

Dense vs. Dilute Choosing the Right Pneumatic Conveying Method

Jonathan McPherson
Kansas State University
Keynote Speaker

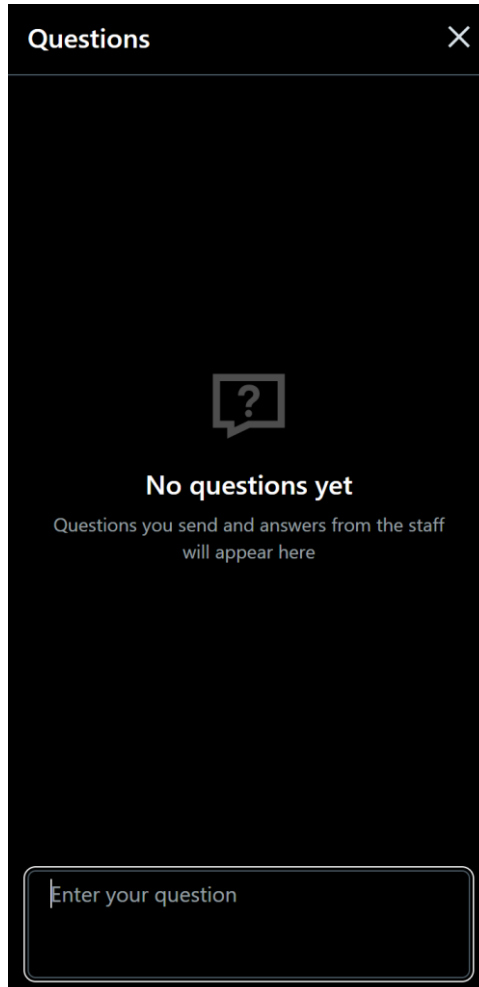
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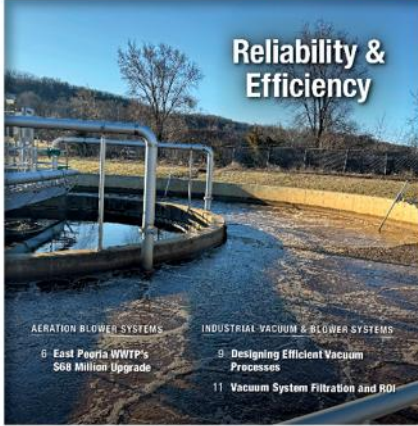
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May 2026

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 **TUESDAY, OCTOBER 13, 2026**

 **INDIANAPOLIS, IN**

- Dense vs. Dilute
- Sizing Components
- Troubleshooting



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Dense vs. Dilute Choosing the Right Pneumatic Conveying Method

Introduction

Blower & Vacuum Best Practices Magazine



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About the Speaker



Jonathan McPherson
Kansas State University

- Director, Advanced Manufacturing & Bulk Solids Technology Center, K-State
- 11 years industry experience in material handling
- Project work across plastics, PVC, paint, batteries, food
- Leads bulk solids and material handling training
- Oversees K-State's advanced manufacturing research and lab operations

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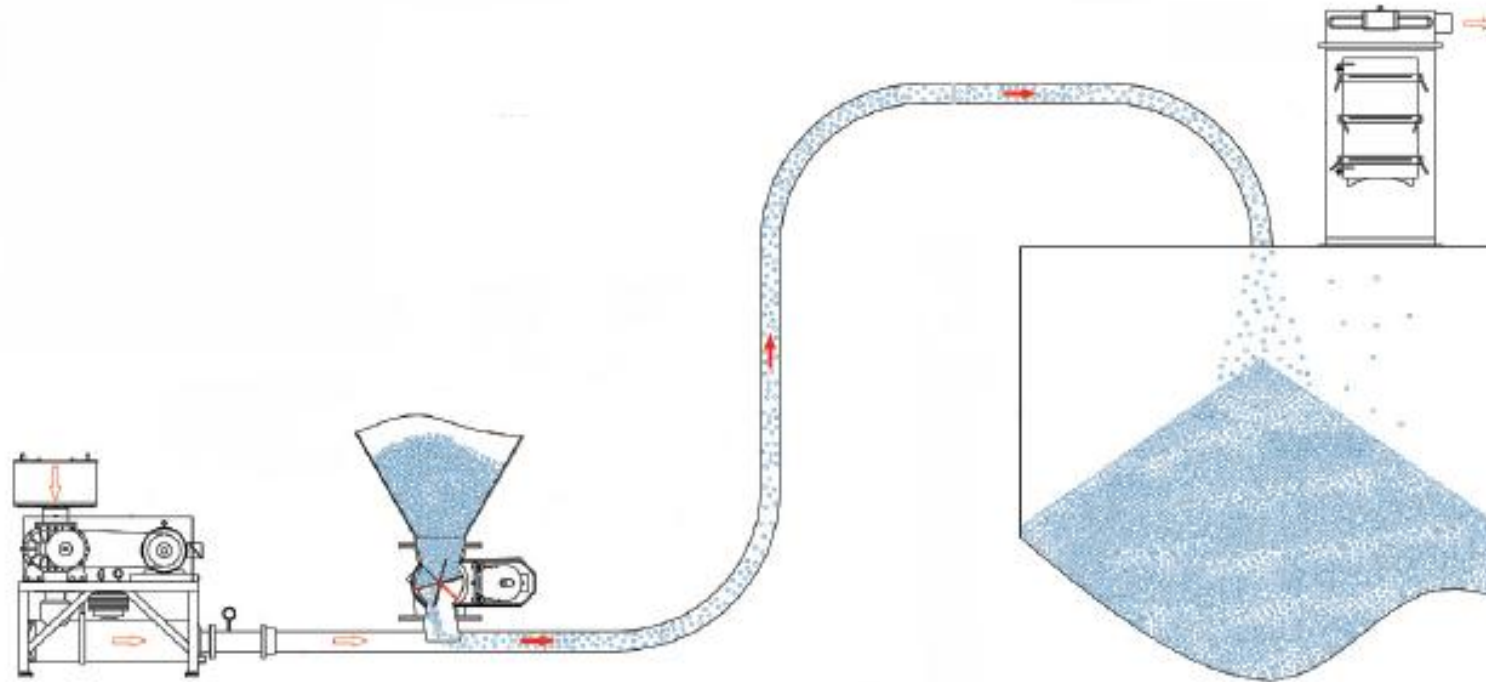
Dense vs. Dilute: Choosing the Right Pneumatic Conveying Method

