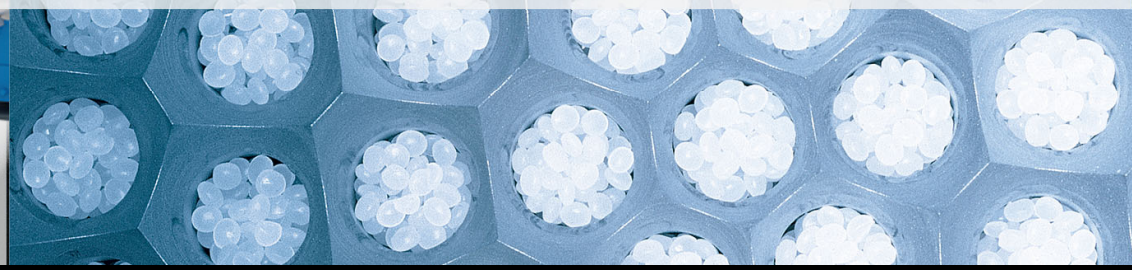
Material Handling – Basic Principle

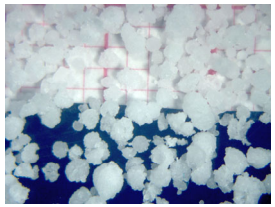
Christoph Schumacher – General Manager Materials Handling Plants & Systems

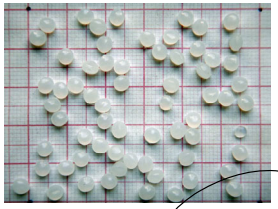


Powders & Pellets

Examples of Bulk Materials

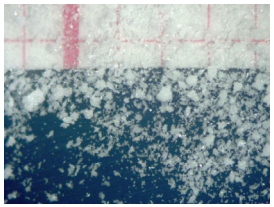
Plastics

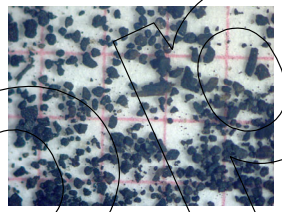

LLDPE Powder

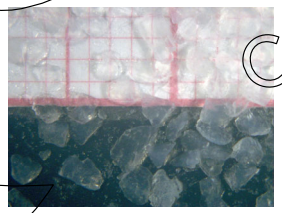

LLDPE Pellets


PP Flakes

Minerals


Lithium Carbonate


Brown coal dust


Silica Sand

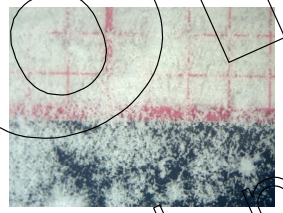
Food


Lactose


Pressed apple


Coffee

Natural products

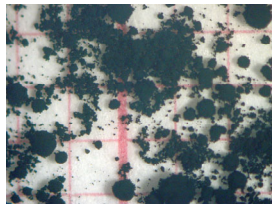

Cellulose


Shredded wood


Tobacco

Others


Furnace slag


Carbon Black


Biopolymer

Powders & Pellets

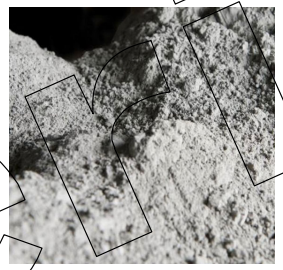
Examples in Food, Minerals & Chemicals

Brown coal

Wood chips

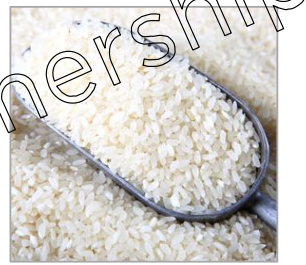
Fluff

Cement



Milk powder

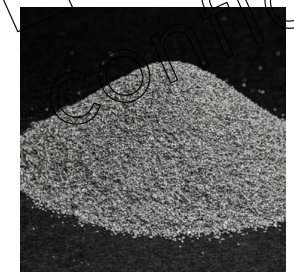
Rice



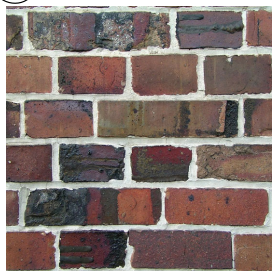
Dry sludge

Quartz sand

Al_2O_3 + Korund



Clinker dust



Coffee, chocolate

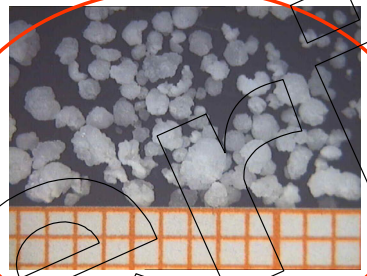
Animal food

Powders & Pellets

Examples in Plastics & Chemicals

Powder / Granules / Flakes (from Reaction / Polymerisation)

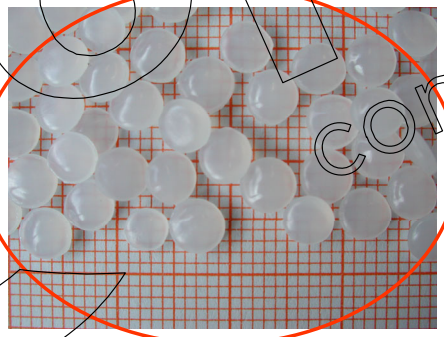
approx. 80µm

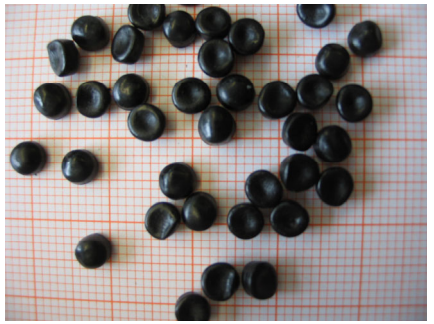


approx. 600µm

approx. 1200µm

Pellets (under water pelletized /extruded)





