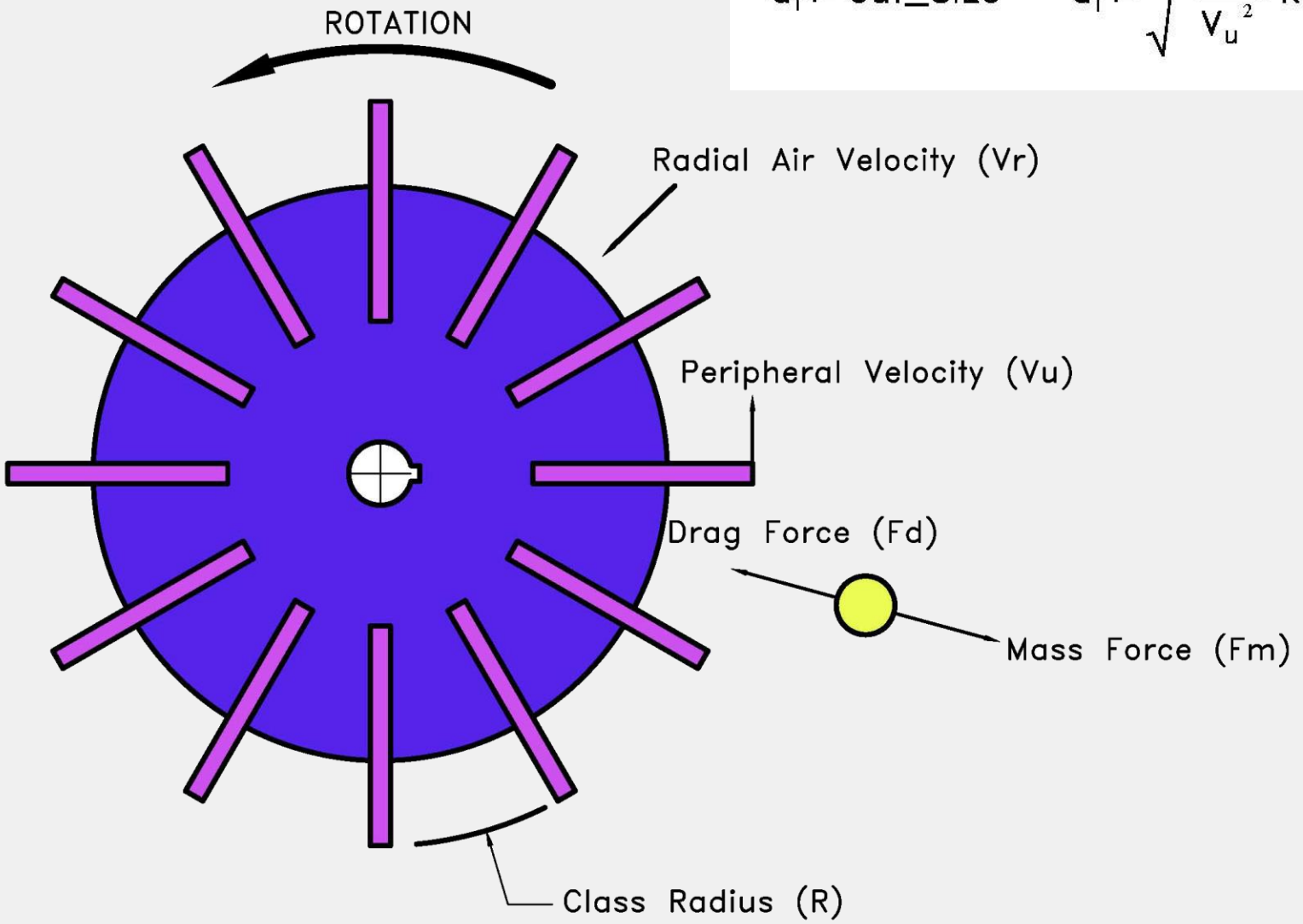
- High tip speeds- 23,000 ft/min
- Screens replaced by forced vortex air classifier
- Independent control of impact mechanism and classifier which equates to narrow PSD's
- Air swept - requires discreet air handling components
- PSD down to D50 = 15 µm
- 50 g/h to 20 t/h

Air Classifier Mill



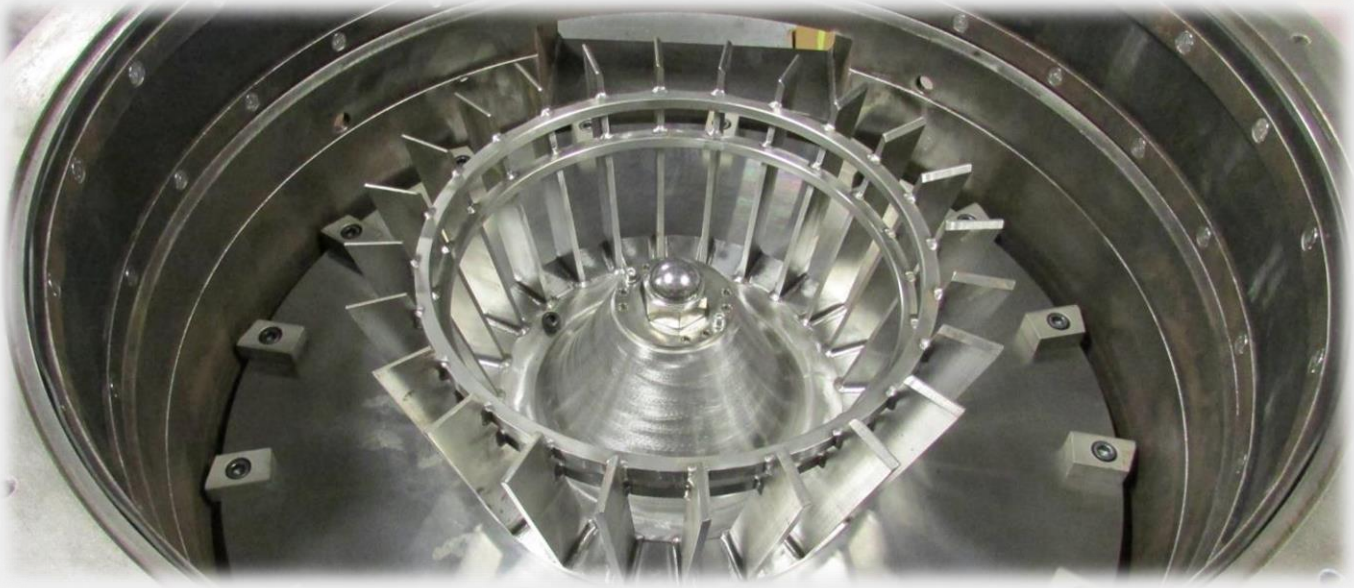
Classification:

$$d_t := Cut\_Size \qquad d_t := \sqrt{\frac{V_r}{V_u^{\,2}} \cdot R}$$



Benefits of Air Classifier Mill

- **Produces a fine particle size distribution with excellent top size control.**
- **Combines a mechanical impact mill and a dynamic classifier in one unit.**
- **Product fineness is easily adjustable by means of the variable speed of the classifier wheel.**