July 16th 2026

Jonathan McPherson, Kansas State University

Intro to Pneumatic Conveying

Typical Dilute Phase Convey System

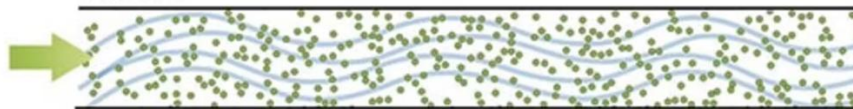


Source: processingmagazine.com | Coperion.com

Defining Dense Phase and Dilute Phase

Dilute Phase

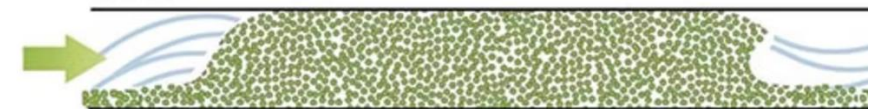
- Velocity: 4,000 ft/min +
- Pressure: 15psi or less
- Solids Ratio: 15:1 or less
- Energy Source: Lobe Blower



Source: plasticsmachinerymanufacturing.com

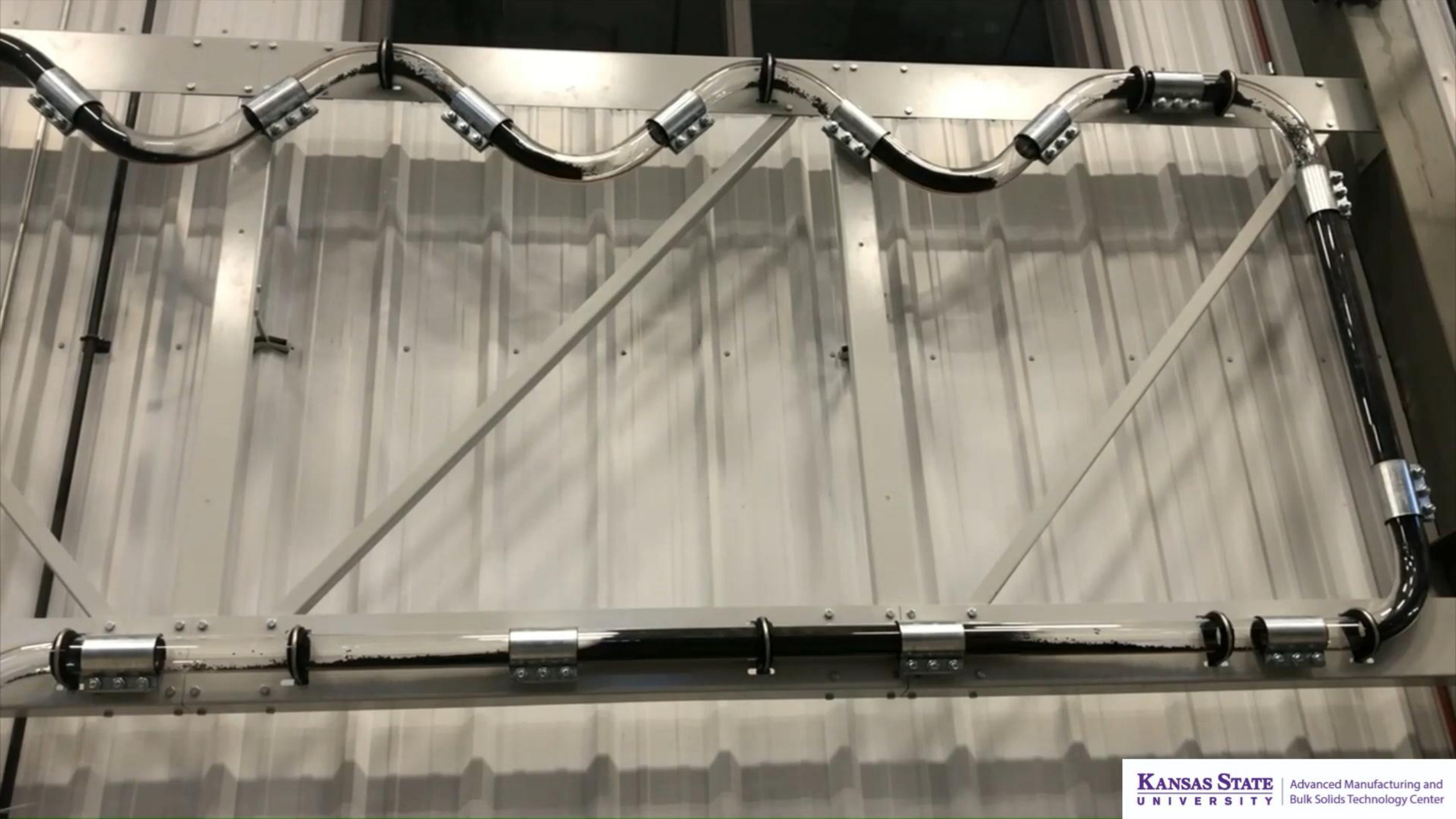
Dense Phase

- Velocity: 500-1,500 ft/min
- Pressure: 15-80 psi
- Solids Ratio: 30:1 +
- Energy Source: Air compressor or specialty blower



Source: plasticsmachinerymanufacturing.com





Where Does Dense Phase Excel

- The critical advantage to a dense phase system is the velocity of the material in the convey line
- Slower velocity leads to:
 - Minimized breakage of fragile materials
 - Reduced abrasion to the system, specifically:
 - Elbows & Piping
 - Receiver Inlets
 - Process valves
 - Additional benefit - Rotary valves can often be eliminated

Where Does Dense Phase Fall Short

- Not all materials can be moved using Dense Phase
- Materials must:
 - Be permeable - Air must be able to pass through the slug as it moves down the line - This helps form and propel the material ahead of it
 - Deaerate well - When air is trapped in the material, slugs can act like a sponge expanding & contracting - this makes the velocity unstable
 - Not remain fluidized - Otherwise material lays out in the convey line and resists forming slugs
 - Not be Compressible, Cohesive, or Interlocking - must be able to form a stable slug without compacting or binding
- Particle size distribution must also be considered
 - A broad PSD is usually advantageous

