PFD Dense Phase Conveyor

An innovative injection system in desulphurisation plants at
ThyssenKrupp Steel in Duisburg, Germany

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Feldhaus-Technik GmbH
www.feldhaus-technik.com

PFD Dense Phase Conveyor's at ThyssenKrupp Steel

An innovation based on process need

- Desulphurisation of iron through submerged lances
- Injection technology remained unchanged since the 1970's
- Increased quality requirements since the 1990's
- Worldwide trend from Mono- to Co- to Tri-Injection
- Impossible to inject Mg, CaC_2 & lime with precision
- No substitute technology readily available before 1998

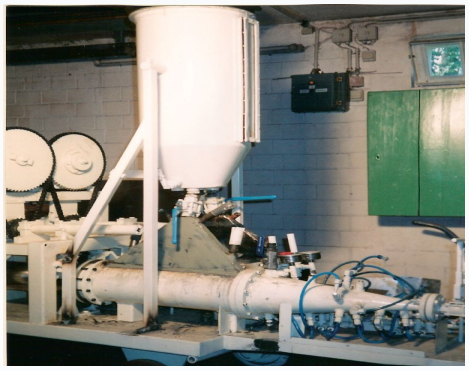
1998: Modern desulphurisation plant commissioned at TKS Steel Plant 1 newly built by Küttner GmbH & Co. KG (conventional technology !)

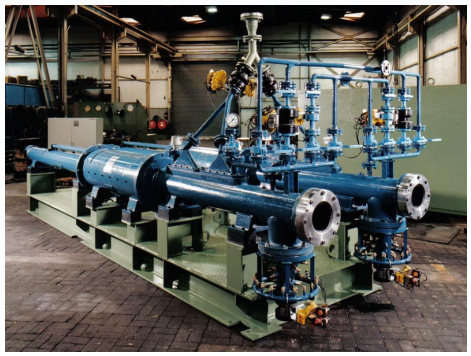
1998: Implementation of the PFD test facility at TKS plant 2

1999: Commissioning of the first PFD Dense Phase Conveyor in steel plant 2 (in continuous operation since 09/1999)

2004: Commissioning of the second machine in steel plant 2 (in continuous operation since 10/2004)

- Two conveyors desulphurise > 5 million tpa today !

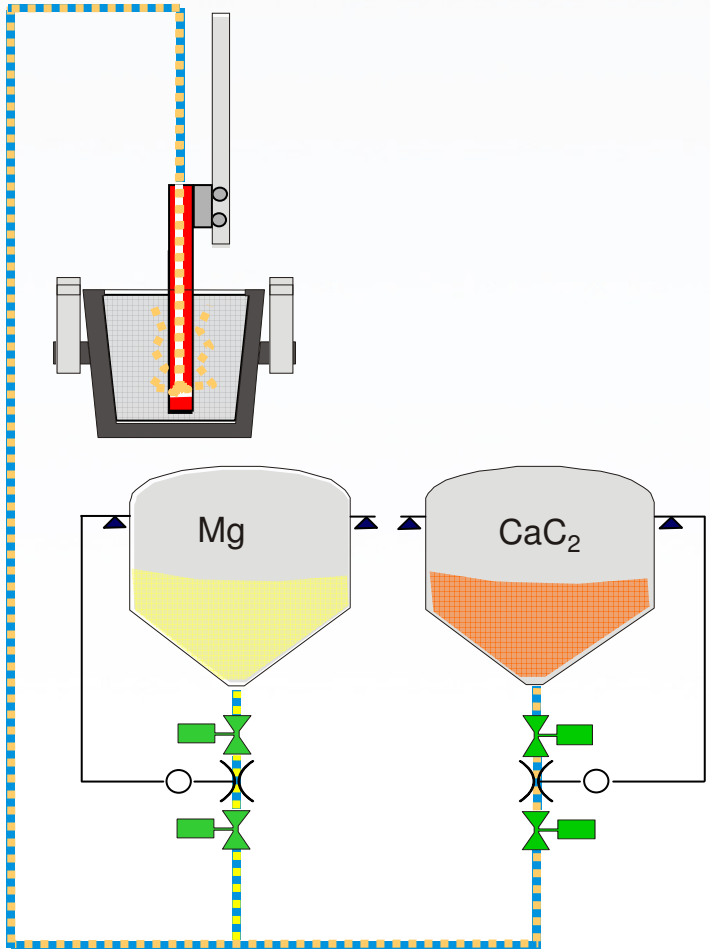




Co-Injection at ThyssenKrupp Steel (1987 – 1992 - 1999)