Plastics & Chemicals

Characteristics

General bulk solids evaluation

- Accumulating / caking
- Forms wall deposits
- Strength of particles/agglomerates
- Adhesive
- Bridging due to particle shape
- only when deaerated
- due to cohesion
- Free-flowing
- Fluidizable
- Erratic flow
- Particle hardness
- Agglomerating

Typical measured Bulk Solids data

Product / Grade / Trade Name

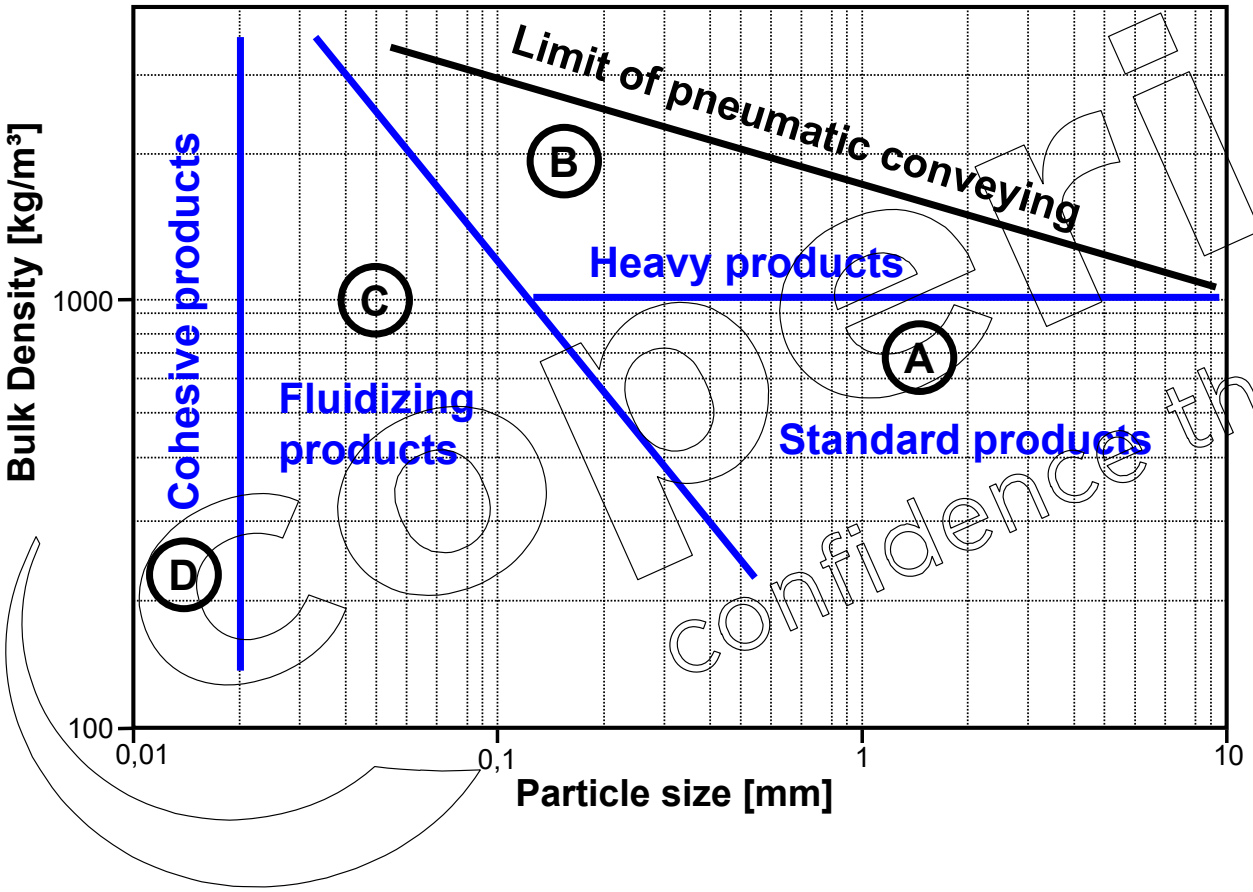
- Solid / Particle Density
- Bulk Density / Packed Density
- Particle size / distribution

- Product Temperature

- Particle Shape
- Strand / Under water cut
- E-Modulus / Secant Modulus
- MFI

Plastics & Chemicals

Geldart Diagram



nach R. Pan

A Dilute / Strand conveying, (unstable area)
Slug Phase conveying

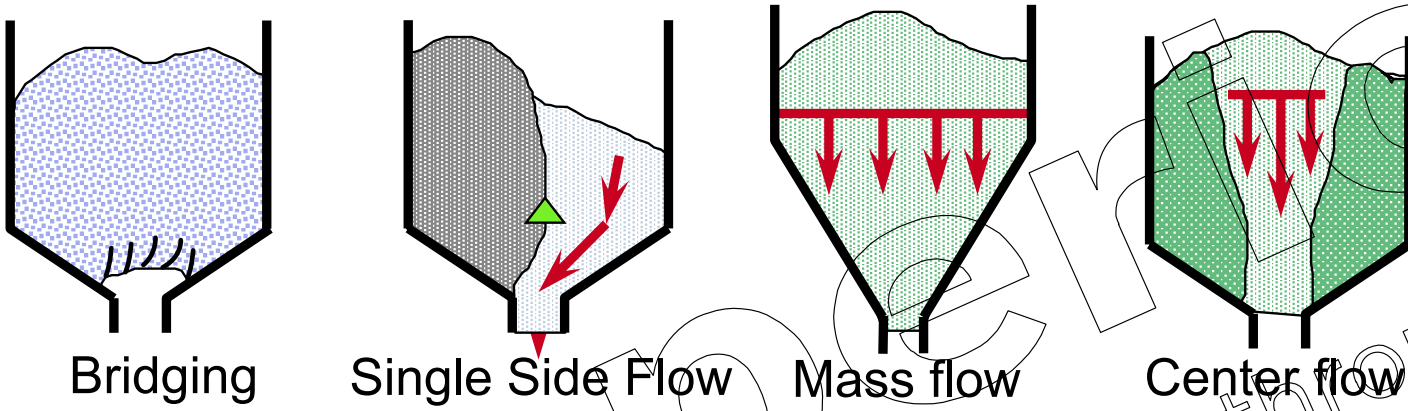
B Dilute Phase conveying without pressure minimum (Deposits)