Where Does Dense Phase Fall Short

- Capital Expense – Typically higher cost due to heavier construction and specialty equipment
- Compressed Air – Typically a dedicated compressor is required
- Less forgiving – Both during commissioning, or as production needs evolve



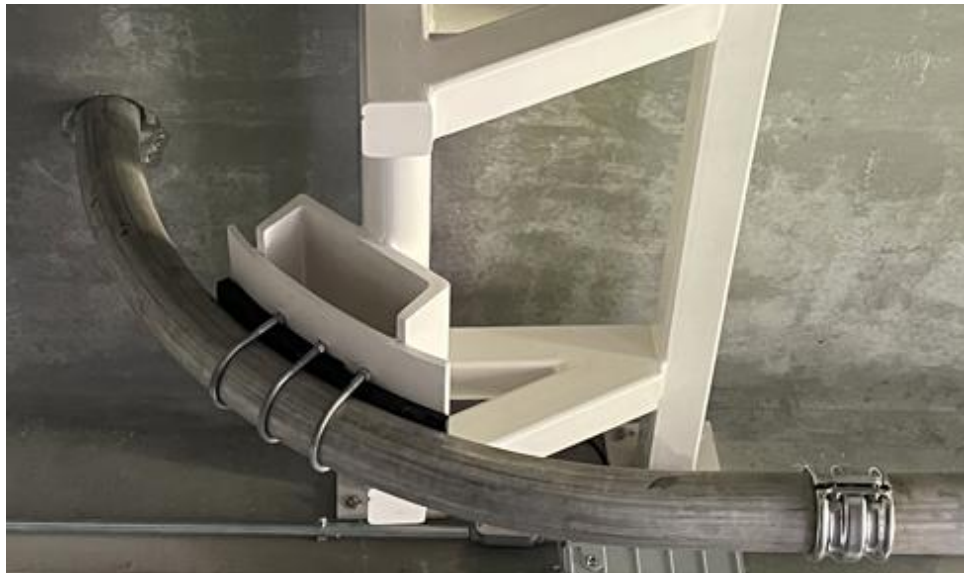
Source: Powderandbulksolids.com | Coperion K-Tron



Source: us.kaeser.com

Additional Considerations

- Pipeline Forces – Dense phase systems require robust support of the elbows and piping due to forces created by movement of the slugs



Source: Kansas State University



Source: Kansas State University

Additional Considerations

- Increased head height requirements
- Continuous operation requires careful planning



Source: rotaryvalves.co



Source: Macawber.com



Source: daniatech.com



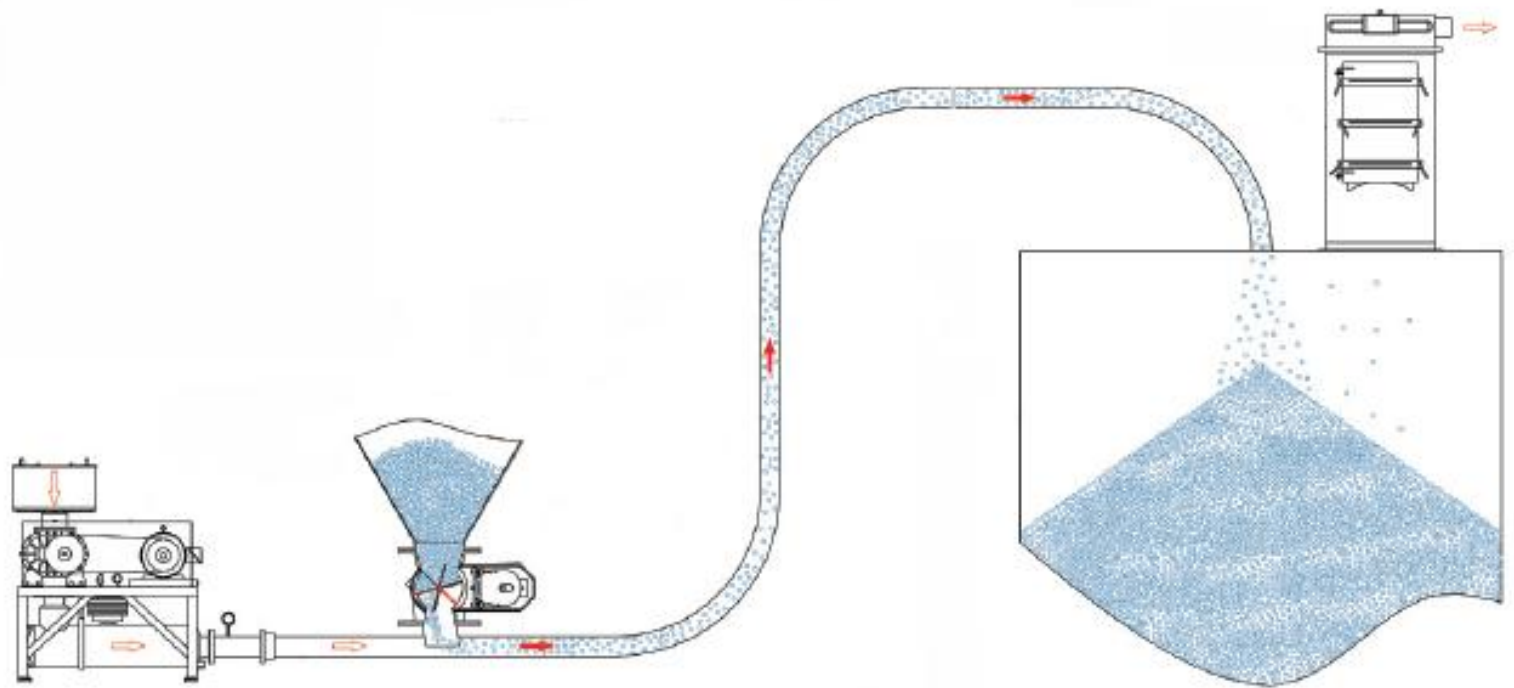
Source: gea.com

Modern Continuous Dense Phase

- True continuous operation
- Blends benefits of a dilute phase system and dense phase system together
- Typically requires specialty blower, airlock, and automation



