Dense vs. Dilute Choosing the Right Pneumatic Conveying Method

Jonathan McPherson
Kansas State University
Keynote Speaker

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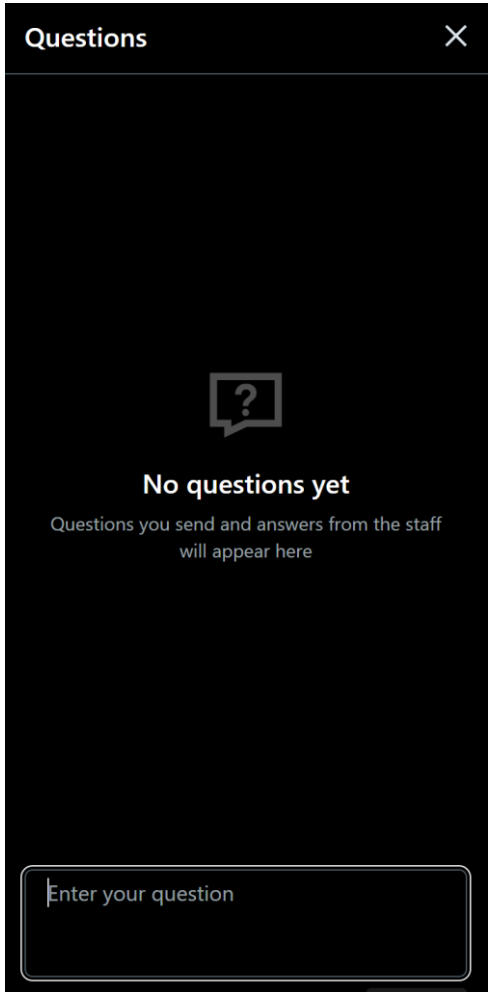

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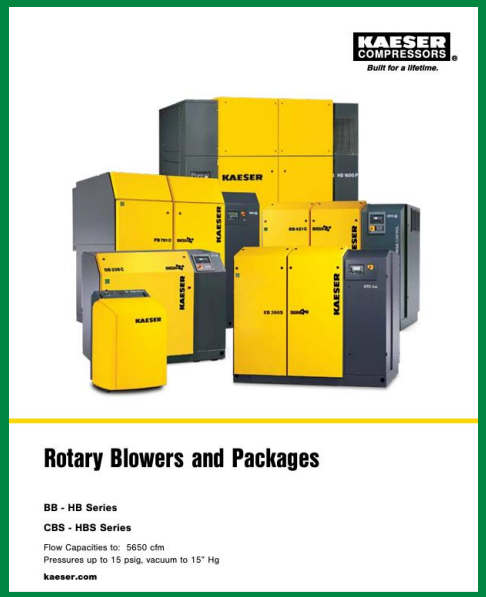

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INDIANPOLIS, IN

- **Dense vs. Dilute**
- **Sizing Components**
- **Troubleshooting**

INSTRUCTOR
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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

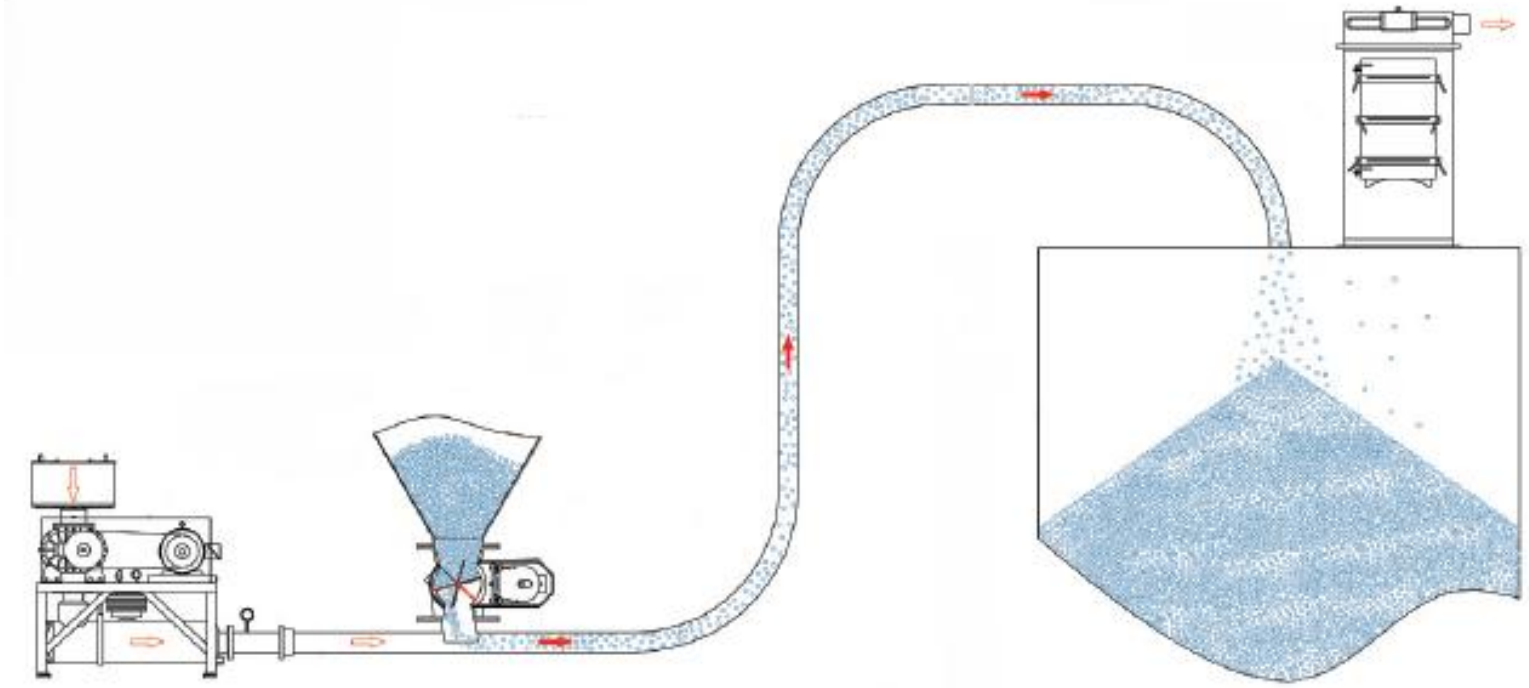
Dense vs. Dilute: Choosing the Right Pneumatic Conveying Method