Before PFD Dense Phase Conveyors were implemented

- Two conventional pressure vessels inject Mg and CaC_2 to desulphurise crude iron in steel plant 2
- In 1992: Flow Control Valves replace fixed nozzles to reach output control
- Gravimetric Dosing Principle through differentiation of the declining weight of the pressure vessel
- Mg filled by 5 m^3 Container
- CaC_2 filled up by central Silo



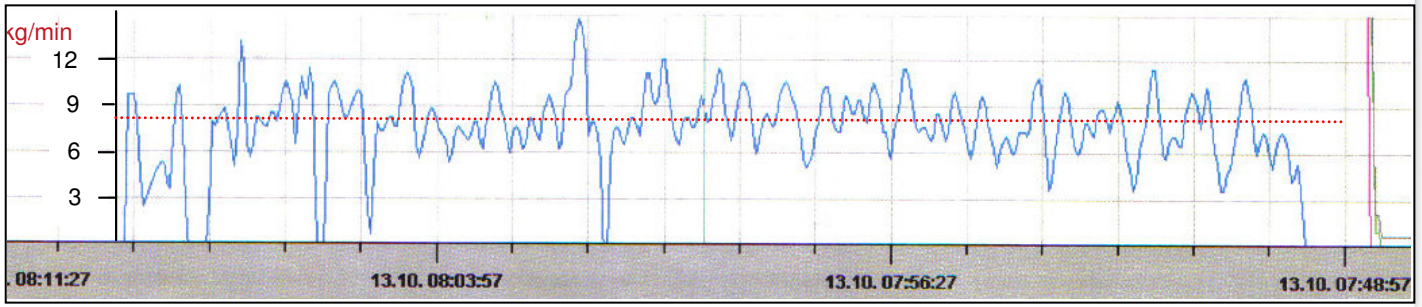
Conventional Technology

The Gravimetric Principle

- The deviating weight of the pressure vessel determines the output rate of the material
- The computed value is obsolete and inaccurate and not suitable for an exact control loop.
- When granulates are conveyed from pressure vessels, gas diffuses from the top zone of the dispenser through the granulate layer into the conveyor line.
- The amplified oscillating output makes a smooth dense phase conveyance impossible
- Changing flowing behaviours, varying resistance in the common conveyor line and crane induced vibrations in the steel construction propel this problem further
- Subsequently, automatic control loops are extremely damped-down
- Nonetheless, the end-result is an oscillating output rate

Random curve at TKS: Mg-Output from a dispenser in Co-Injection with CaC_2

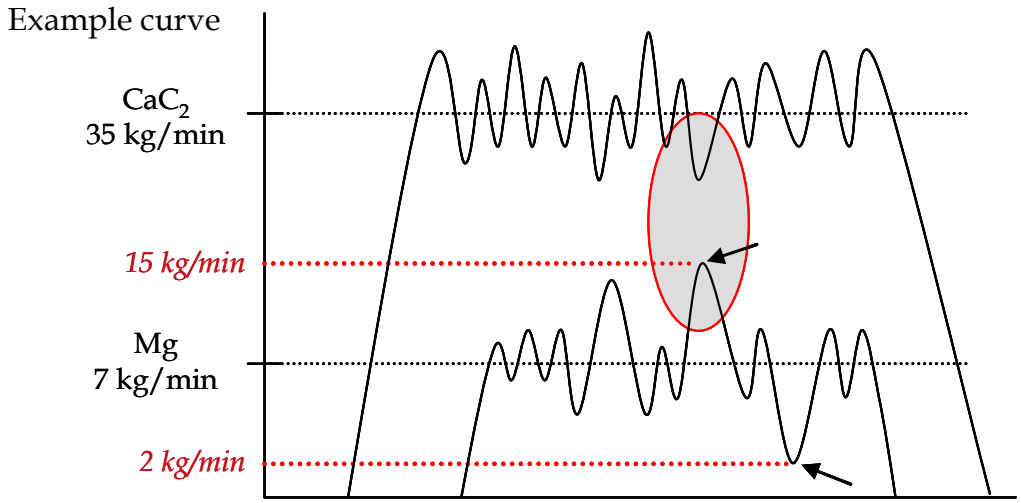
- Target: 8 kg/min (Constant)
- Actual: 0 - 15 kg/min (Oscillating)