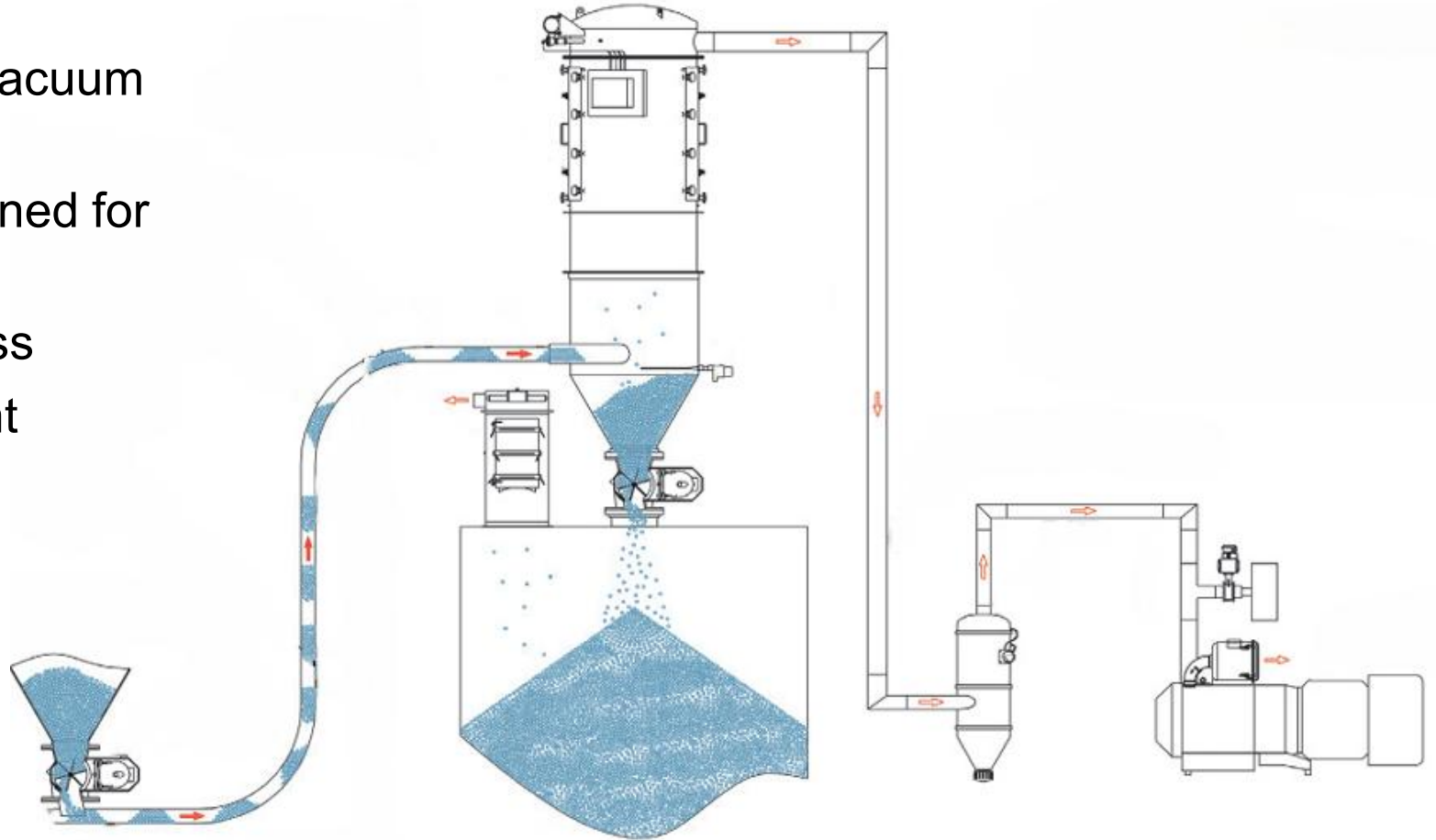
Source: Kansas State University



Source: processingmagazine.com | Coperion.com

Vacuum Dense Phase

- True continuous operation
- Typically requires specialty vacuum pump
- Components generally designed for full vacuum
- Limited to around 200ft or less
- Low head height at feed point



Source: processingmagazine.com | Coperion.com

When to Choose Dense Phase vs. Dilute Phase

- Abrasive materials
- Friable products where degradation needs to be minimized
- To maintain a homogeneous mixture
- Extreme distances (>500ft)

Good Candidates for Dense Phase

Dense Phase Candidates

- Alumina – Abrasive
- Cement - Abrasive
- Pet food - Friable
- Soda Ash - Friable
- Sand - Abrasive

It Depends

- Calcium Carbonate
- Plastic Pellets
- Sugar

Dilute Phase Candidates

- Expanded Perlite – Low density
- Flour – Easy to handle
- Grain – Easy to handle
- PVC Resin – Easy to handle
- Starch – Easy to handle
- TiO₂ – Cohesive

Best Practices

- Work with a lab or an OEM supplier to test your material at scale
- Take in historical knowledge from your supplier
- Seek out a site tour or existing operation whenever possible
- Proper design of pipe supports is critical

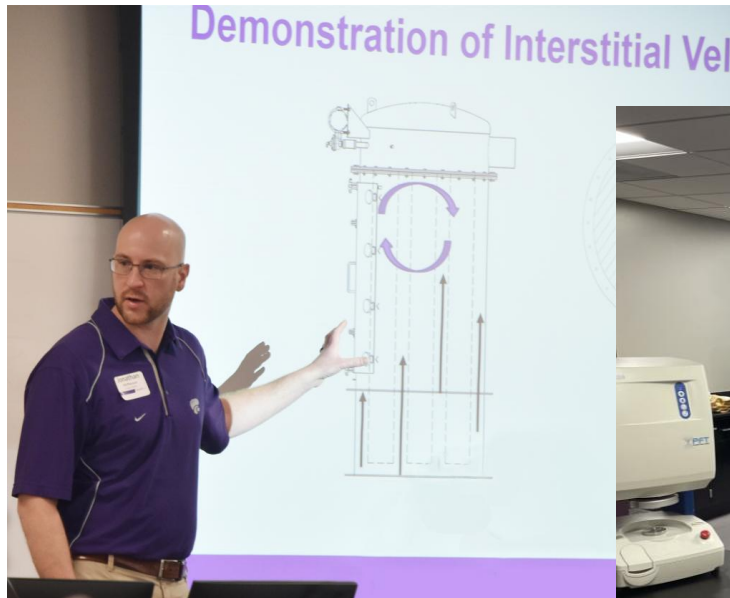
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About the Speaker