July 16th 2026

Jonathan McPherson, Kansas State University

Intro to Pneumatic Conveying

Typical Dilute Phase Convey System



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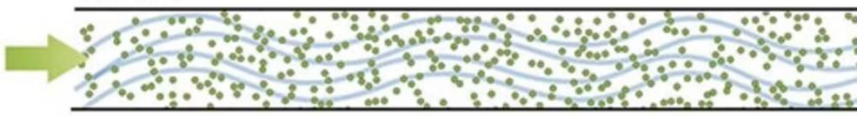
Defining Dense Phase and Dilute Phase

Dilute Phase

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

Dense Phase

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



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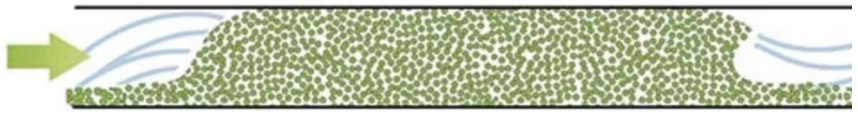

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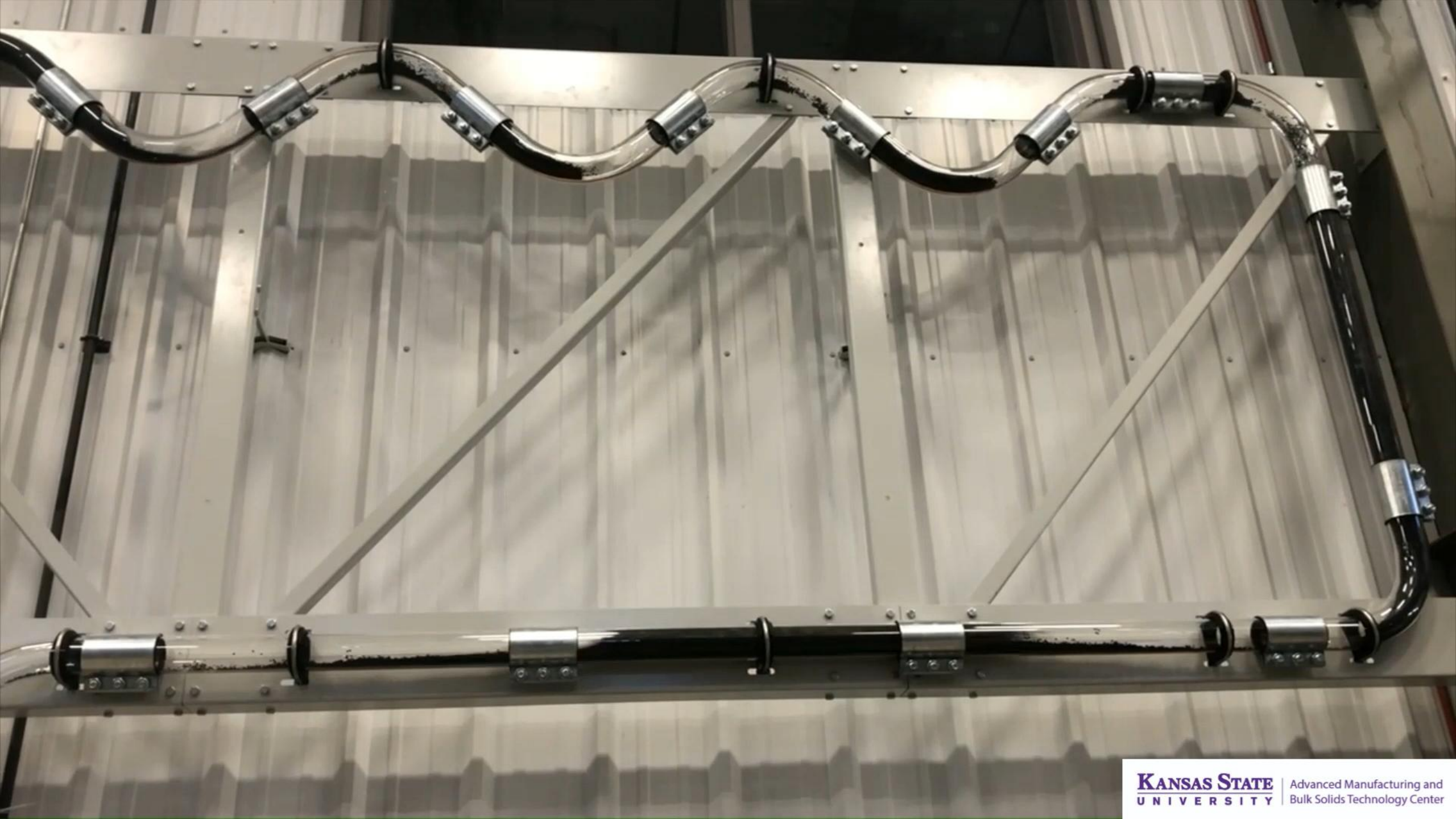


Where Does Dense Phase Excel

- 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 on binding
- Particle size distribution must also be considered
  - A broad PSD is usually advantageous