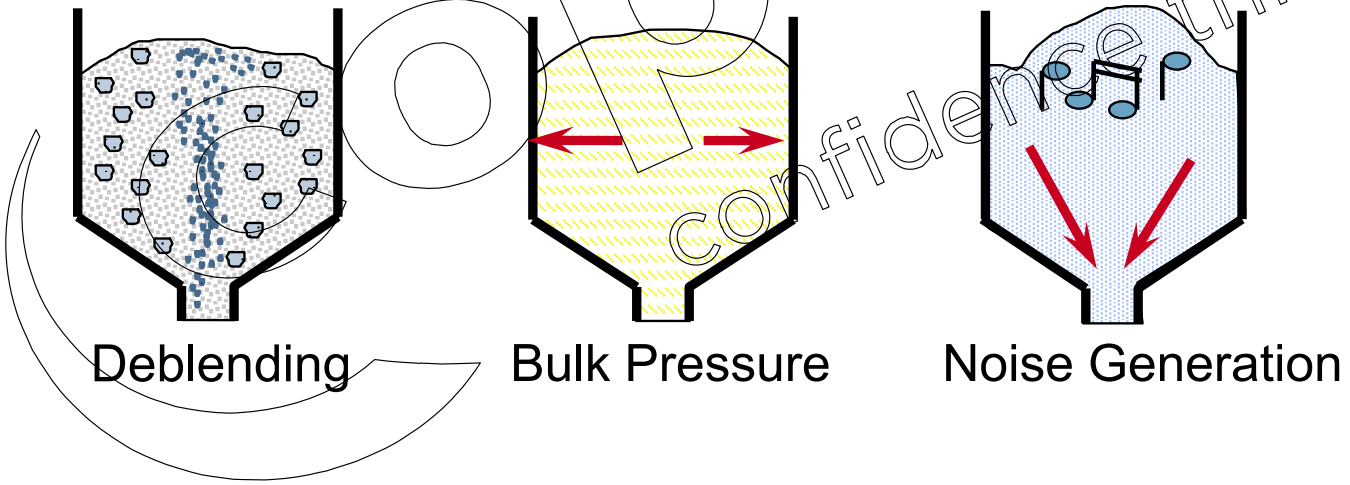
C Dilute / Strand conveying, (Dense Phase flow conveying)

D Dilute Phase conveying (Coating)

Plastics & Chemicals

Flow properties



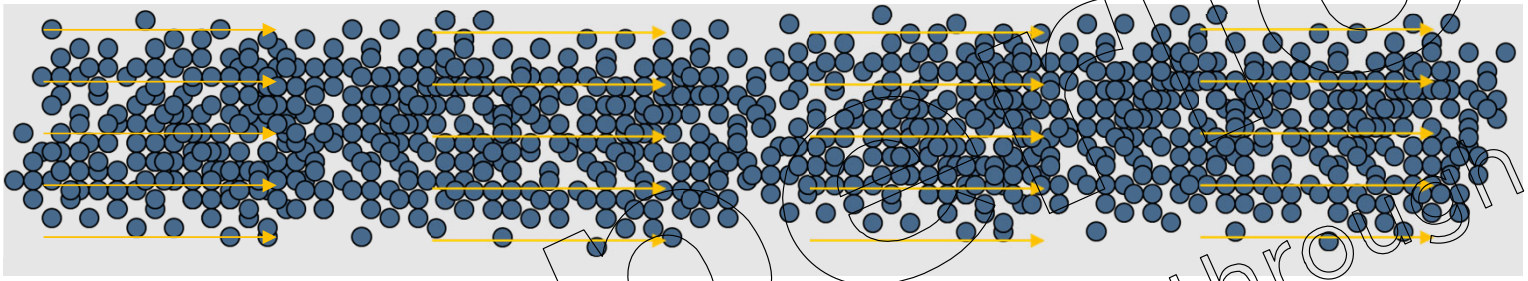


unit weight (min)	g_l [kN/m³]
unit weight (max)	g_u [kN/m³]
particle size	d_{s50} [mm]
angle of repose	j_r[°]
wall friction coefficient - **jacket**	μ_{m-1} [-]
conversion factor for wall friction - jacket	$a_{m\,m-1}$ [-]
wall friction coefficient - **hopper**	μ_{m-2} [-]
conv. factor for wall friction - hopper	$a_{m\,m2}$ [-]
angle of internal friction	j_{im} [°]
conversion factor for internal friction	a_j [-]
lateral pressure ratio	K_m [-]
conv. factor for horizontal pressure ratio	a_K [-]
patch load solid reference factor	C_{op} [-]