Stephen Horne
Kaeser

- Blower Product Manager at Kaeser Compressors
- 20+ years designing blower systems for wastewater aeration
- Active in CAGI's Blower & Vacuum section, developing testing and reporting standards

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Design Considerations for Blowers Used in Pneumatic Conveying

By: Stephen Horne – Kaeser Compressors



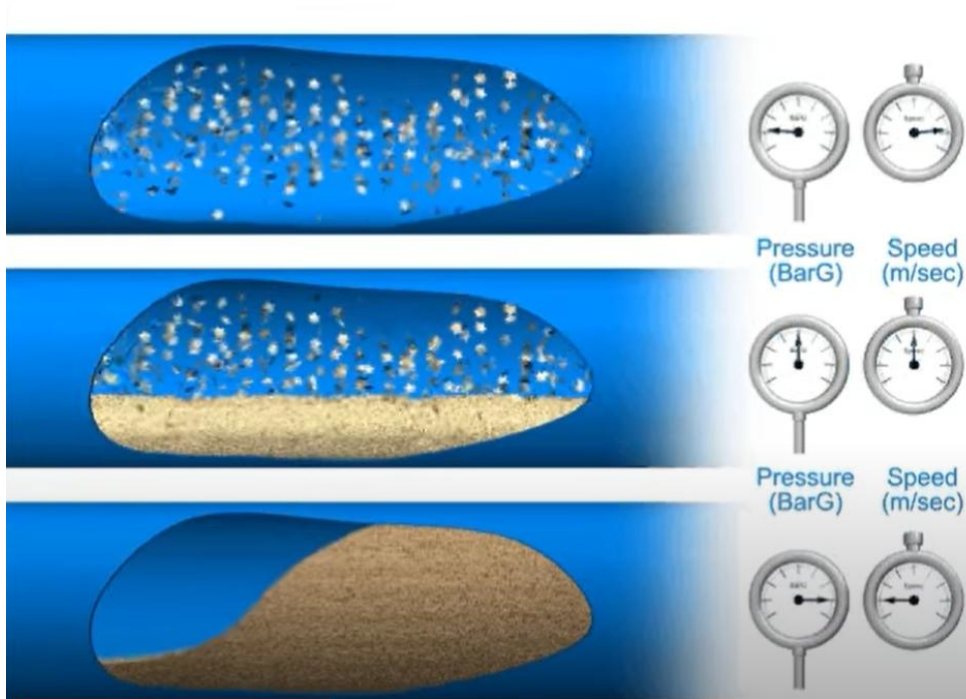
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Topics

- Types of pneumatic conveying
- Blower technologies
- Technology considerations
- Blowers and blower packages
- Environmental impacts on blowers