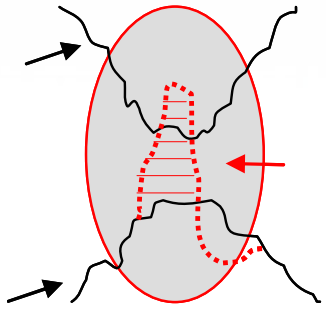
Conventional Technology

Results and Constraints

- Efficiency deteriorates when target ratios are not met
- Trace of curve is a computed average (displayed values up to 15 sec. delayed)
  - Proven at TKS - Real output is even worse !
- Lance chokes when peaks are oppositional
  - Mg is highly concentrated and almost no CaC_2 at the lance hole for < 2 sec.
  - Mg melts inside the lance at 650 °C congesting the lance hole



Real Mg Output shortly exceeds displayed value

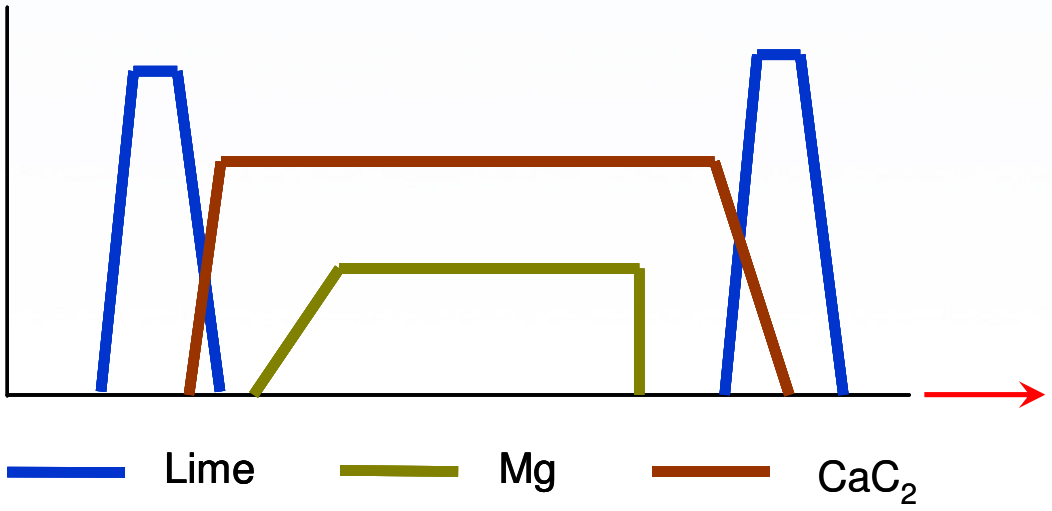


The project at ThyssenKrupp Steel

… to upgrade the desulphurisation units from Co- to Tri-injection

- A third sender must be implemented to convey lime as a third desulphurisation reagent
- The low-cost reagent lime substitutes CaC_2 in the beginning and in the end of the process
- Problems with Co-Injection multiply when more than 2 agents are to be injected