Pneumatic Conveying

Basics: Definition and Variables

transport of bulk material	with a gas flow	in a pipeline



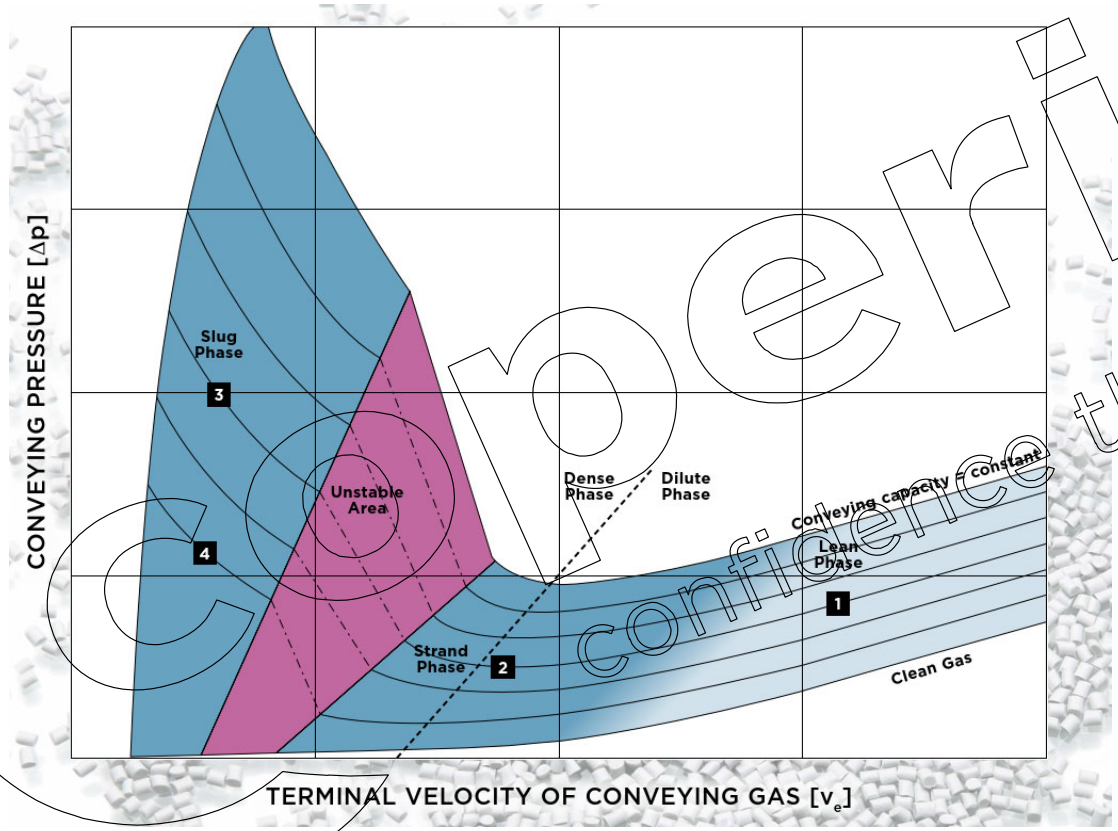
capacity particle properties	volume flow velocity	diameter length, height, bends

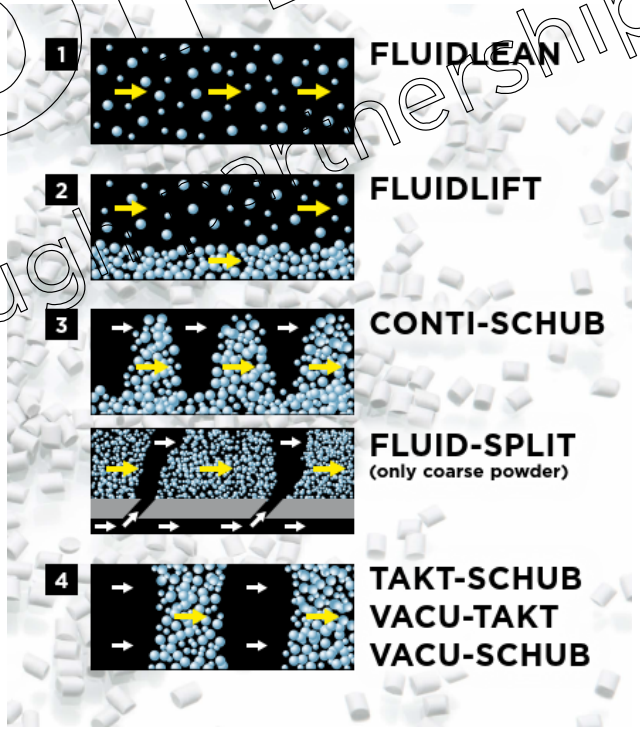
Conveying phases

Depending on the selection of the variables, the bulk material moves in different ways through the pipe
→ **Conveying Phases**