Types of Pneumatic Conveying



Dilute phase conveying

- High velocity
- Low pressure

Semi-dense phase conveying

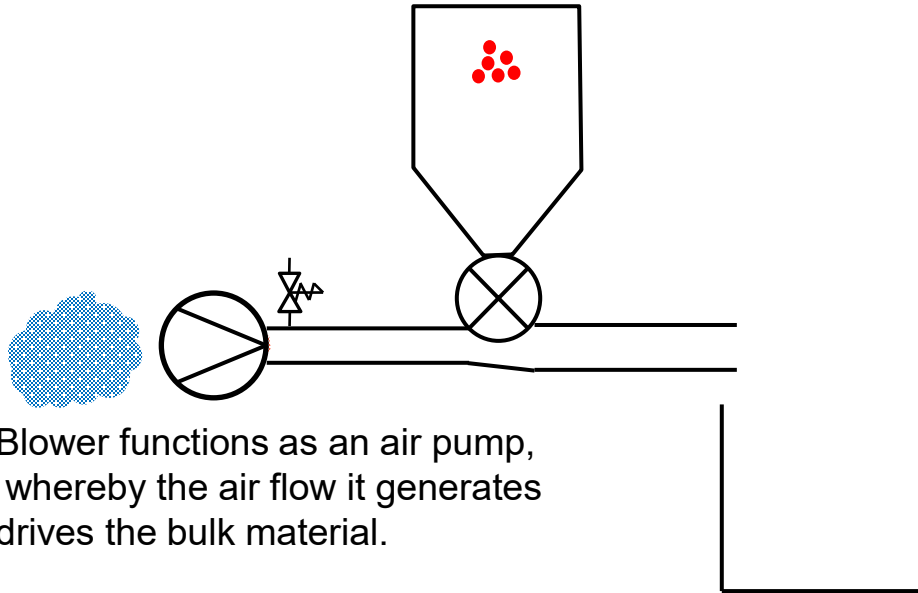
- Medium velocity
- Medium pressure

Dense phase conveying

- Low velocity
- High pressure

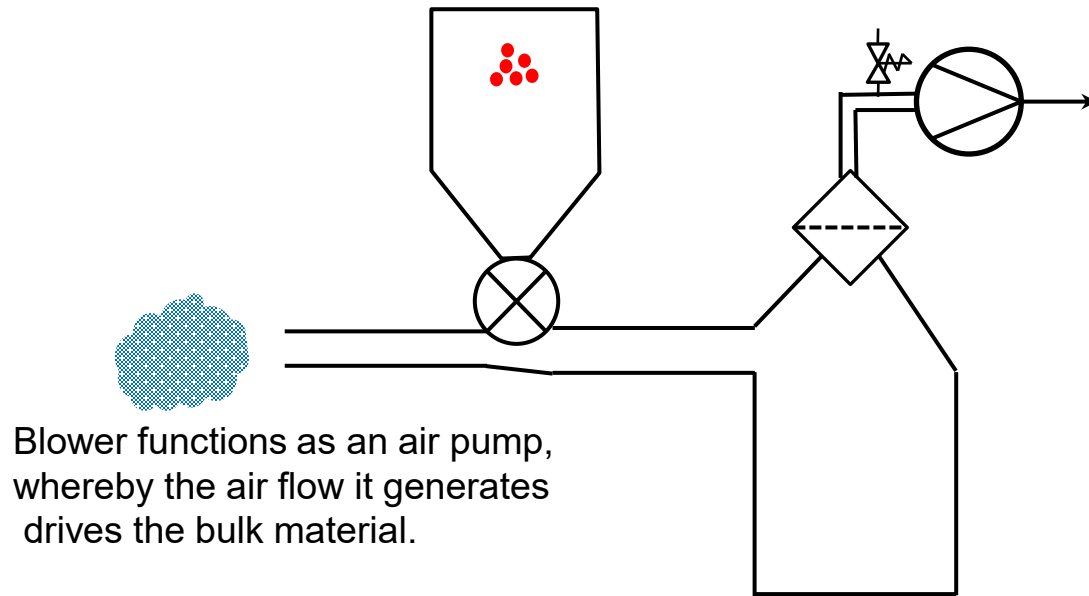
Types of Pneumatic Conveying

Pneumatic conveying – Gauge pressure operation

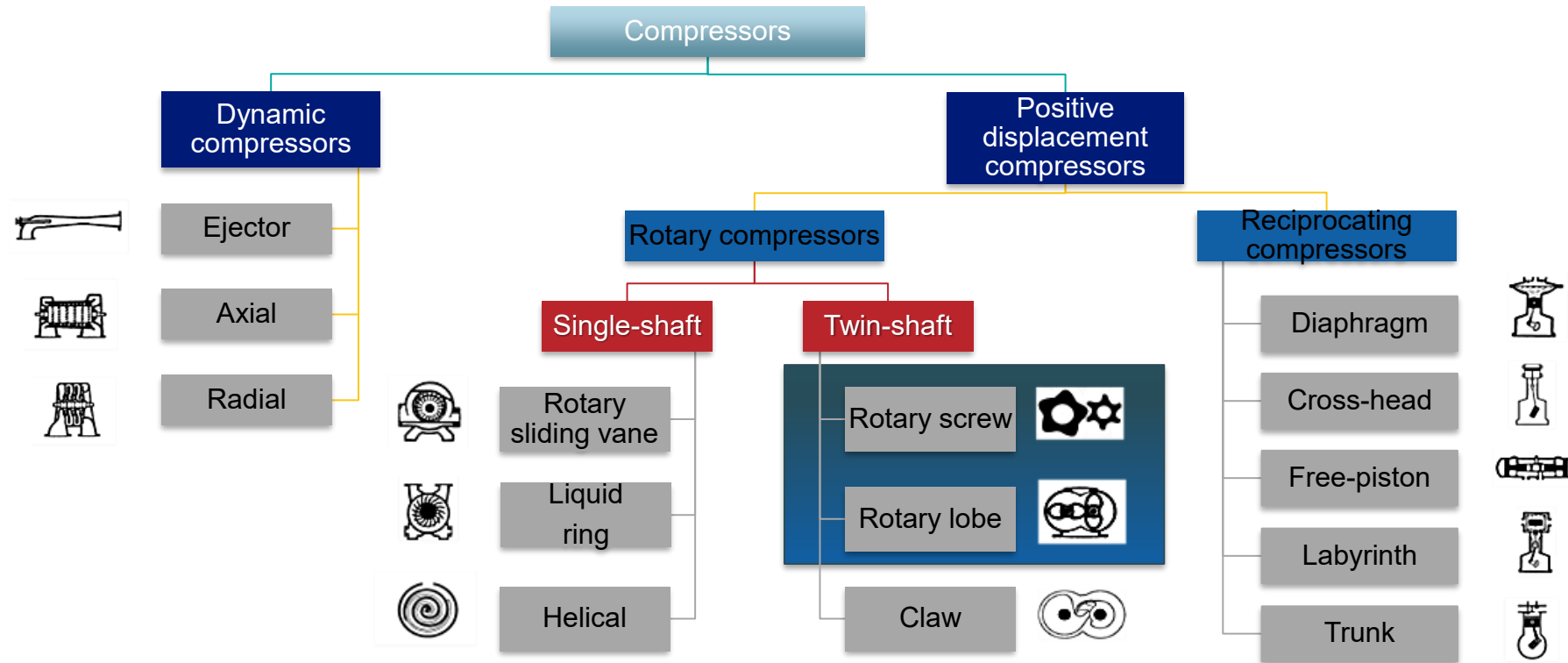


Types of Pneumatic Conveying

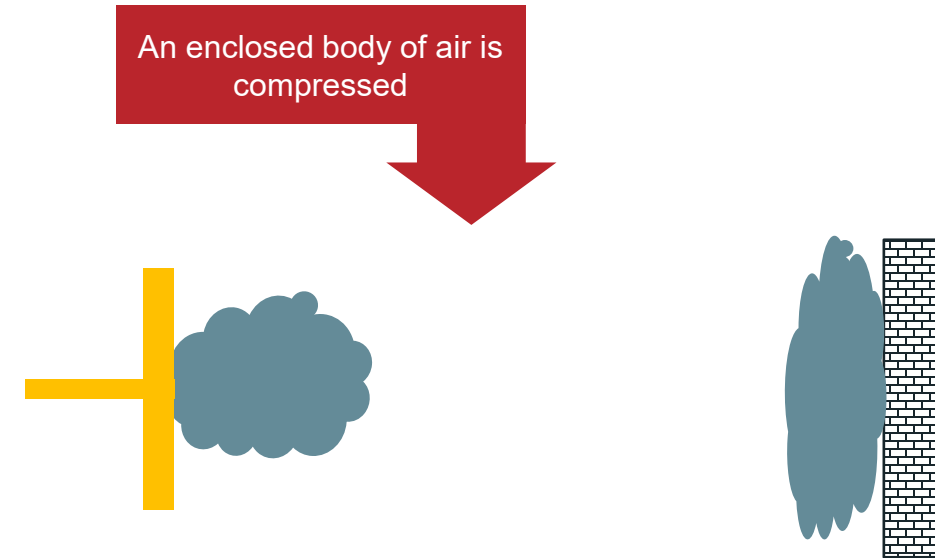
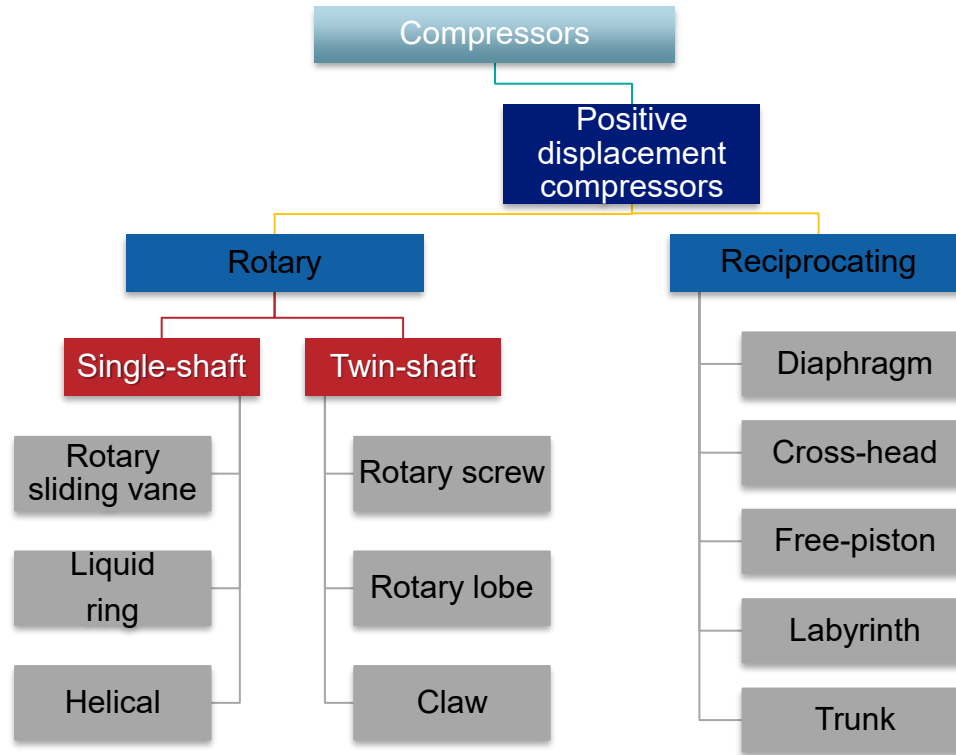
Pneumatic conveying – Vacuum operation