Where Does Dense Phase Fall Short

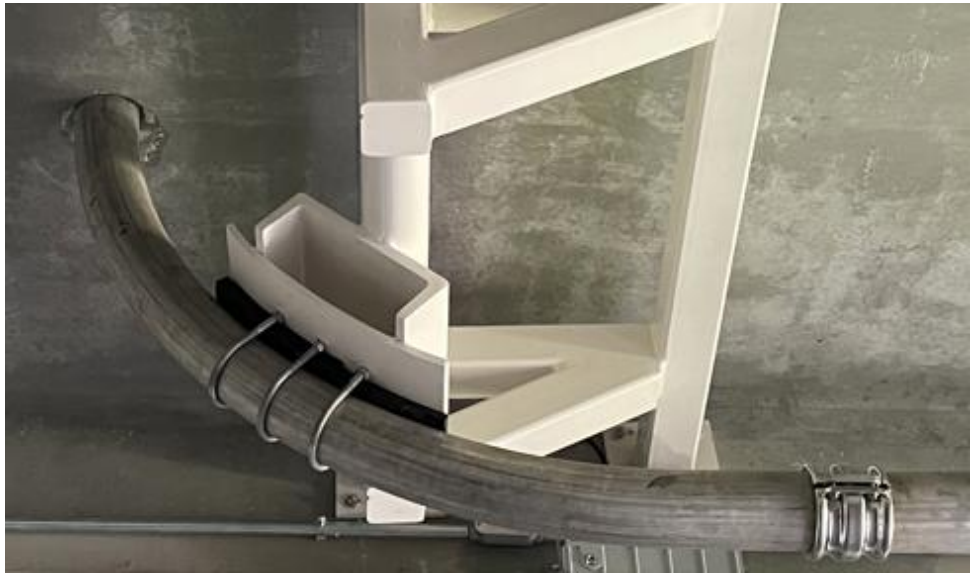
- Capital Expense – Typically higher cost due to heavier construction and specialty equipment
- Compressed Air – Typically a dedicated compressor is required
- Less forgiving – Both during commissioning, or as production needs evolve

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

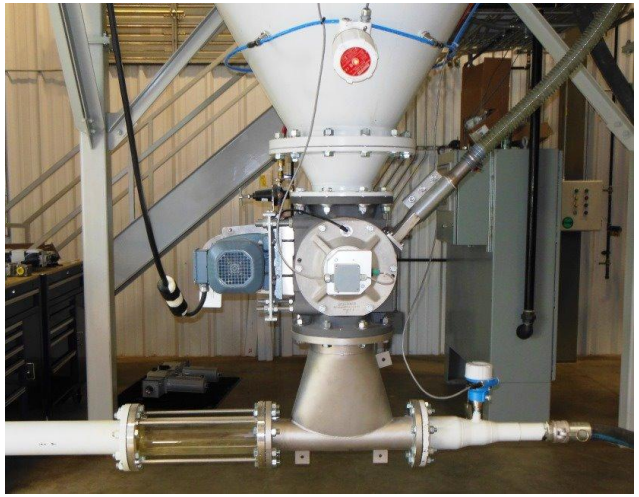
Source: Macawber.com

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



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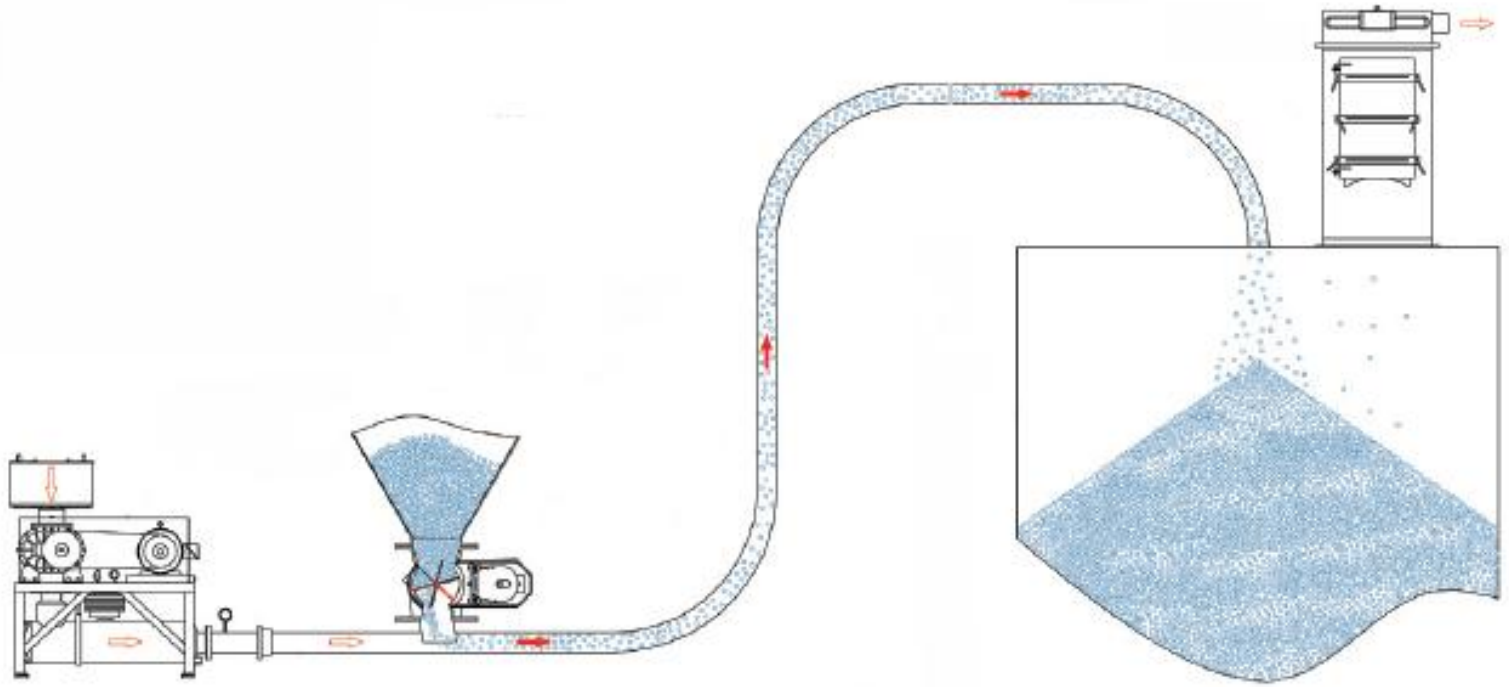