Conveying Modes

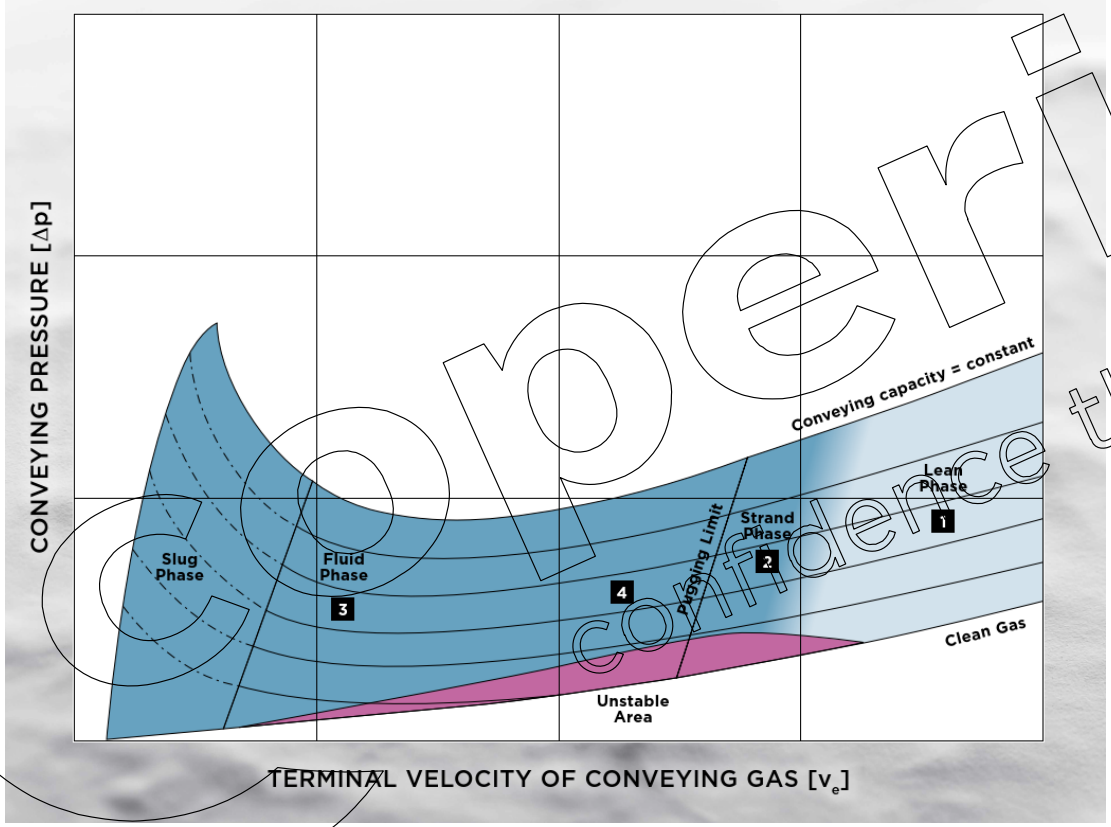
Phase Diagram for Pellets

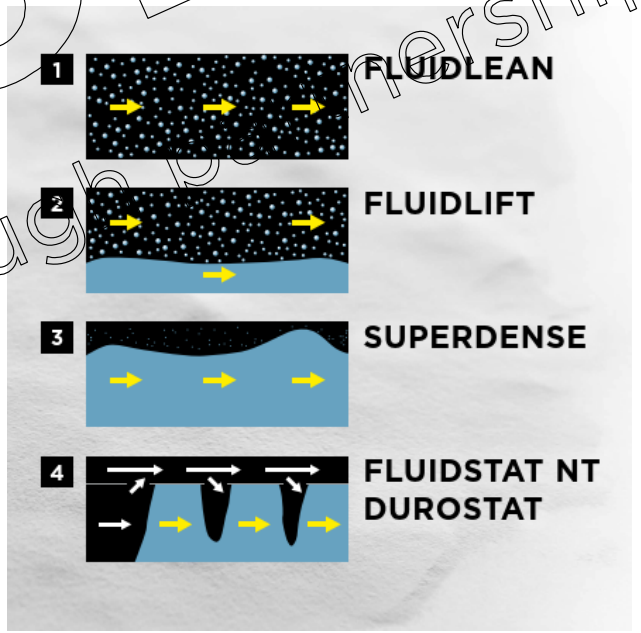




Conveying Modes

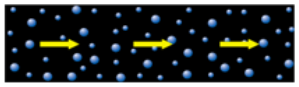
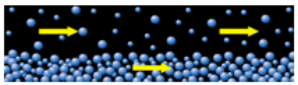
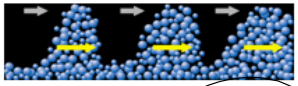
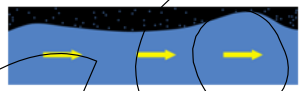
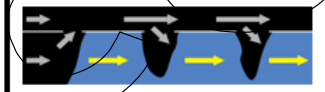
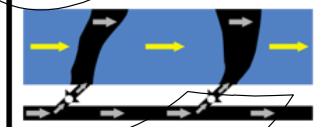
Phase Diagram for Powder





Conveying Modes

Overview

	Conveying mode	Characterised by	Products	Trade Name
	**Dilute-phase (lean phase)**	High energy consumption High operational reliability	Wide product range	**FLUIDLEAN®**
	**Dense-phase (strand phase)**	Low energy consumption Smaller pipe size	Free-flowing products (fluff, granules, pellets)	**FLUID-LIFT®**
	**Slow motion dense-phase (plug phase)**	High load ratio Less dust and streamers Low wear	Pellets	**CONTI-SCHUB® TAKT-SCHUB®**
	**Dense-phase (fluid phase)**	Low energy consumption Smaller pipe size	Fluidisable powders	**SUPER DENSE®**
	**Dense-phase with internal bypass**	Self-stabilising No obstruction	Powders with average fluidisation properties,finely-grained bulk material	**FLUID-STAT®**
	**Dense-phase with external bypass (plug phase)**	No obstruction Gentle conveying	Non-fluidisable powders, fine to coarse bulk material	**FLUID-SPLIT®**