Blower Technologies

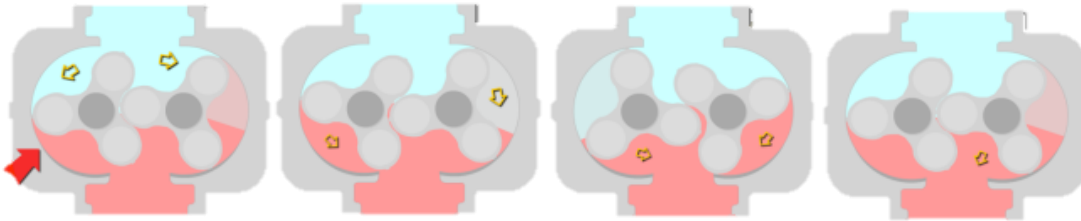


Blower Technologies



Blower Technologies

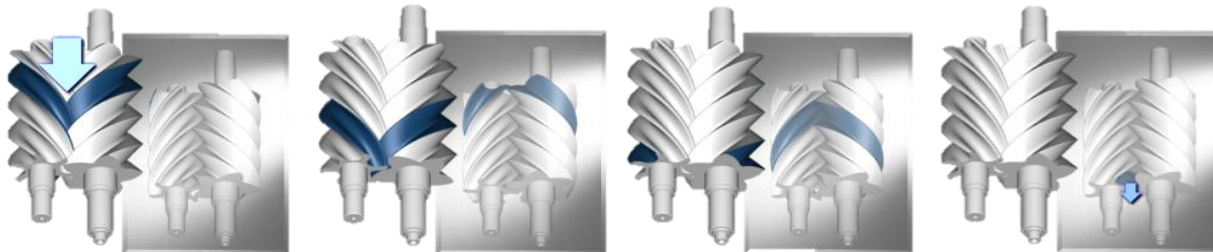
– Rotary lobe blowers:



Volume remains constant
= **external compression.**

Displacement of the full volume against the prevailing back pressure in the process piping (adaptive) = external compression.

– Rotary screw blowers:



Progressive rotation of the rotors gradually reduces the volume of an enclosed body of air
= **Internal compression.**

Displacement of smaller volumes against the back pressure in the process line
= less displacement work required.

Blower Technologies

- Efficiency

- Isentropic Efficiency

- Isentropic efficiency in air compressors, as defined by the [Compressed Air and Gas Institute \(CAGI\)](#), is a measure of how efficiently a compressor converts electrical energy into compressed air potential energy, compared to an ideal, isentropic process. It's a ratio that helps compare the energy consumption of different compressors, regardless of their specific technology or operating pressure

$$\eta_{isen} = \frac{16.52 \times \left(\left(\frac{p_2 + 14.5}{14.5} \right)^{0.2857} - 1 \right)}{P_{spec}}$$

η IS FOR EFFICIENCY
"ISEN" IS AN ABBREVIATION
FOR ISENTROPIC

COMPRESSOR
SPECIFIC
POWER = $\frac{\text{KW}}{\text{CFM}}$



Blower Technologies

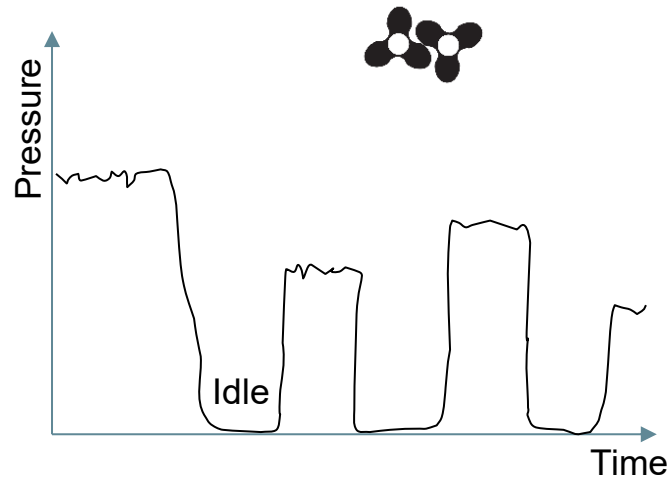
Type	Description	Isentropic Efficiency*
Rotary Lobe	Positive Displacement Adaptive Pressure	45-65%
Rotary Screw	Positive Displacement Internal Compression	65-80%