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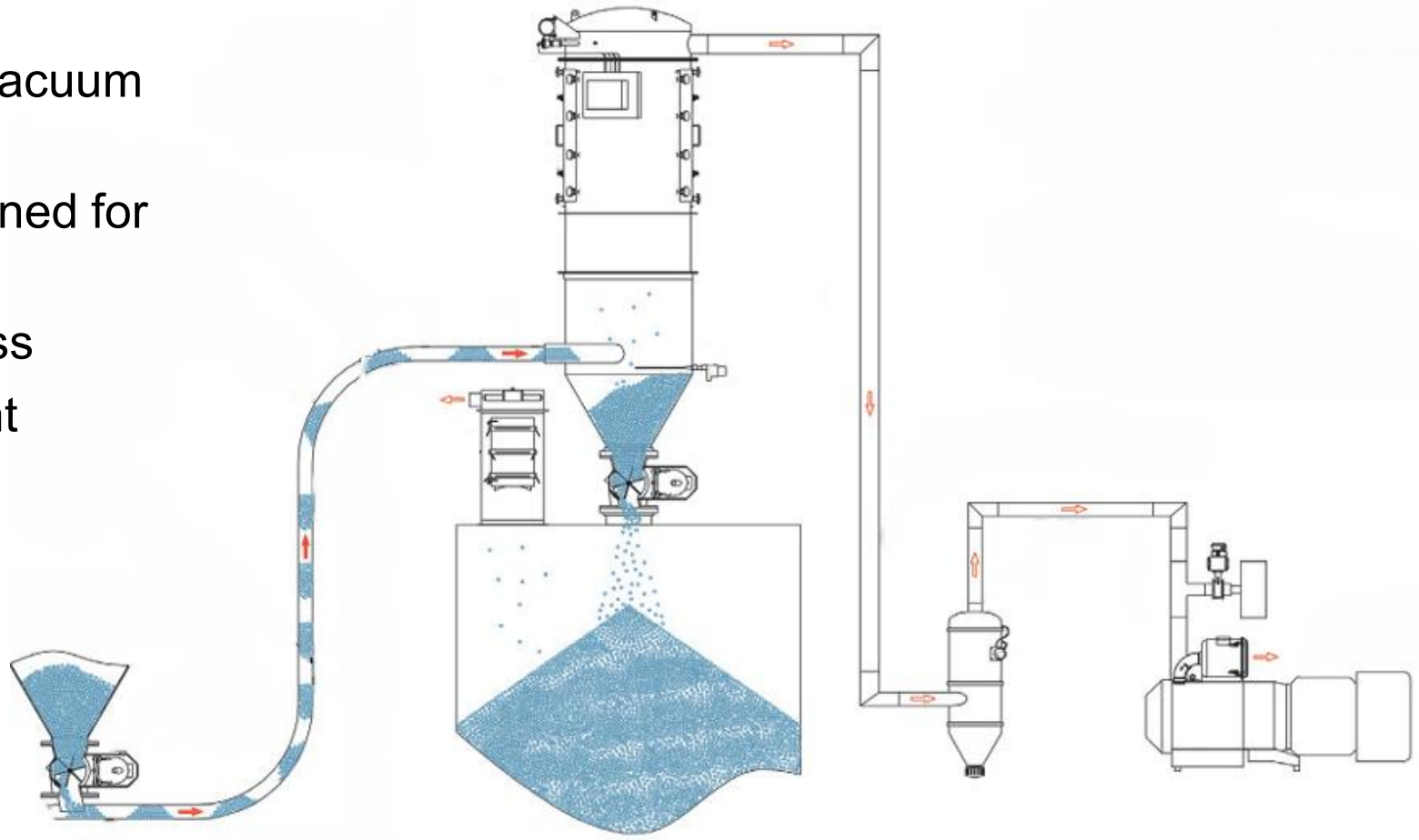
Vacuum Dense Phase

- 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



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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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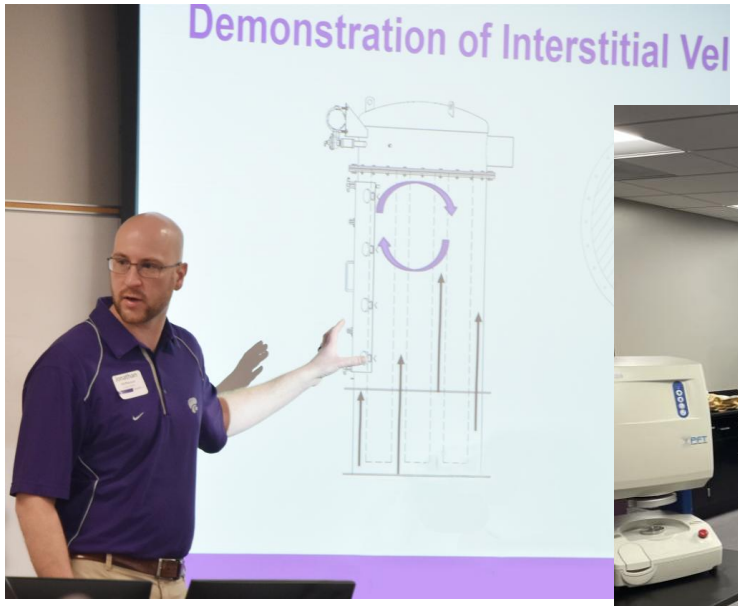