Pneumatic Conveying

Basics: Definition and Variables

Type of gas

- Air
- Nitrogen
- others

Gas velocity

$$v = \frac{\dot{V}}{A} = \frac{\dot{V} \cdot 4}{d^2 \cdot \pi} * 3600$$

Product to gas ratio

$$\mu = \frac{\dot{m}_{product}}{\dot{m}_{air}}$$

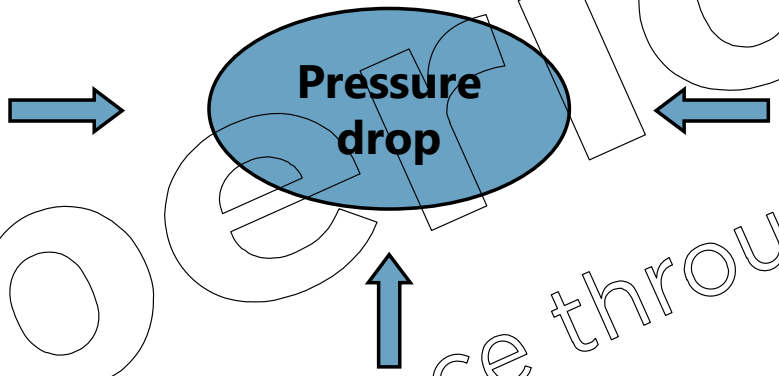
d – Inner pipe diameter [m]
V – conveying gas volume flow [m³/h]
A – cross section [m²]
$\dot{m}$ – mass flow

Design of Conveying Systems

Pressure Drop as a Result of Various Parameters

Product

- Temperature
- Particle size / Particle size distribution
- Product friction
- Pipe friction
- Bulk density
- Particle density
- Particle hardness
- Moisture content
- Additive (e.g. lubricant)



Operation

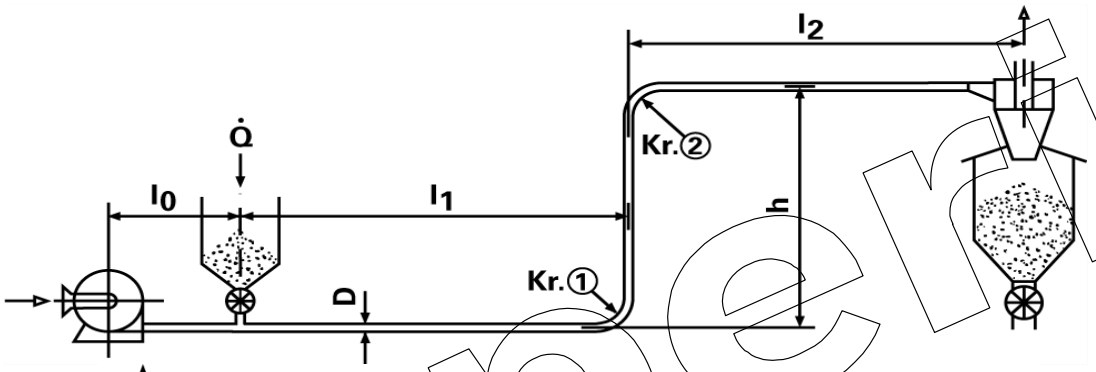
- Air/gas density
- Velocity
- Product/gas ratio
- Conveying gas temperature
- Capacity

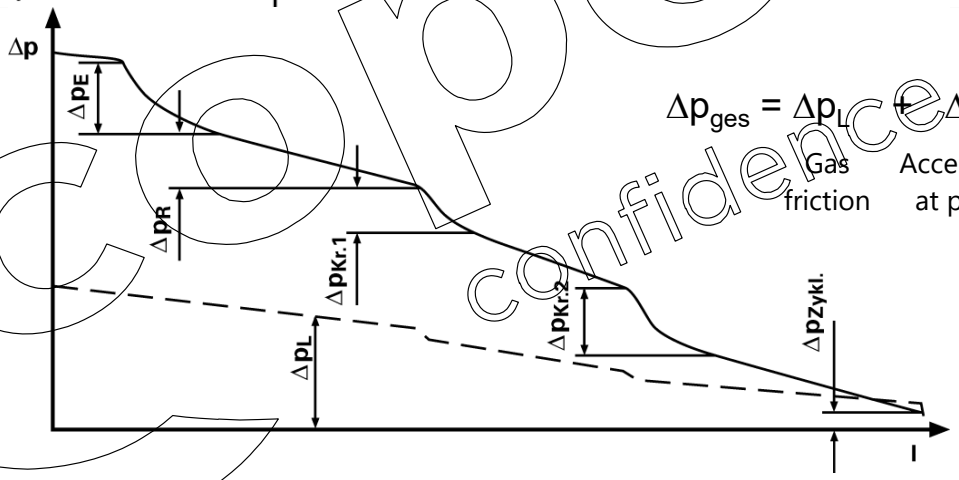
Plant Layout

- Length
- Diameter
- Height
- Number of bends and type of bends
- Product feeding
- No. of diverter valves
- Closed/open loop
- Pipe friction

Design of Conveying Systems

Pressure Drop Calculation in Dilute-Phase Conveying





$$\Delta p_{ges} = \Delta p_L + \Delta p_E + \Delta p_R + \Delta p_H + \Delta p_B + \Delta p_{other}$$

Δp_L	Δp_E	Δp_R	Δp_H	Δp_B	Δp_{other}
Gas friction	Acceleration at pick up	Friction of product	Elevation in vertical pipe	Acceleration after bends	Cyclone (or filter)