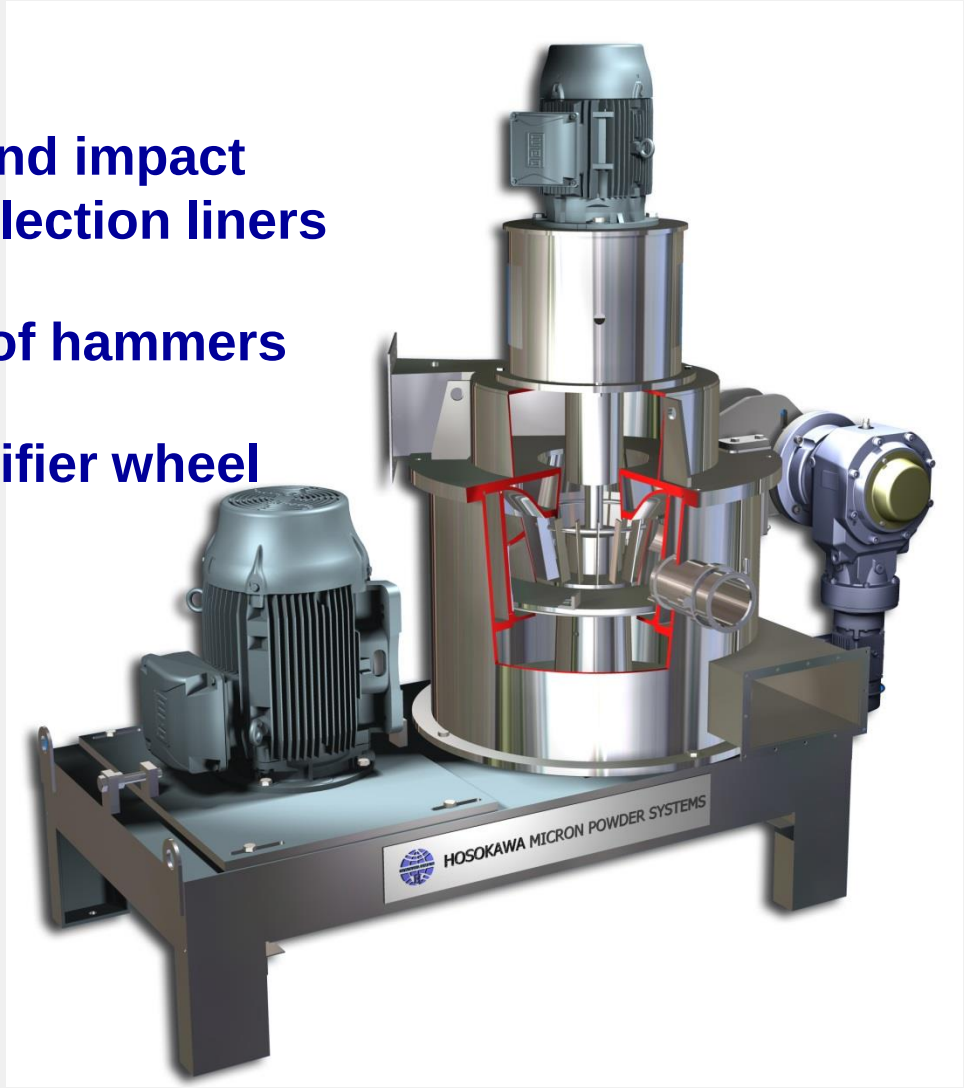


Benefits of Air Classifier Mill

- Continuous discharge of properly sized material minimizes the production of fines and maintains a consistent particle size distribution.
- Large volumes of air flow provide for cooler grinding and allow the processing of heat sensitive materials.
- Can be wear protected to handle abrasive materials.
- Ideal for high capacity continuous processing.

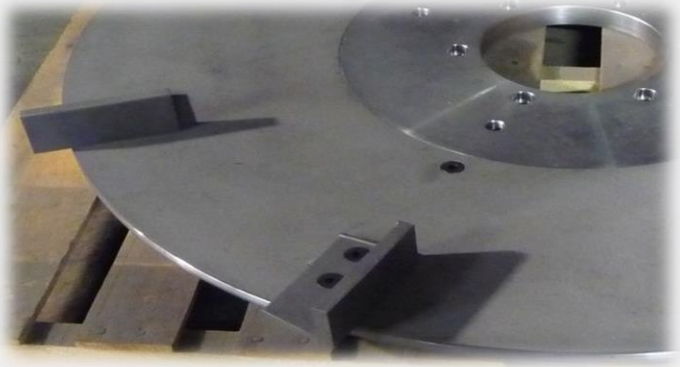
ACM Important Variables

- Configuration of grinding and impact surfaces, i.e. smooth or deflection liners
- Peripheral speed and type of hammers
- Speed and size of the classifier wheel
- Airflow through the mill
- Feed rate