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About the Speaker

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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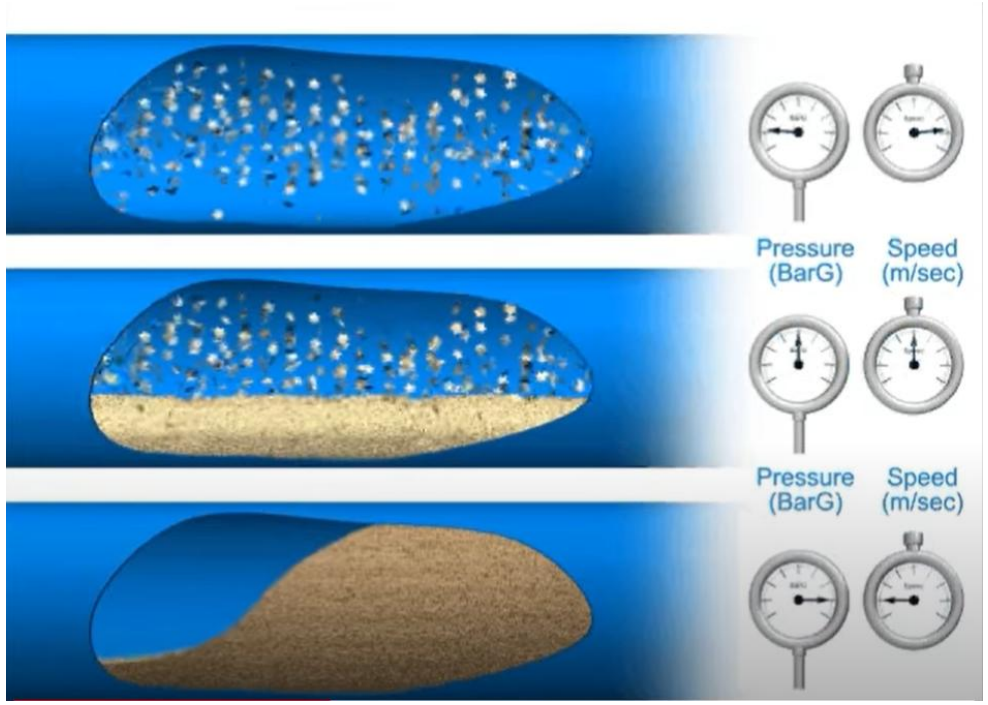
Topics

- 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

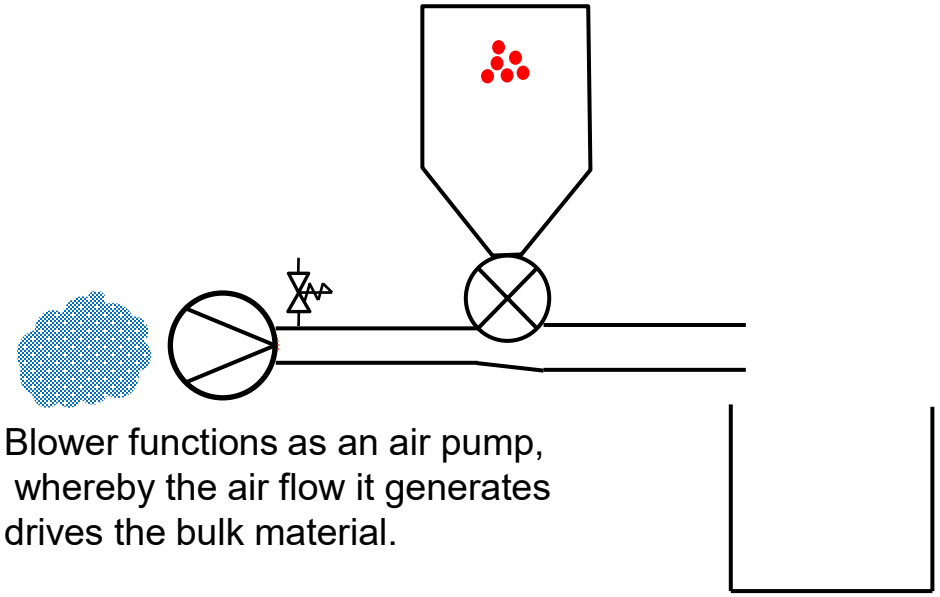
- Medium velocity
- Medium pressure

Dense phase conveying

- Low velocity
- High pressure

Types of Pneumatic Conveying

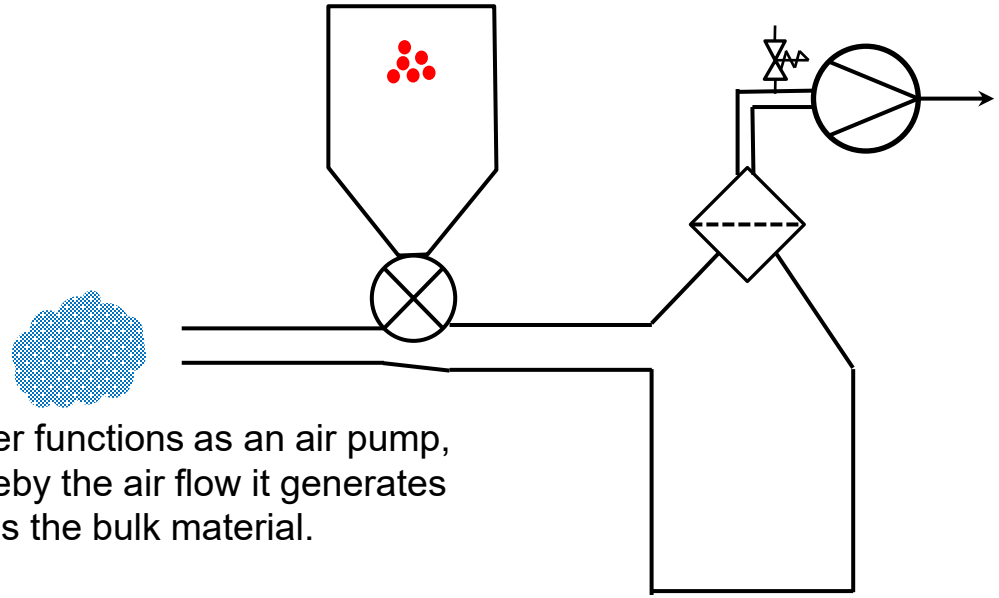
Pneumatic conveying – Gauge pressure operation