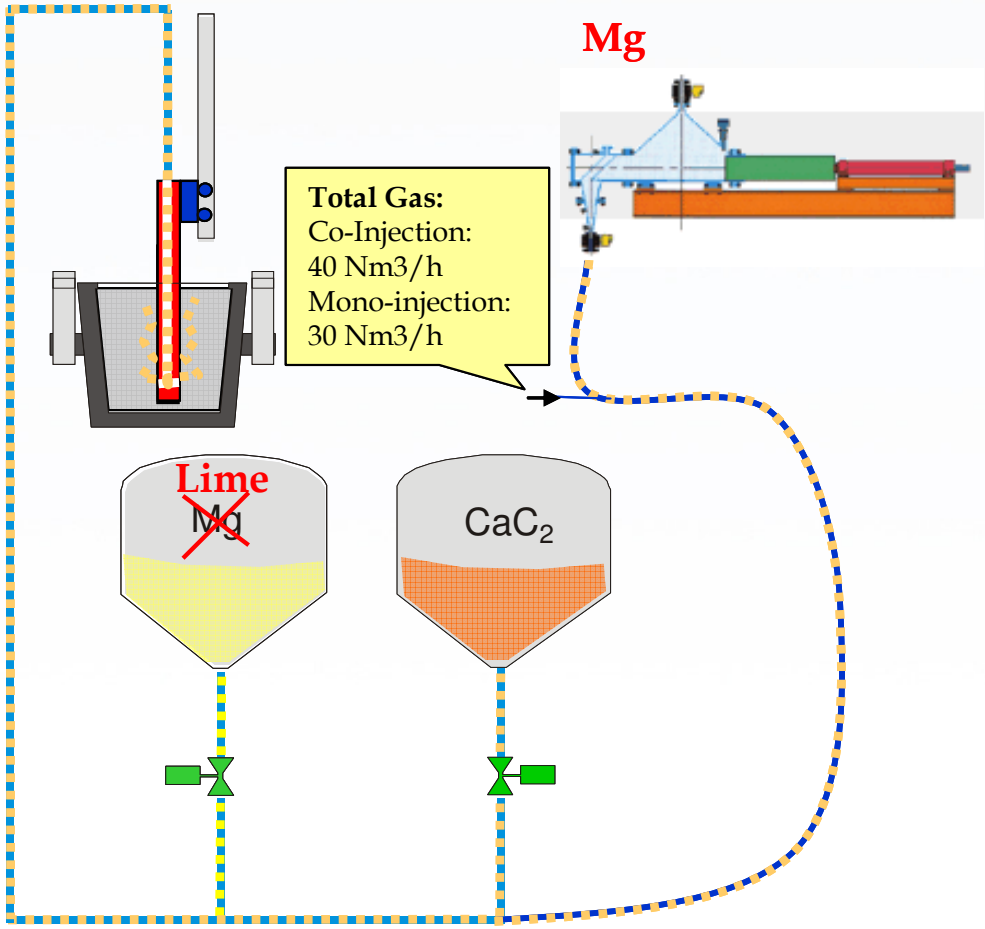
➢ 2 options: 3rd Pressure Vessel (as done in 1998) or PFD Dense Phase Conveyor



Benchmarking at ThyssenKrupp Steel

TKS Management favors the new technology in 1999 and 2004

- Pilot Plant in continuous operation since Sept. 1999
- Second machine in continuous operation since Oct. 2004
- Technology always meets the desired output rate 100 % (Target = Actual)
- Little transport gas needed because of even material flow
- Magnesium grain clears the conveyor line from lime cakings as the conveyor is farthest away from the ladle



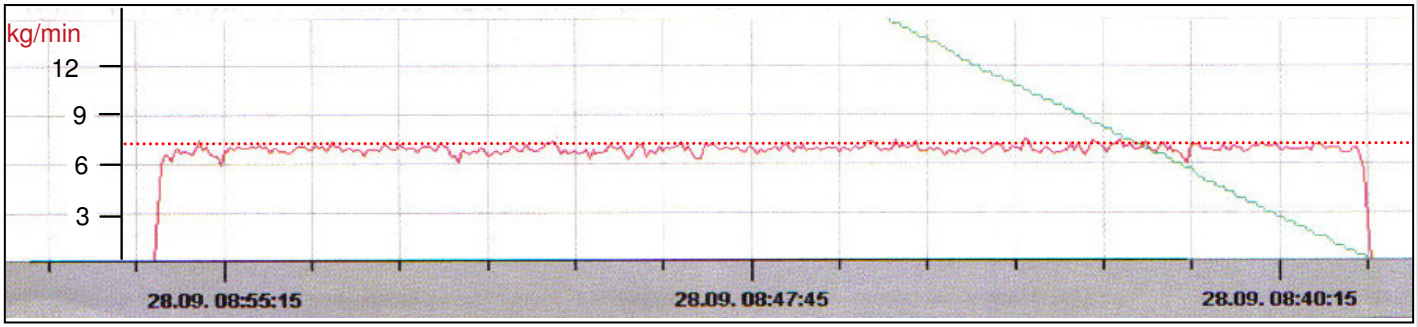
Facts at ThyssenKrupp Steel

The volumetric principle of the PFD Dense Phase Conveyor

- A PFD Dense Phase Conveyor can be situated anywhere
- A PFD Dense Phase Conveyor is fully pre-assembled at the supplier
- Installation and commissioning in very short time during full production
- In 1999 and in 2004 the former Mg dispenser has been used for lime conveyance
- Both machines have been put into operation without causing any plant downtimes
- The conveyor is situated farthest away from the ladle; lime goes in front.
- At TKS the conveyor is filled by container. Filling by silos / Big-Bags also possible
- Displaced volume x bulk density = Output