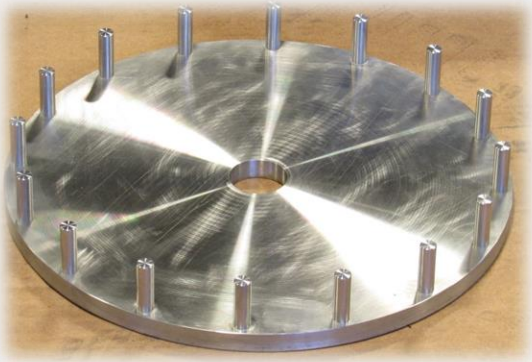


ACM Hammer Designs

Bar Hammers



Angle Hammers



Pins

Flag Hammers

ACM Classifier Wheel Designs

Radial Short Blade

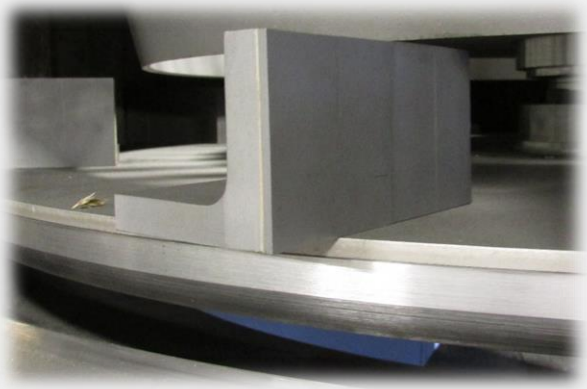
Radial Long Blade with top Ring

Wear Protection Options for ACM

Ceramic Liners

Nickel Hardened Liners

T/C Coated Classifier Wheel

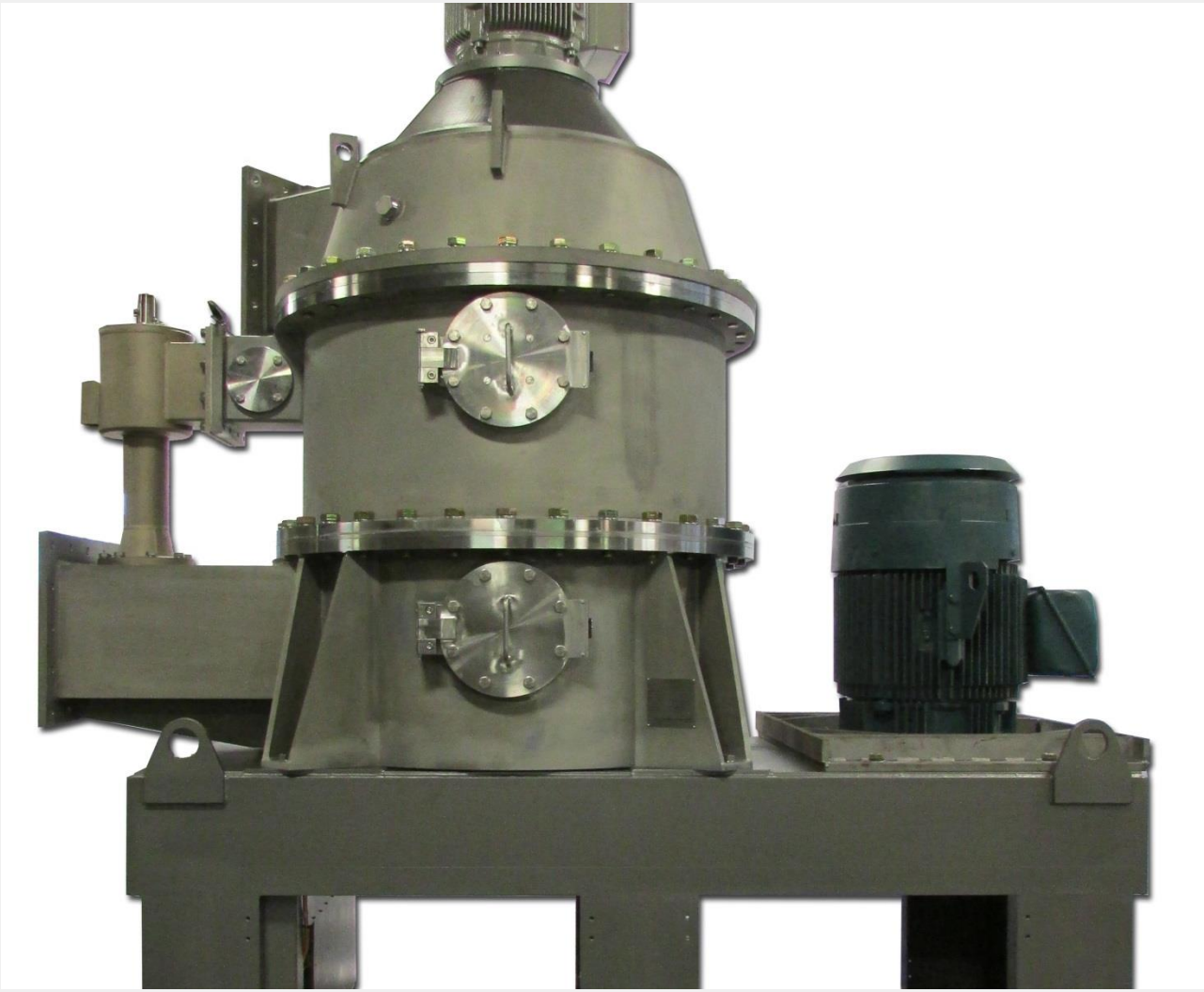


T/C tiled Hammers
And Rotor Wear Plate

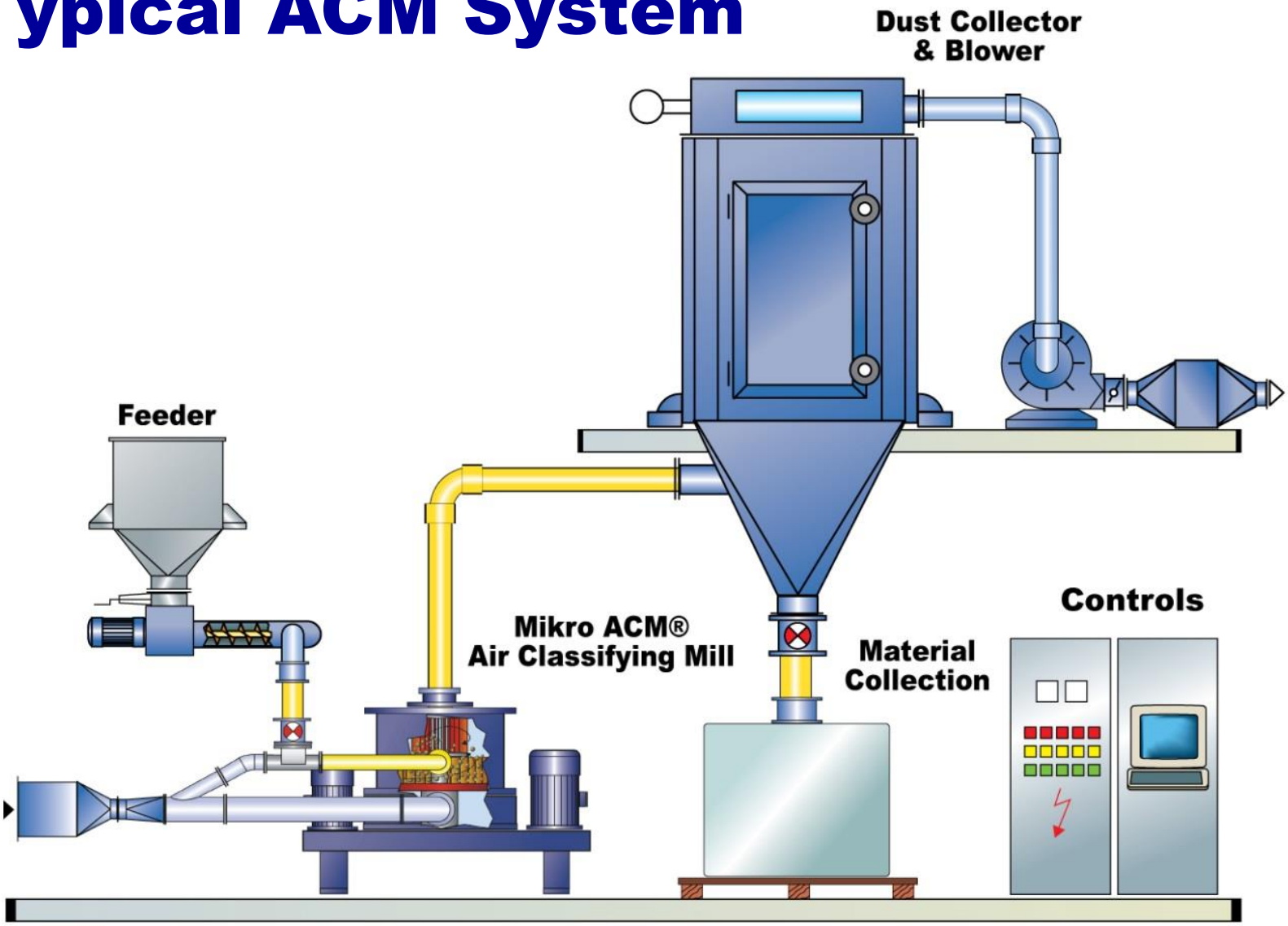
Typical Applications

Cane Sugar	98% < 45 microns
Talc	98% < 45 microns
Powder Coatings	50% < 20 microns
Zinc Oxide	99.9% < 23 microns
Sodium Bicarbonate	90% < 20 microns
Calcium Phosphate	97% < 15 microns
Cocoa Press Cake	99.9% < 75 microns
Pectin	97% < 45 microns
Lactose	97% < 75 microns
Phenolic Resin	97% < 200 mesh