Blower functions as an air pump, whereby the air flow it generates drives the bulk material.

Types of Pneumatic Conveying

Pneumatic conveying – Vacuum operation



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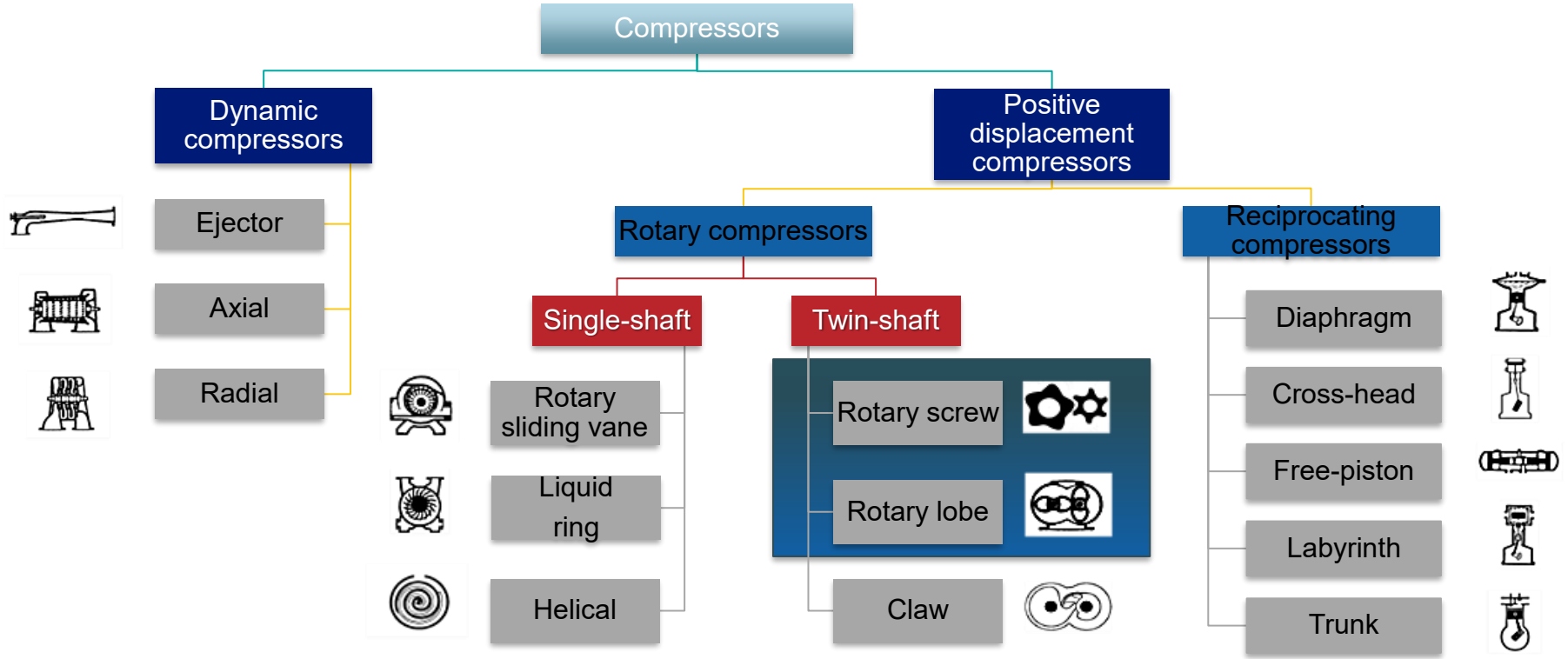
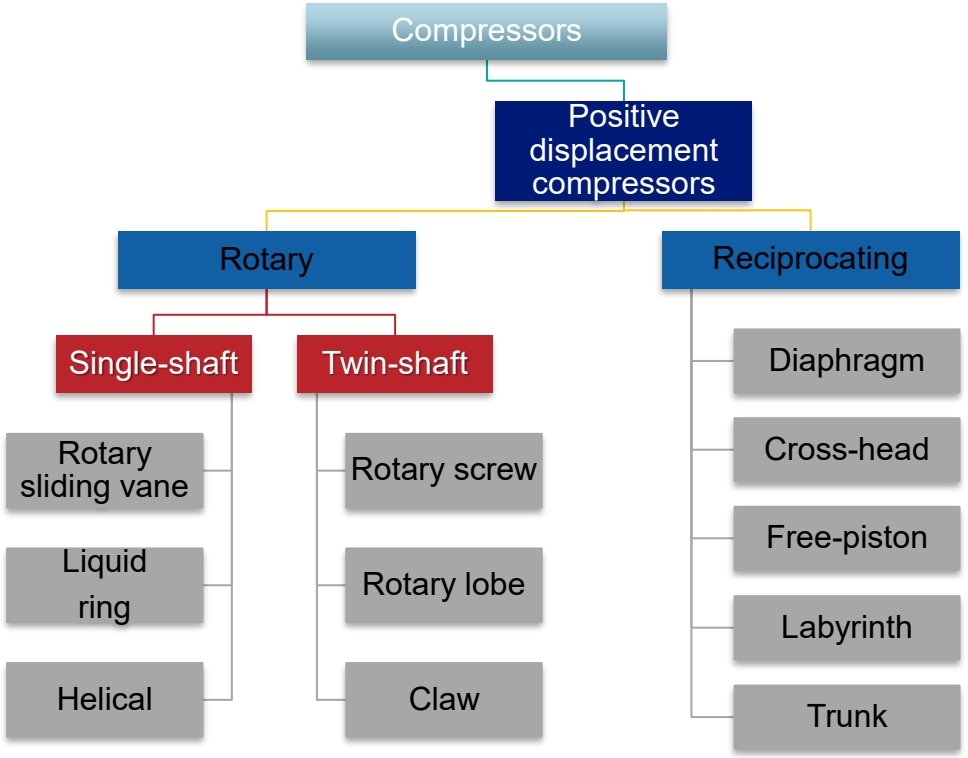
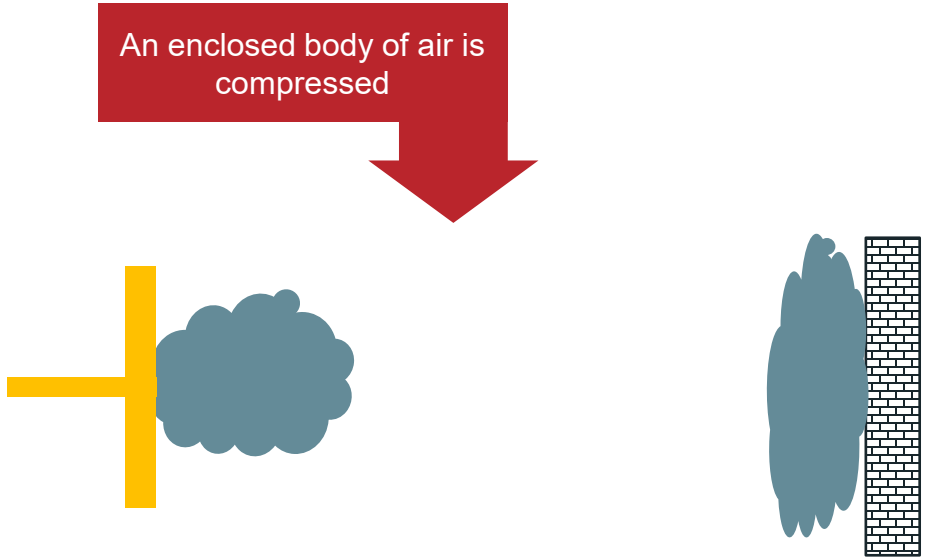
Blower Technologies