Conveying Modes

- Video: https://www.youtube.com/watch?v=48VxWo_qpMA

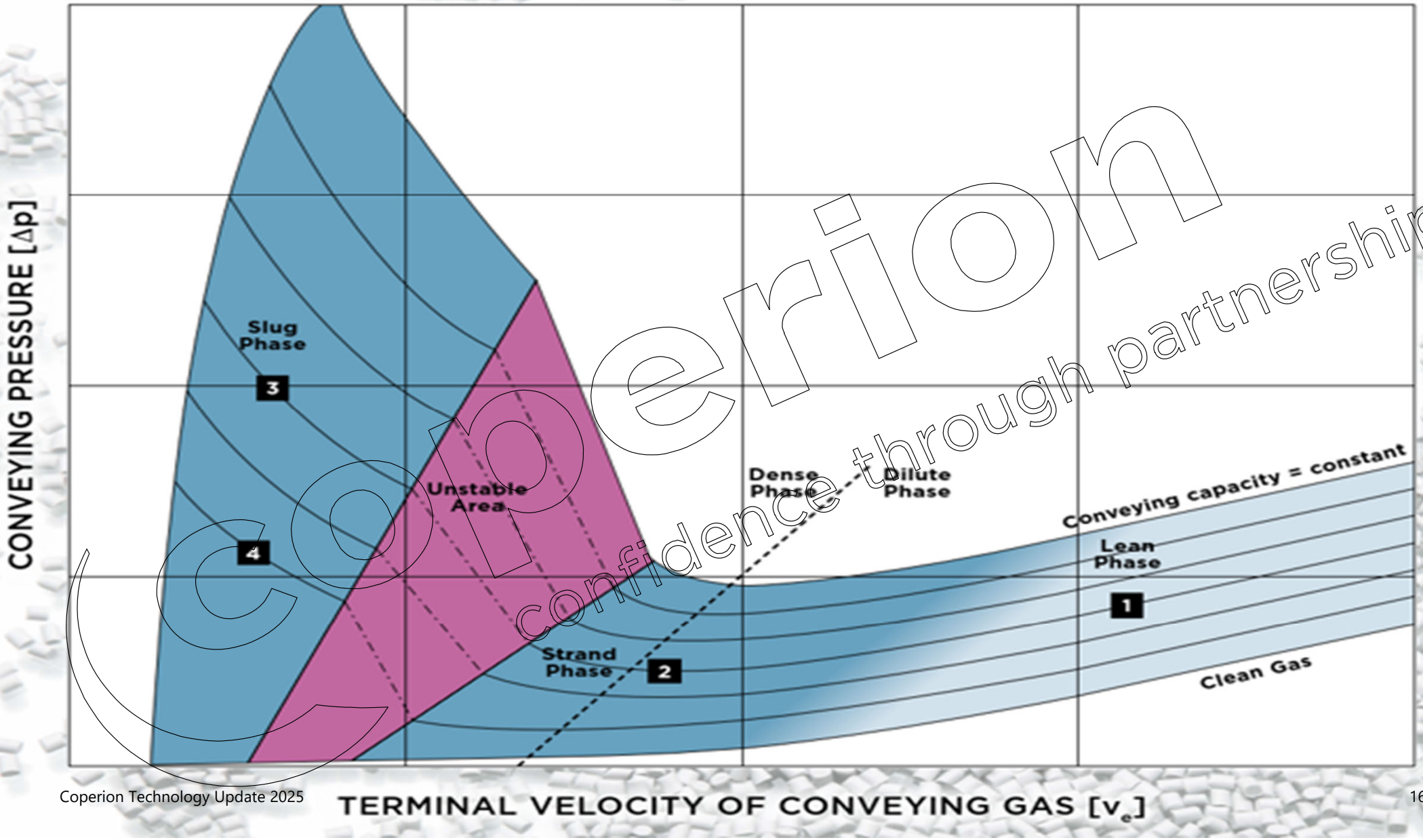
Definition

- Dense phase conveying with slow motion

Applications

- Pellets (Plastics)
- Similar particle shape:
  3 – 10 mm
  narrow PSD

>> Dense phase conveying with slow motion is the best technology for certain applications.



Design of Pneumatic Conveying Systems

Introduction

Design Parameters

- Conveying pressure
  depending on product type and properties, conveying pipe isometric, operating conditions, conveying mode, available pressure supply
- Air volume, air velocity
  keep minimum and maximum velocities
- Product/Gas-ratio
- Pipe diameter
  Stepping of the pipe diameter in order to have moderate velocities along the pipe

Aim

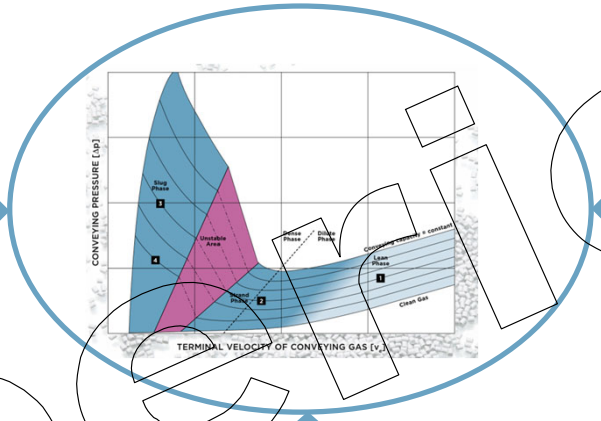
- Reliable function with guaranteed capacity
- Minimum impact on product quality and creation of fines dust / streamers
- Economical solution (low investment and operating cost)

Design of Pneumatic Conveying Systems

Pressure Drop Dependencies

Product

- Density
- Bulk Density
- Temperature
- Particle Size
- Particle Size Distribution
- Shape
- Humidity
- Elasticity
- Additives



Operation

- Velocity
- Air / Gas Density
- Product to air ratio
- Gas Temperature
- Product temperature
- Capacity

System Properties

- Length
- Height
- Pipe Diameter
- Pipe Material
- # of Bends
- Type of Bends
- # of Diverter Valves
- Product Feed
- Filter / Cyclone
- Open / Closed System
- Suction / Pressure Conveying

Conveying Modes

Pellet and Coarse Powder Conveying

Lean-Phase Conveying/ FLUIDLEAN®

- High gas velocity v = 25 - 40 m/s
- Low solids loading μ = 1- 10
- Low specific pressure drop
- Pressure range Δp = 0.1 - 1.5 bar
- Bulk material in suspension flow