From 1 HP to 600 HP

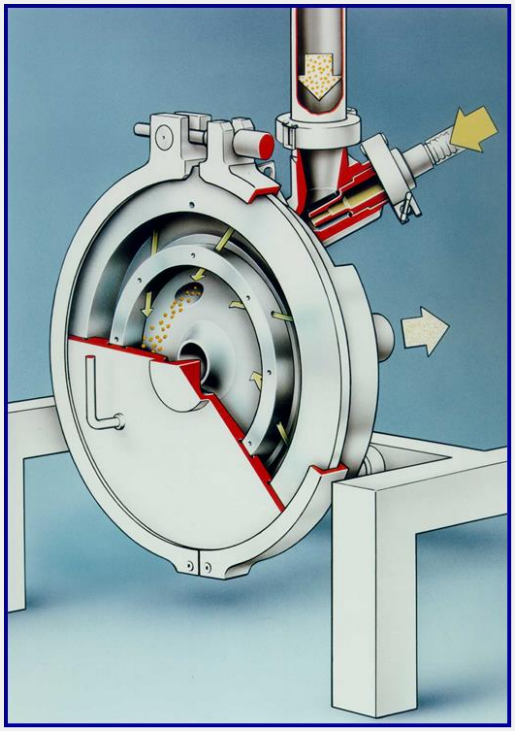


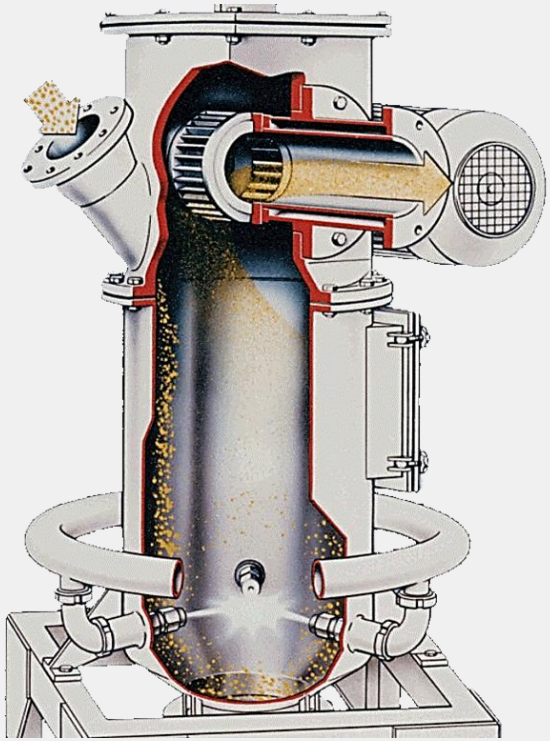
Typical ACM System



Fluid Energy Jet Mills

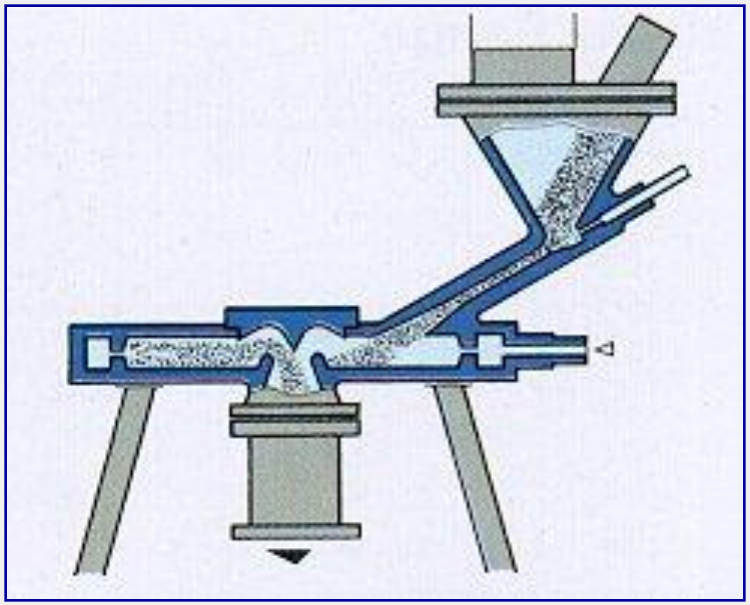
Spiral Jet Mills

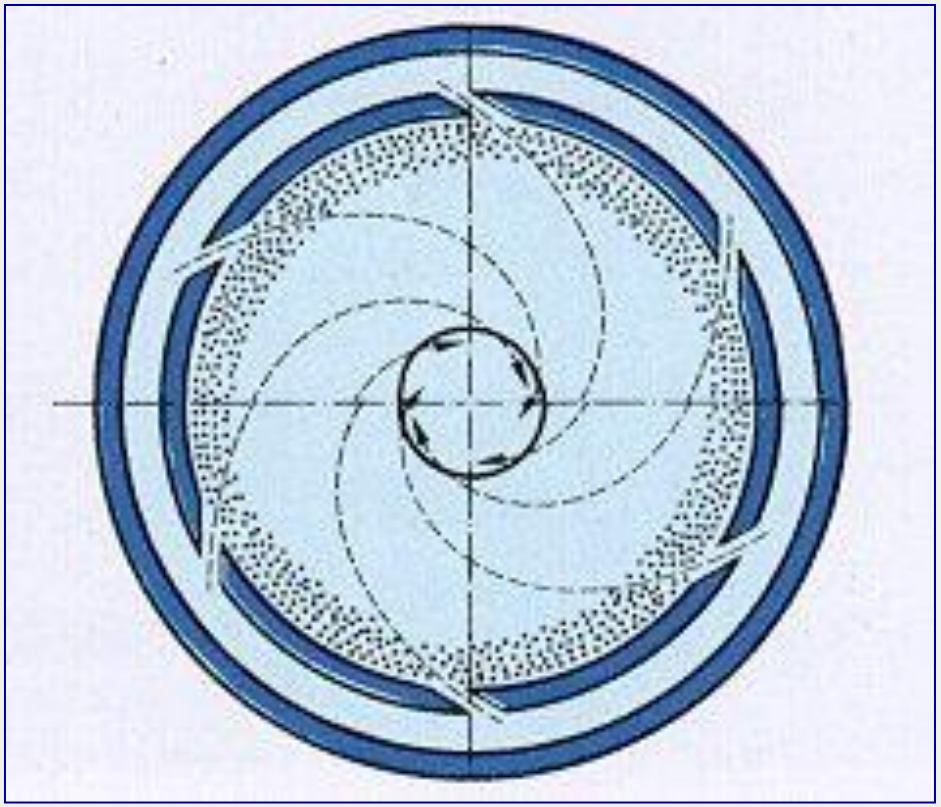




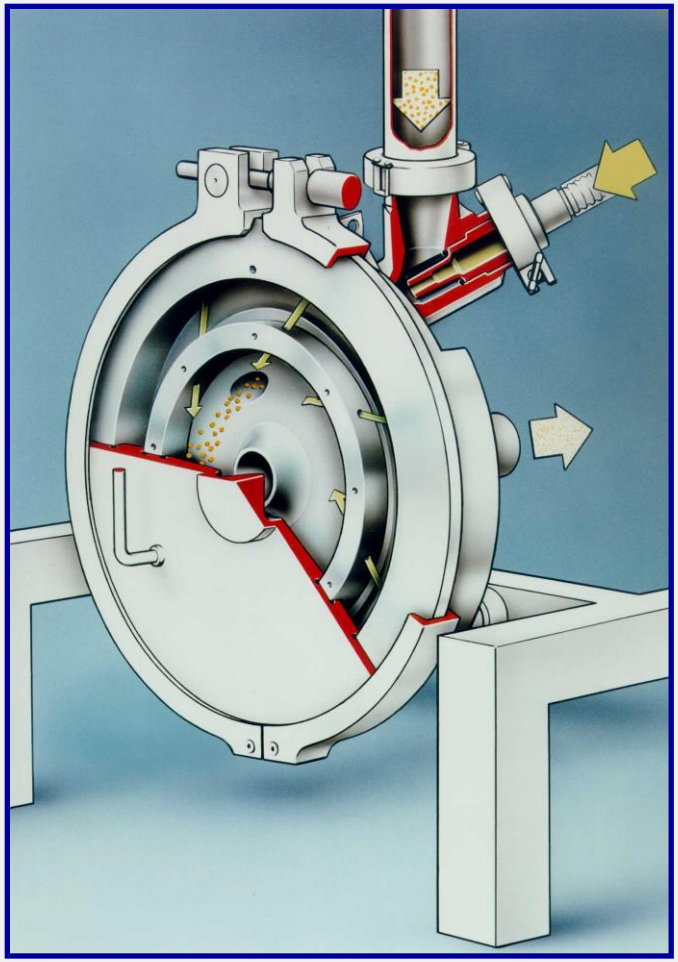
Fluidized Bed Jet Mills

Spiral Jet Mill





Typical Spiral Jet Mill Design

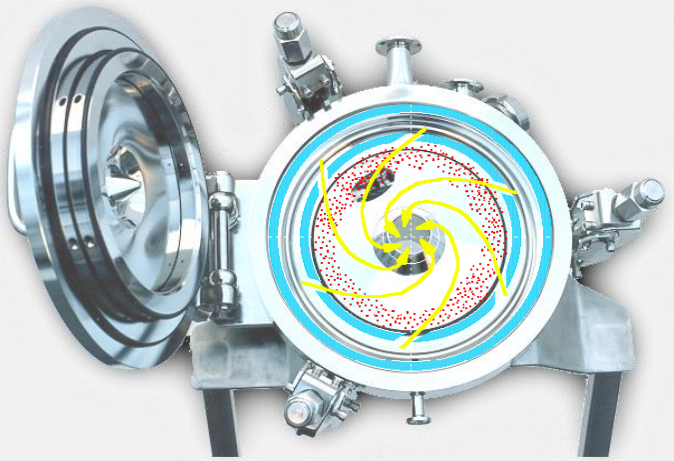


- Flat cylindrical grinding chamber
- Nozzle ring with tangential nozzle arrangement
- Feeding via injector
- Ceramic wear protection available

Operating Parameters

End Product Fineness influenced by

- Gas flow rate
- Grinding pressure
- Injector pressure
- Feed Rate
- Nozzle angle
- Nozzle size



Spiral Jet Mill

- Benefits
  - Simple design and operation
  - No moving parts
  - Easy to clean and inspect
- Limitations
  - Oversized feed particles can block inlet
  - Buildup and scaling with sticky materials
  - Lack of particle size control
  - Difficult to process heat sensitive or abrasive materials