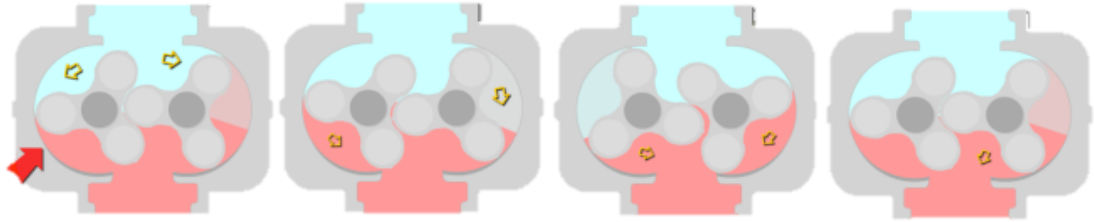
Blower Technologies





Blower Technologies

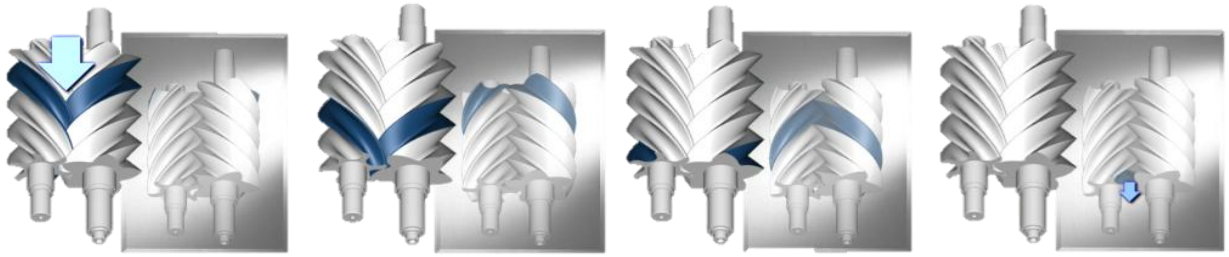
– Rotary lobe blowers:



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

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

Blower Technologies

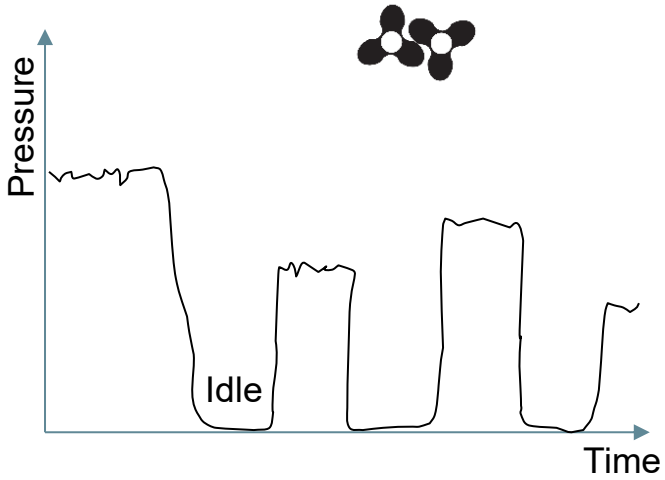
Type	Description	Isentropic Efficiency*
Rotary Lobe	Positive Displacement Adaptive Pressure	45-65%
Rotary Screw	Positive Displacement Internal Compression	65-80%