Strand Conveying/ FLUIDLIFT®

- Gas velocity v = 15 - 30 m/s
- Greater solids loading μ = 5 - 25
- Low specific pressure drop
- Pressure range Δp = 0.5 - 3.0 bar
- Bulk material floating, sliding or recumbent bulk strand

FLUIDLIFT ecoblue®

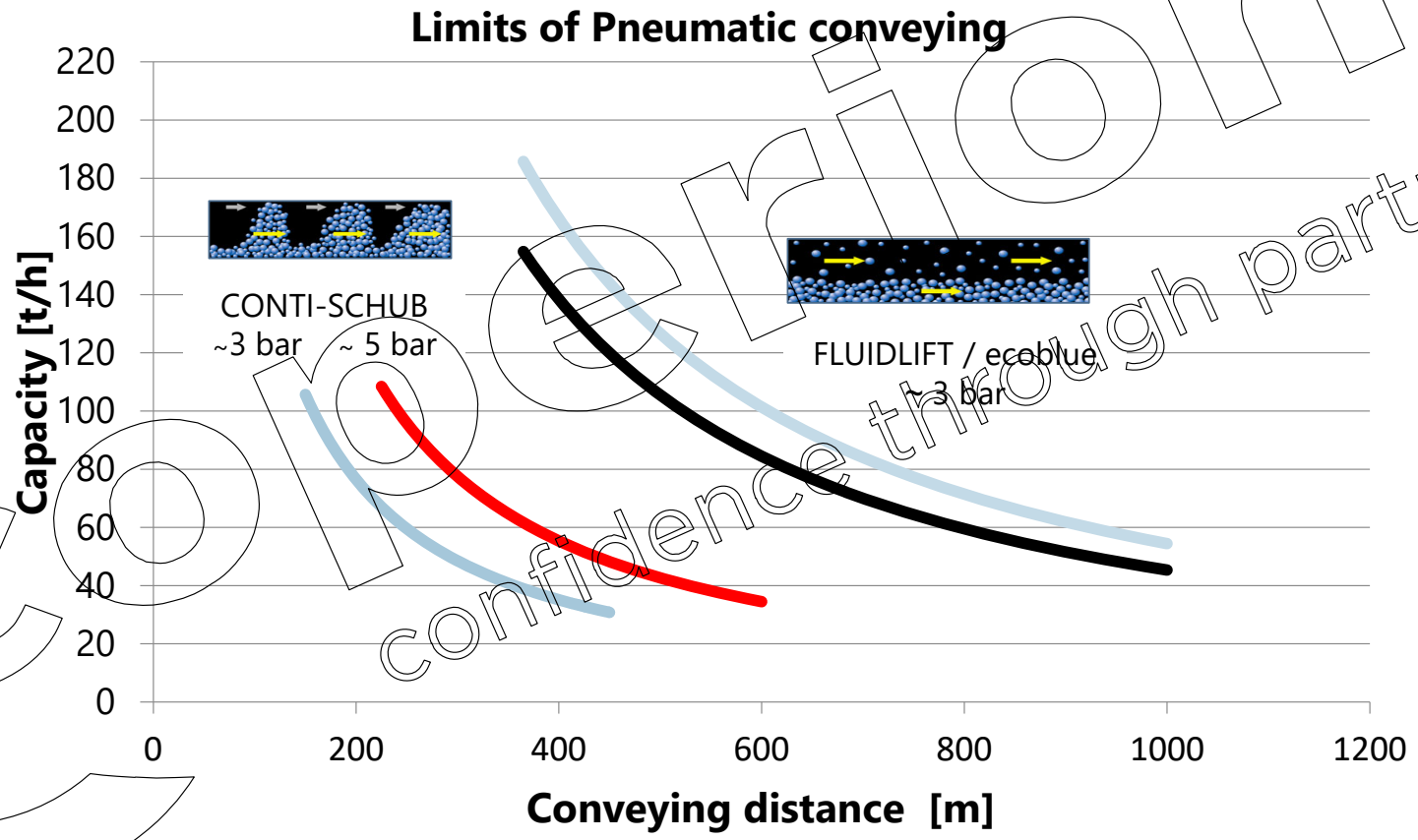
- Enhancement of **FLUIDLIFT®**
- Sliding strands with reduced friction
- Water injection into conveying air

Slug Conveying / CONTI-SCHUB® or TAKT-SCHUB®

- Low gas velocity v = 4 - 10 m/s
- High solids loading μ = 10 - 50
- High pressure drop
- Pressure range Δp = 0.5 - 6 bar
- Bulk material concentrated in plugs (“Plug conveying”)
- Self-acting formation of the plugs (CONTI-SCHUB®,
- Artificial plug formation may be necessary (TAKT-SCHUB®)

Pellet Convey at Throughput

Limits of Pneumatic conveying



Design of Pneumatic Conveying Systems

Technical Center: Features

- Full size conveying systems (up to DN200) for investigating pneumatic conveying in dilute phase / dense phase including impact forces
- Conveying can be done with different feeding devices
- Full size conveying systems (up to DN100) for conveying of difficult powders (normal piping / FLUIDSTAT / FLUIDSPLIT / flexible rubber pipe)
- Conveying system for suction conveying
- Insulated conveying system to measure temperature influence on conveying pressure
- Rotary valve test station for full size capacity tests of rotary valves (up to rotor size 800)
- Conveying system for determination of fines creation in all common pipe materials / surfaces / with different bend types and possibility of variation of temperature
- Complete hydraulic conveying system (DN100)
- Various pellet cleaning devices (UGS / HFS)
- More than 800 evaluated conveying tests
- More than 10.000 analyzed lab product samples → High number of data sets for designing pneumatic conveying systems

Thank you very much for your attention.