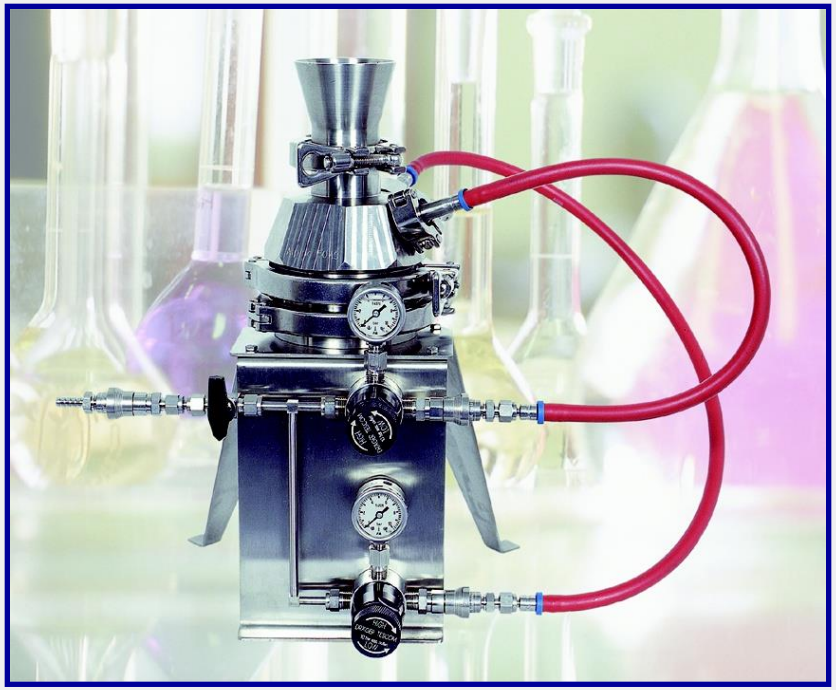
Spiral Jet Mill Performance

- Powder fineness achievable D97 of 3-90 microns
- Throughput @ D97 of 10 microns 45 – 80 lbs/hr
- Throughput @ D97 of 20 microns 100 – 160 lbs/hr

(Sample data for a 12“ diameter Spiral Jet Mill with nominal air consumption of 270 scfm)

Small Laboratory Scale Mill

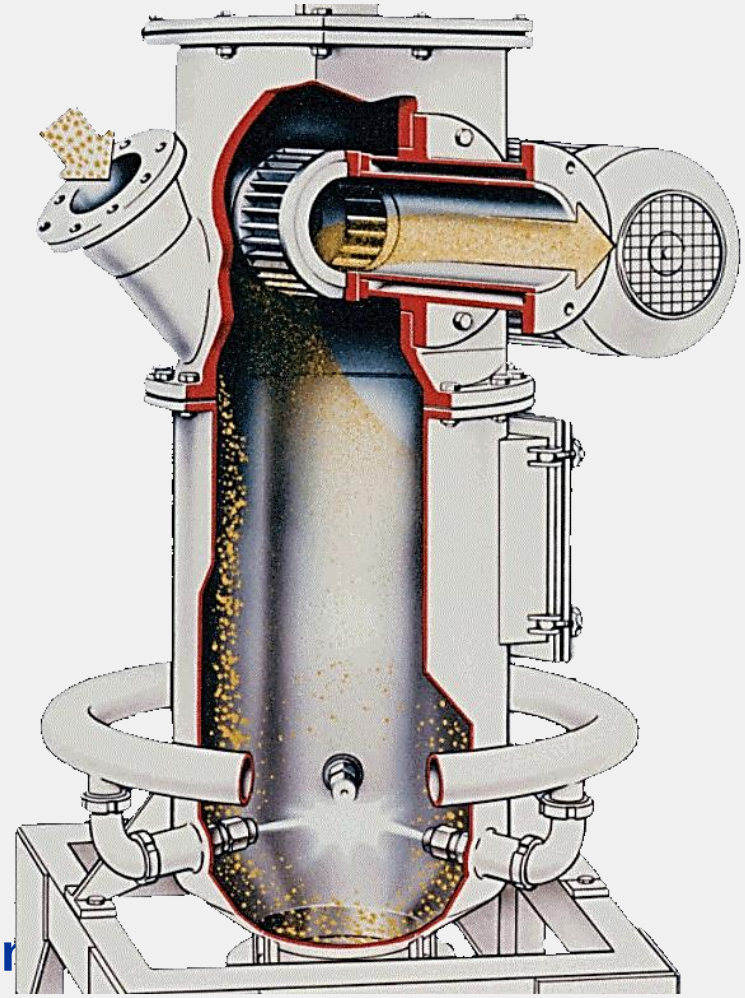
- Batch size 5g-100 g
- Capacity 0.1 - 1 kg/h
- Fineness < 3 µm
- Monobloc construction
- Autoclavable



Fluidized Bed Jet Mill

Fluidized Bed Jet Mill

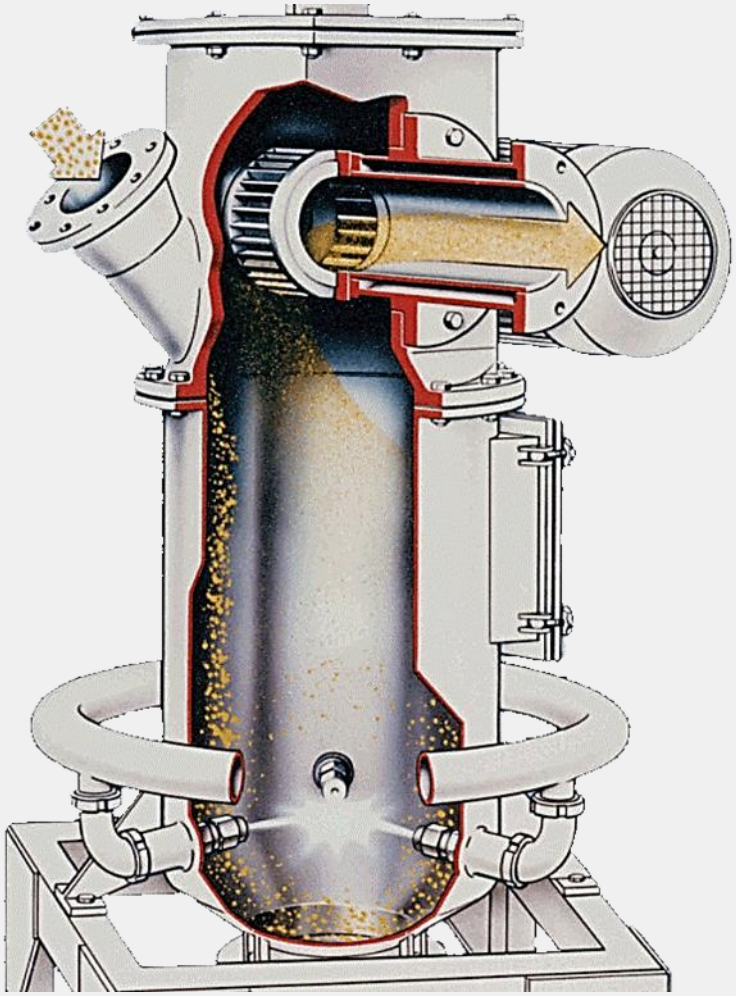
- Gravity feed inlet
- Integral centrifugal air classifier
- Grinding zone
- Quick disconnect air plenum
- Radial nozzle arrangement
- Integrated base for load cell bed cor



Operating Parameters

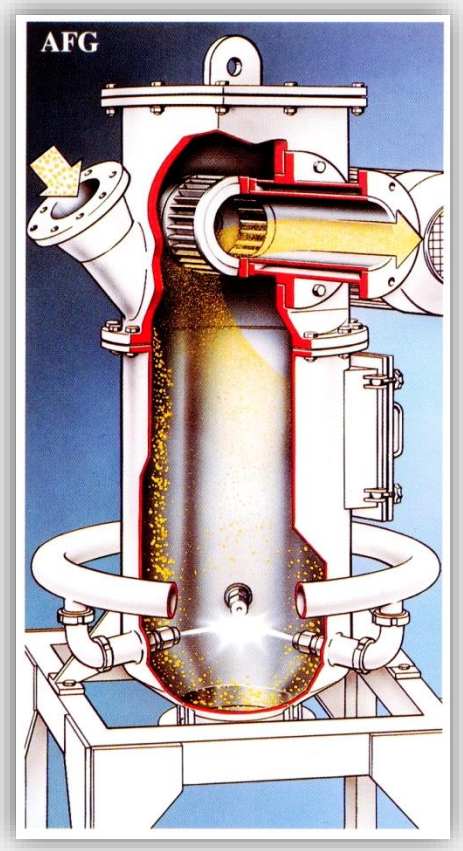
End Product Fineness influenced by

- **Gas flow rate**
- **Grinding gas pressure**
- **Nozzle size**
- **Classifier Speed**