* Isentropic efficiency varies with operating pressure and blower speed

Blower Technologies

Lobe vs Screw – Principle areas of application

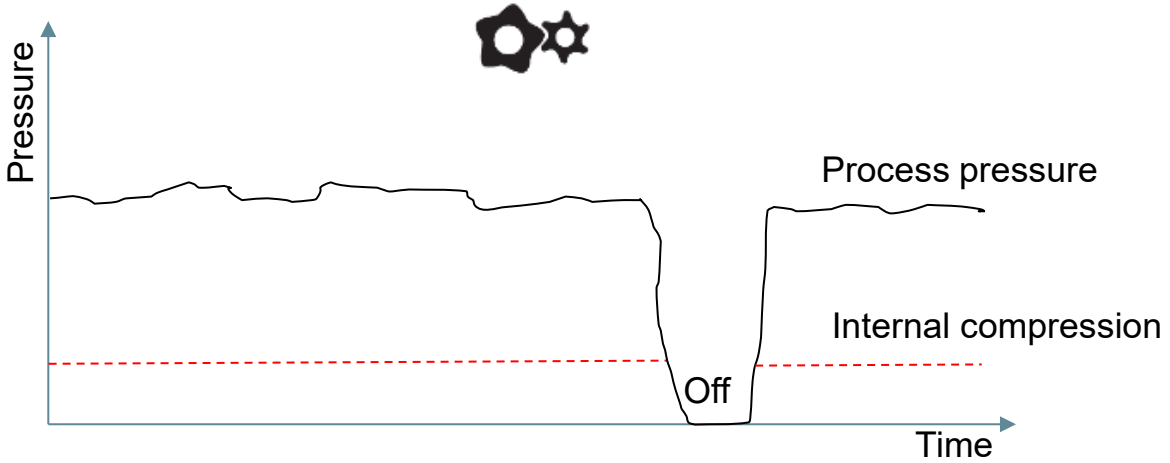
rotary lobe blower



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

☞ **Pneumatic conveying** – Dilute Phase

rotary screw blower



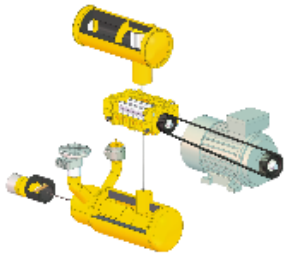
Differential pressures > 7 psi to 30+ psi
Operating hours > 4000 h per year
(Energy costs [$]= P [kW] x t [h] x rate [$/kWh])

☞ 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

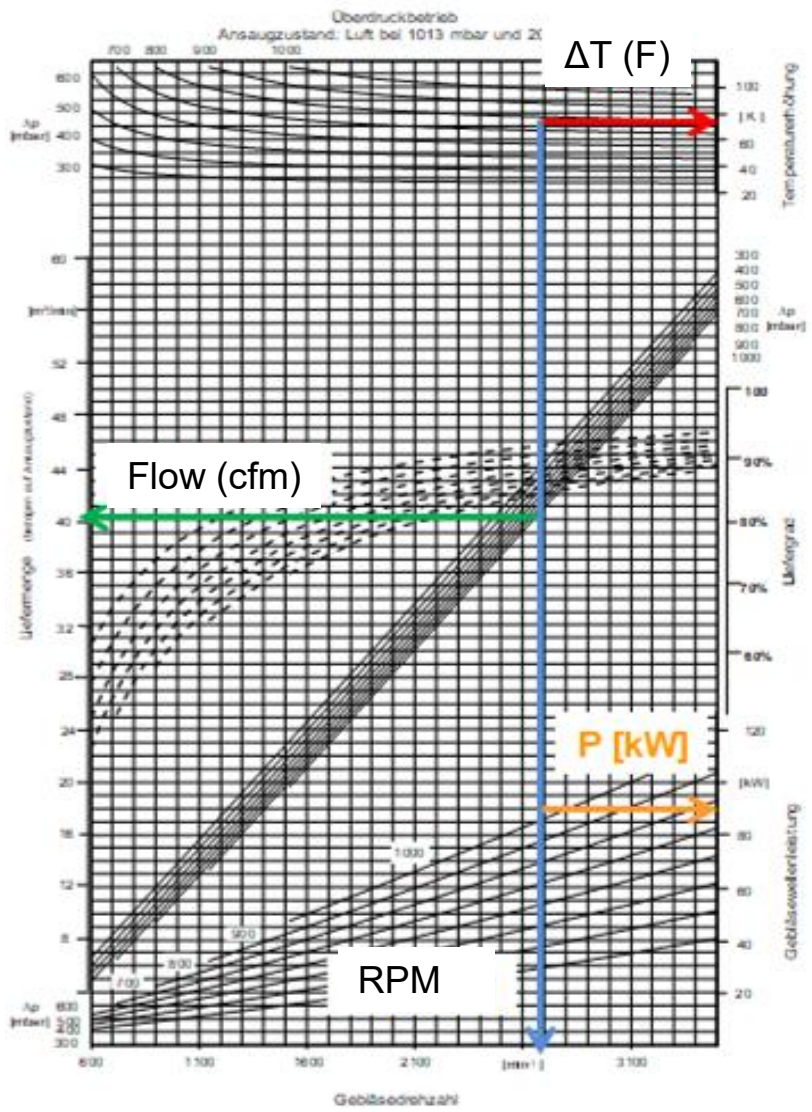
Typical Lobe Blower Characteristic Curve

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

Max. compression ratio: p2/p1 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 temperaturas 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

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Q&A

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