* Isentropic efficiency varies with operating pressure and blower speed

Blower Technologies

Lobe vs Screw – Principle areas of application

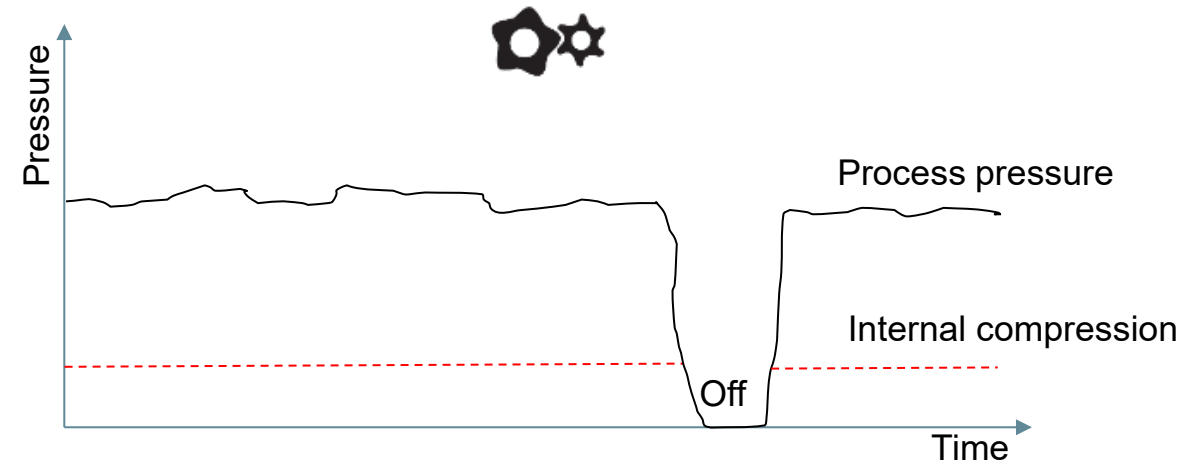
rotary lobe blower



Processes with a large proportion of time spent at idle
Low pressures, few operating hours

☞ **Pneumatic conveying – Dilute Phase**

rotary screw blower



Differential pressures > 7 psi to 30+ psi
Operating hours > 4000 h per year
(Energy costs [\$] = $P \text{ [kW]} \times t \text{ [h]} \times \text{rate} \text{ [$/kWh]}$)

☞ Dilute phase, fluidisation, dense phase

Blower Package Types

Incomplete:
External power electronics

Without sound enclosure



With sound enclosure



Complete:
Integrated power electronics

With sound enclosure



Environmental Impacts

Typical Lobe Blower Characteristic Curve

Intake conditions: Air at +68°F / 14.7 psia

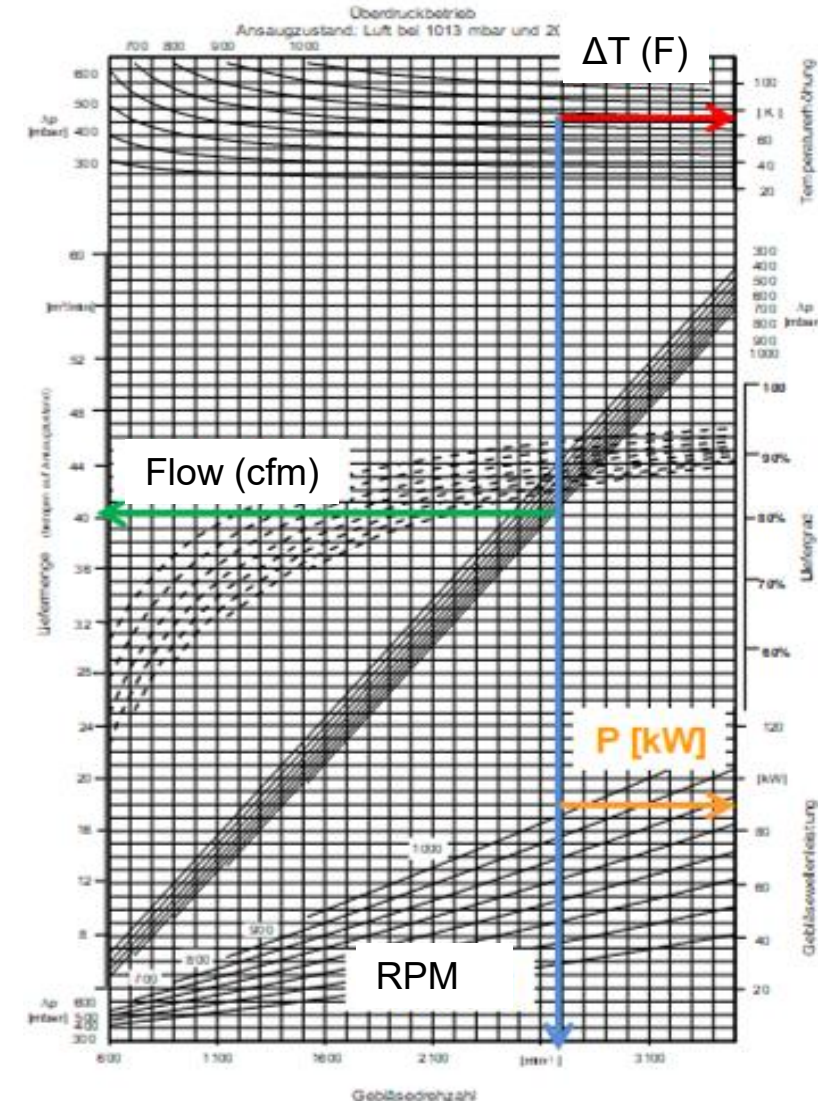
Max. compression ratio: p_2/p_1 less than/equal to 2

Vacuum operation ⇨ 15"Hg-V

Gauge pressure operation ⇨ 15 psig

Additional operating limits:

- **Discharge temperature: max. 320°F**
- Max. temperature differential 216°F
- Elevation matters !
- Ambient temperatures matter !
- Pressure Surges ? Always good to pressure and power reserve





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Dilute phase systems typically operate at what pressure range?

A

- Under 15 psi

B

- 30–80 psi

C

- Over 100 psi

Dense vs. Dilute Choosing the Right Pneumatic Conveying Method

Q&A

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Peter Vinck
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