Fluidized Bed Jetmill Designs

- Mild Steel/Stainless Steel
- Lined Chamber for iron free grinding
- Pressureless
- Pressure Shock Resistant to 10 barg
- Wear Protection
- Gas Tight Design
- Hot Gas Design

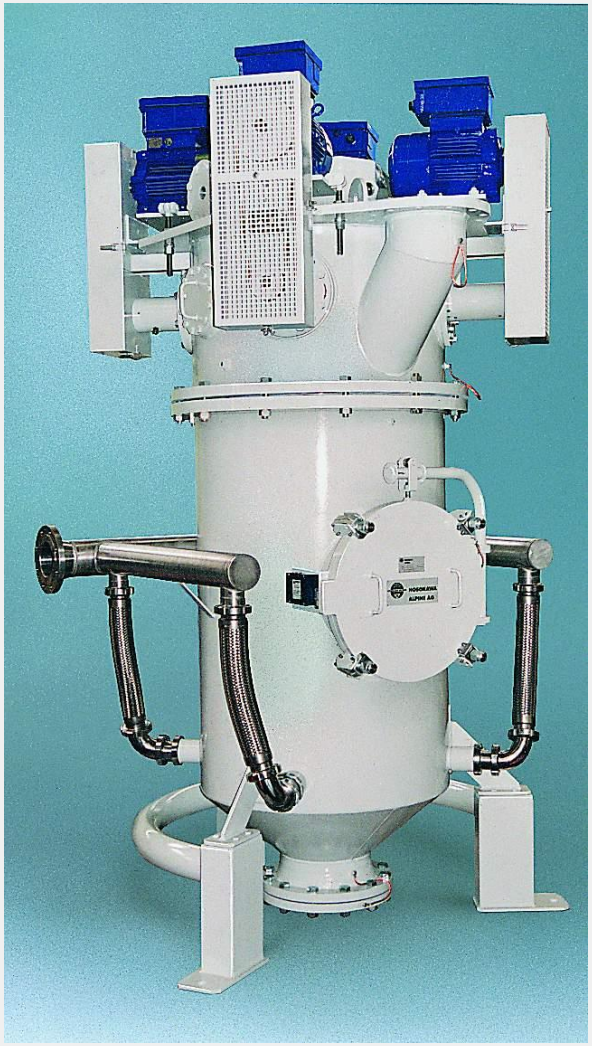


Special wear protection classifier wheels from SIC and Aluminum Oxide

Fluidized Bed Jet Mill

Benefits

- Products with a requirement for an extremely steep particle size distribution, without oversize (grit) and a minimum of fines
- Grinding powders to ultrafine sizes down to a D97 of 4 microns with a sharp top size limitation
- Iron contamination free grinding
- Processing of heat sensitive products
- Grinding of abrasive materials



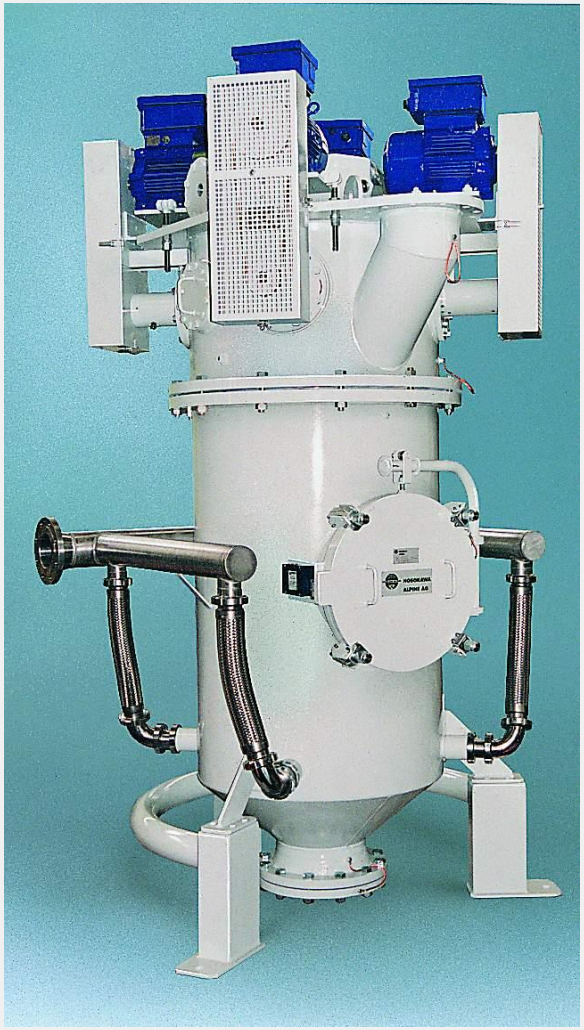
Fluidized Bed Jet Mill

Benefits continued

- Improved and consistent product quality
- Ability to process heat sensitive or sticky materials
- Suitable for CIP/SIP and explosion containment design
- Reduced energy cost
- No limitation on feed size

Limitations

- Processing of small samples
- Residual material in mill bed



Typical Applications

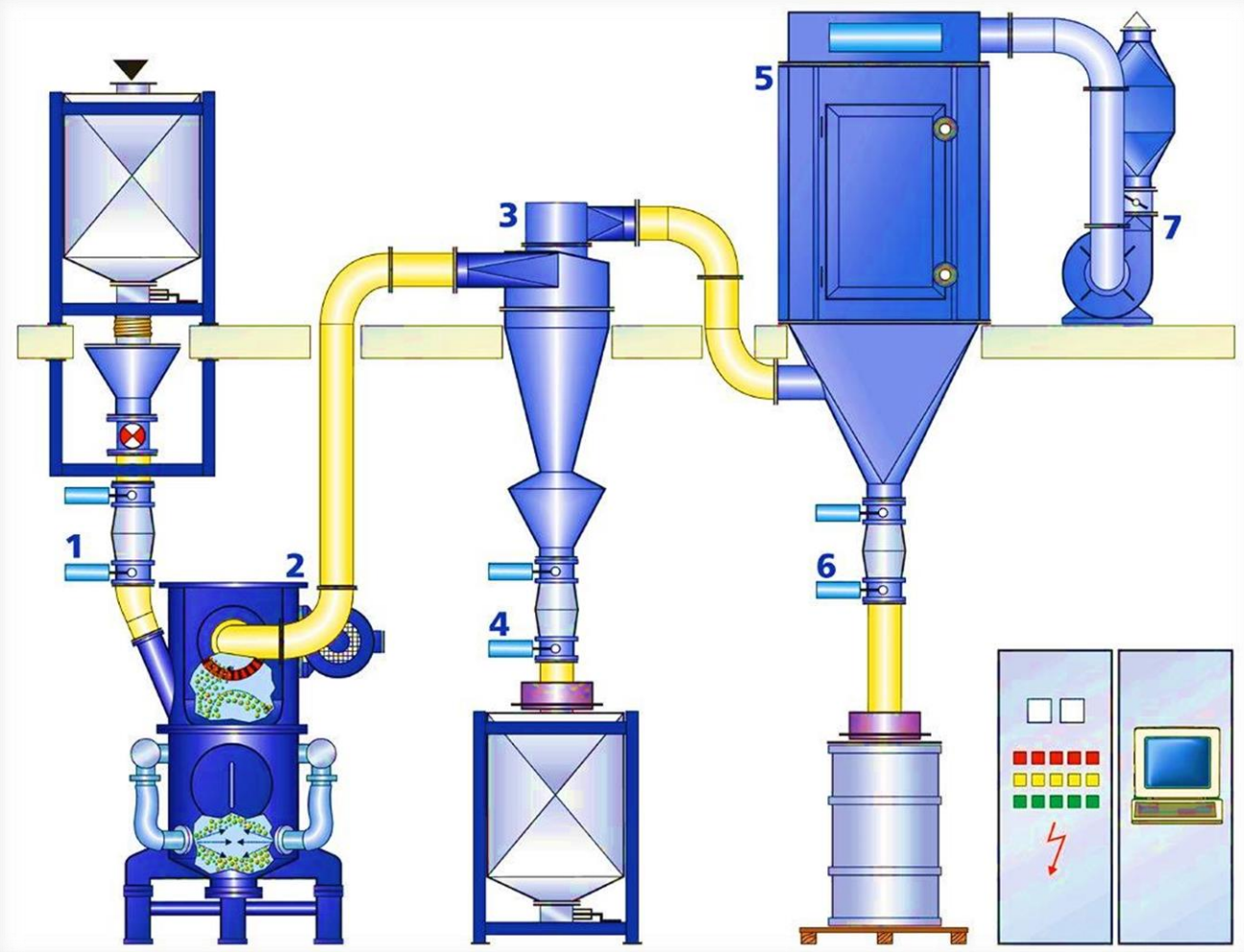
Silica Gel	97% < 15 microns
PTFE	97% < 22 microns
PE Wax	99% < 15 microns
Ceramic Pigments	99% < 10 microns
Iron Phosphate	97% < 2.5 microns
Herbicide	97% < 12 microns
Glass Frit	50% < 1.5 microns
Tungsten Carbide	99% < 7 microns
Graphite	95% < 8 microns
Molybdenum	98.7% < 2 microns

Fluidized Bed Jet Mill Performance

- Powder fineness achievable D97 of 3-40 microns
- Throughput @ D97 of 10 microns 175 – 225 lbs/hr
- Throughput @ D97 of 20 microns 350 – 525 lbs/hr

(Sample data for a 16“ diameter Fluidized Bed Jet Mill with nominal air consumption of 600 scfm)

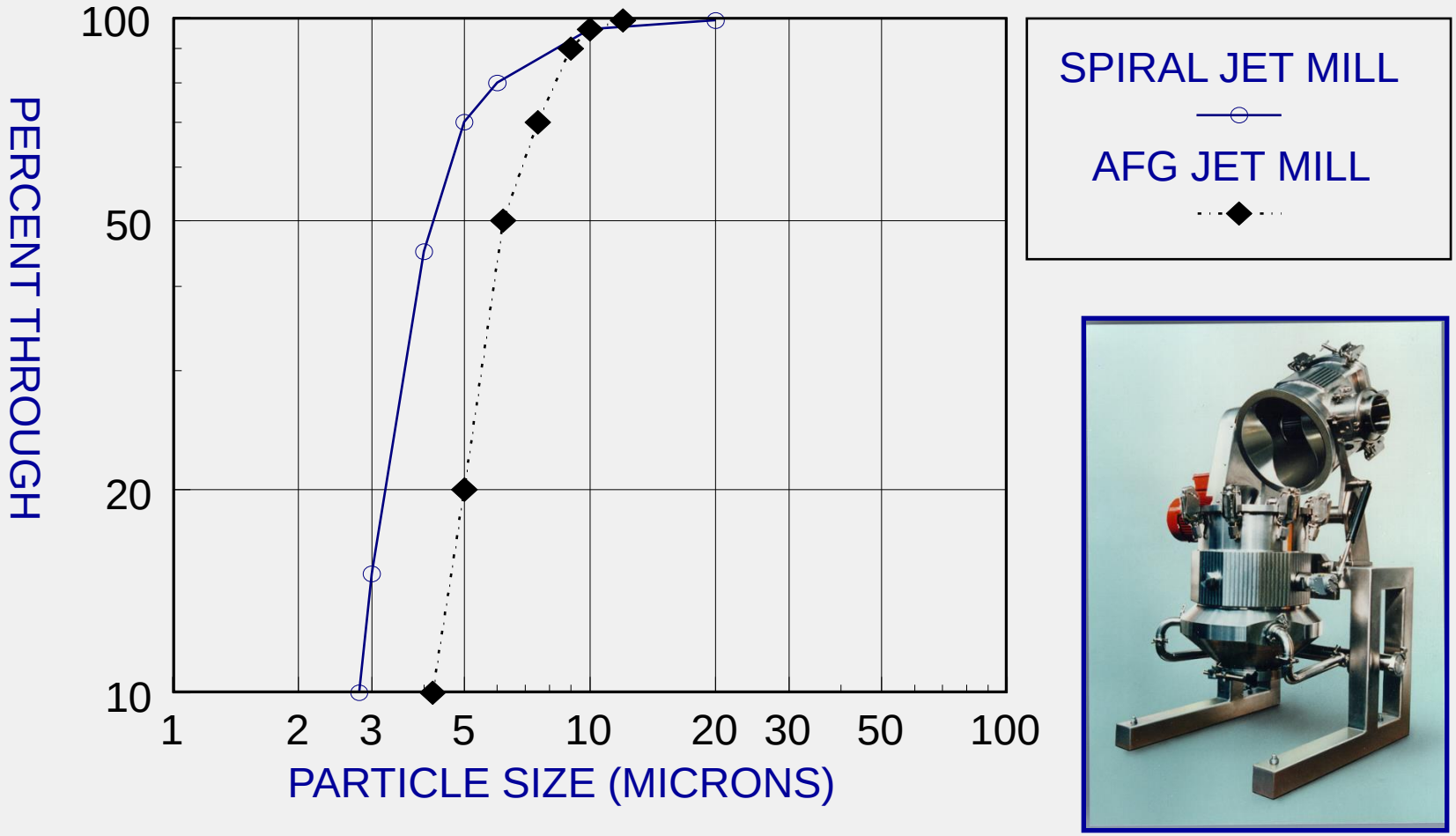
Typical Fluidized Bed Jet Mill System



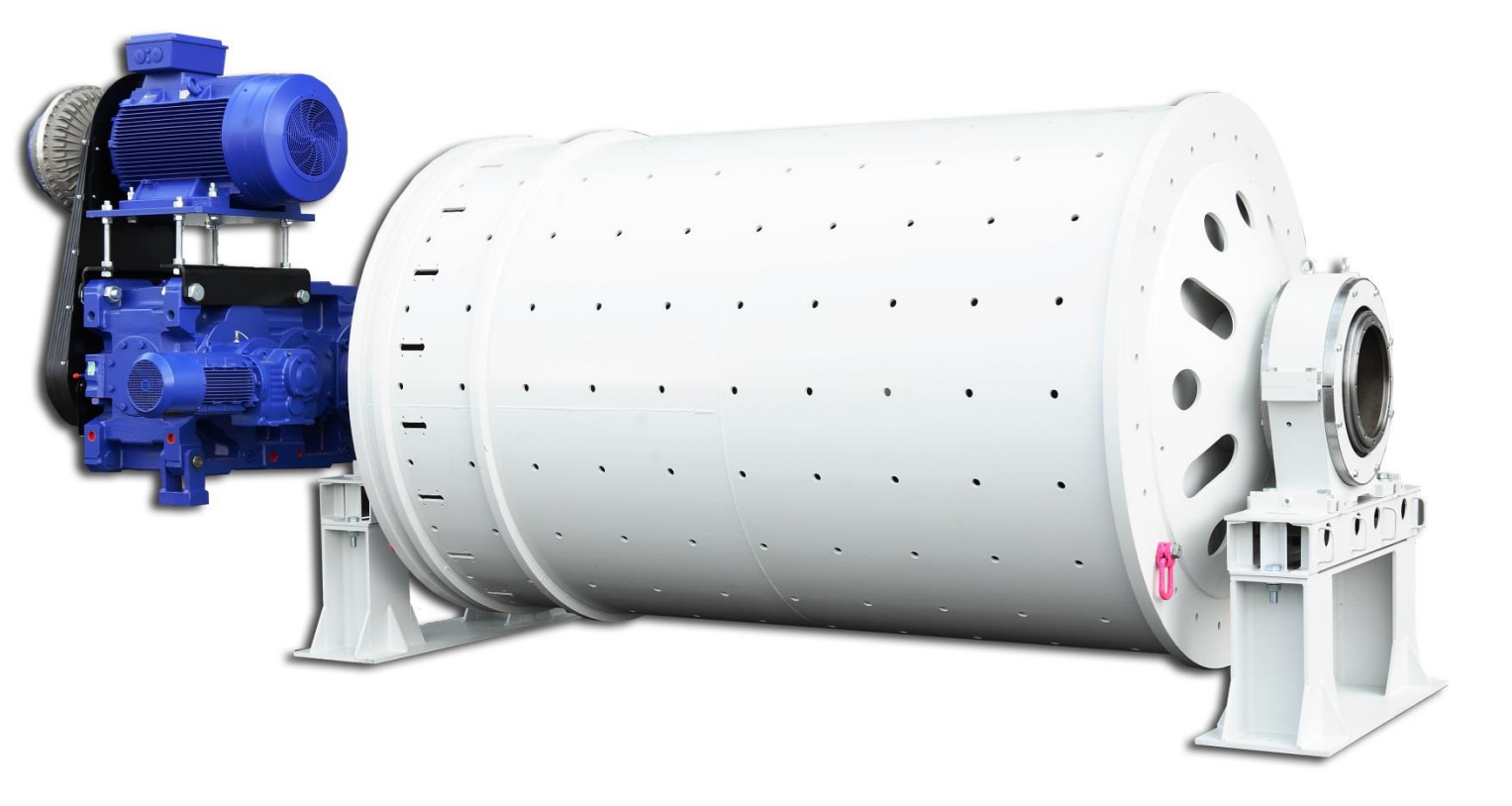
Lab Scale Fluidized Bed Jet Mill

Fluidized Bed Jet Micronization

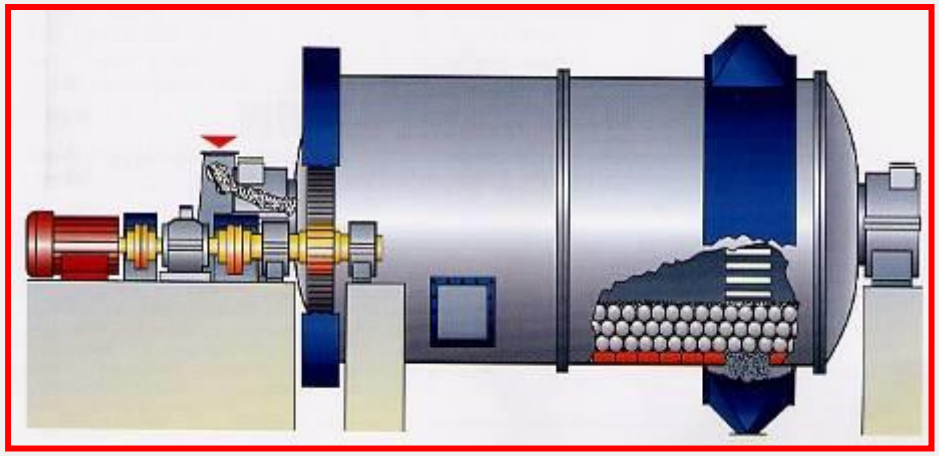
Improved product quality

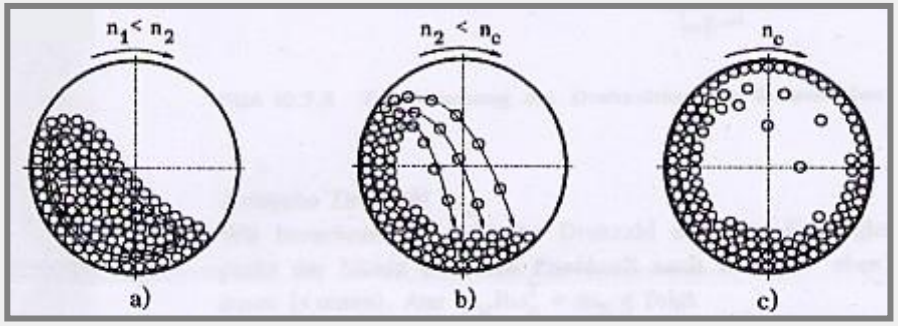


Ball Mills



Ball Mills





Superfine Ball Mill systems

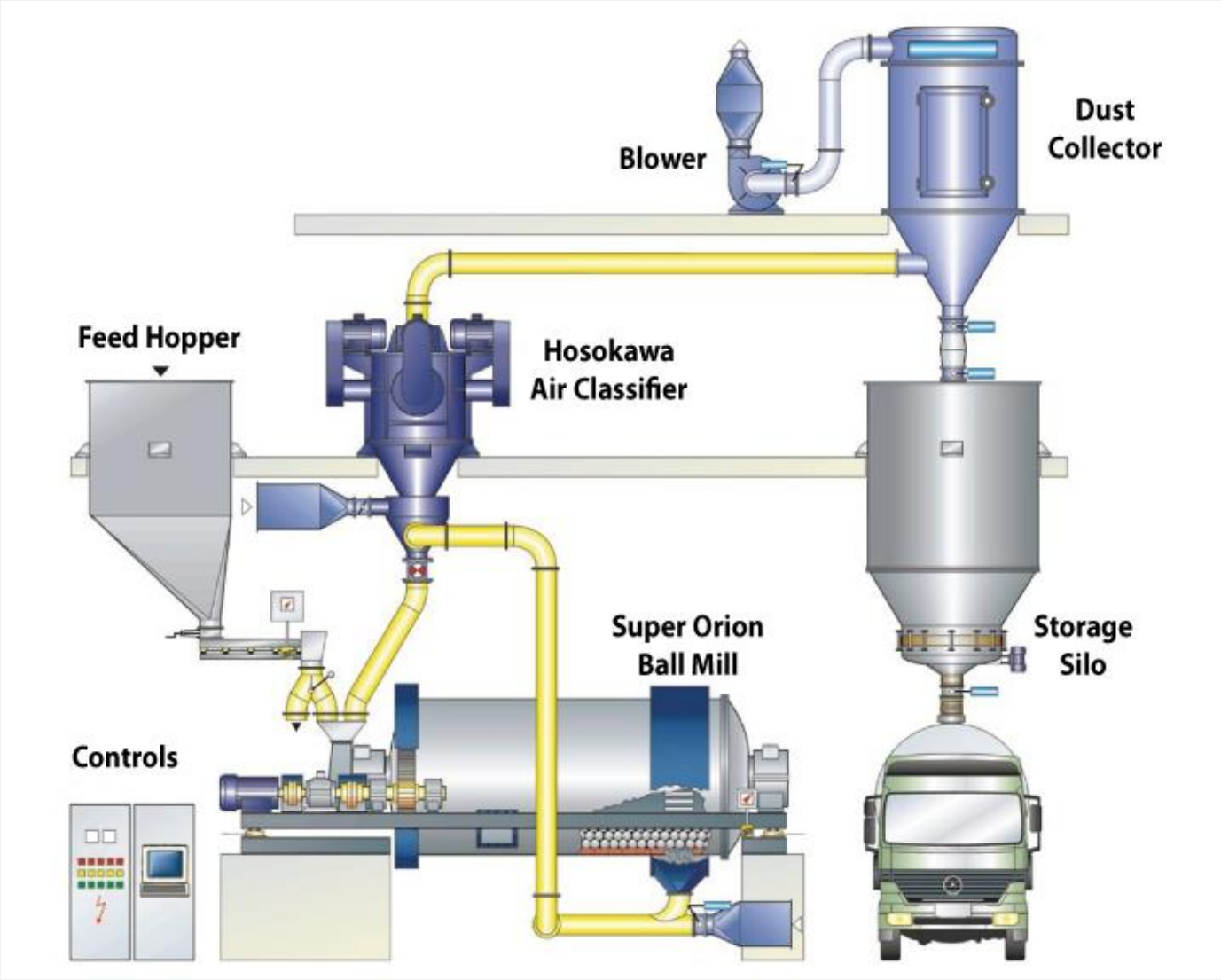
Processing of Industrial Mineral Fillers

- Calcium Carbonate
- Talcum
- Barite
- Kaolin
- Wollastonite
- Bentonite
- Diatomite
- Quartz, silica sand
- Feldspar
- Nepheline
- Zircon Sand
- Natural iron oxide
- Bauxite

Common Sizes of Industrial Mineral Fillers

- **Standard products:** **D97 = 20 – 100 µm**
- **Ultrafine products:** **D97 = 5 – 20 µm**
- **Superfine products:** **D97 < 5 µm**

Ball Mill / Classifier System



Thank you!