Random curve at TKS: Mg-Output from a PFD Dense Phase Conveyor in Co-Injection with CaC_2

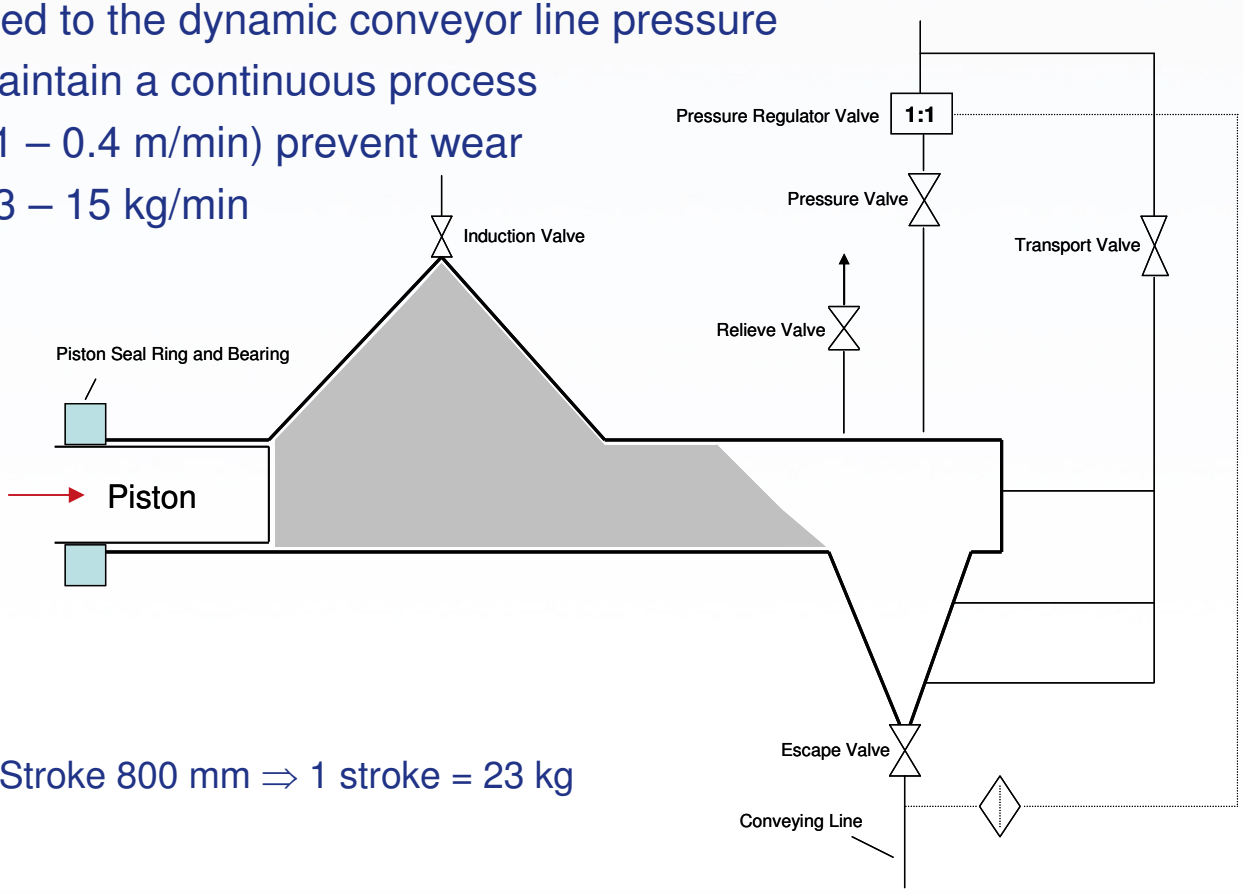
- Target: 7 kg/min (Constant)
- Actual: 7 kg/min (Constant)



The PFD Dense Phase Conveyor

Simple and robust

- One piston pushes material forward according to the required output rate
- Inside pressure is adjusted to the dynamic conveyor line pressure
- Two collateral pistons maintain a continuous process
- Slow moving pistons (0.1 – 0.4 m/min) prevent wear
- Conveying rate at TKS: 3 – 15 kg/min



Basic Principle:

Piston pushes the material forward according to the desired output rate

At TKS: Piston Ø 200 mm, Stroke 800 mm ⇒ 1 stroke = 23 kg

ThyssenKrupp Steel Expert's Report

Benefits

- Ratio CaC_2:Mg changed from 7:1 to 3:1
- Injection ratio CaC_2:Mg changed from 6:1 to 2.5:1
- CaC_2:Mg ratio optimised according to market prices
- Shorter Treatments (up to 30 % less)
- Higher steel plant productivity
- Reduced Lance wear-out
- Even and foresighted Mg flow
- Better matching of sulphur targets
- Reduced Risk of congested lances
- Little maintenance required
- Investments below the cost for the conventional technology

➢ All these benefits for free! No additional investment required for the new technology

ThyssenKrupp Steel

Duisburg, March 2007

Expert's Report

Dense Phase Conveyors (Patent Bernd Feldhaus DE 195 38 62)

Implementation of Dense Phase Conveyors in Hot-metal Desulphurisation Plants of ThyssenKrupp Steel AG in Duisburg-Beeckerwerth, Germany

In 1999 and 2004 ThyssenKrupp Steel put a Dense Phase Conveyor (patented by Bernd Feldhaus under the title „Dosierförderanlage" and code DE 195 38 62) into operation in their desulphurisation plants to inject magnesium granulate into the hot-metal. Both machines desulphurise approx. 5 million tons annually in combination with conventional pressure vessels.

The output precision of the Dense Phase Conveyors always meets the target values based on metallurgical requirements. As a result of its coercive dosing principle, oscillating pressures and typical crane movement induced vibrations in the steel plant construction do not affect the conveyor's precision capabilities.

Operations have clearly shown the following benefits:

- During the co-injection phase, the quantity ratio of CaC_2 : Mg could be reduced from approx. 7 : 1 to approx. 3 : 1.
- According to the actual development of the different desulphurisation agents' market prices, the injection rate ratios can be economically optimised.
- Due to this flexibility, the efficiency of the desulphurisation reagents can be improved. This resulted in savings of approx. 10 % of the magnesium needed.
- Better matching of sulphur target values due to the even flow of magnesium granulate.
- Despite heightened injection rates, the even magnesium flow reduces the risk of congested 2-hole lances.
- Shorter treatment times enhance the lances' operating life.
- Litte maintenance is required as only a few functional parts are subject to wear.

In both cases, the investment costs for a Dense Phase Conveyor were lower than the required investment costs for a conventional pressure vessel.

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Future Developments

Based on the experience at TKS

- Desulphurisation plant (Co-/Tri-Injection) consisting of PFD Dense Phase Conveyor's only
  - Simple fully automated process
  - No supervising personnel needed
  - Any grain size possible to maximise efficiencies
  - Shortening of process times
- Injecting Soda / Cryolite to minimise loss when deslagging

Future Developments

In the desulphurisation of crude iron

- Injecting CaC_2 granulate to increase the efficiency of CaC_2 from 30 % to 100 % (?!).
  - Today's poor efficiency of CaC_2 powder (0.01 – 0.1 mm) is evident as approx. 70 % of the material is found in the slag after the process
  - Powder forms to agglomerations that are not consumed entirely by the heat
  - Coarse-grained material never tested because Conventional Technologies are unable to inject significant amounts of granulates in a non-oscillating way
  - As a matter of fact, a PDF Dense Phase Conveyor can convey solids of all kinds, also CaC_2 granulate (e.g. 0.1 – 1 mm) with max. precision
  - When granulates are injected, every single corn makes contact with the heat
  - If not consumed up, the lose particle is pulled down again because of the current inside the ladle

Future Developments

Inside and outside the steel industry

- A PFD Dense Phase Conveyor is particularly superior when valuable bulk solids with a bulk density > 0.5 are to be conveyed at high transfer pressures !
- With regard to the ‘Closed Loop Recycle Management’
  - Injecting Fe-particles through tuyères into cupola furnaces in foundries (with O_2)
  - Injecting coarse converter dust with 70 % Fe-Particles straight back into the converter
  - Co-Injecting mill dusts & pulverised coal into furnaces or Oxi-Cup furnaces (with O_2)
- Conveyance of extremely small quantities of extremely fine powders into reactors for the chemical industry (e.g. potassium chloride (KCl) at 0.1 – 3.75 kg/h)
- .....
- .....

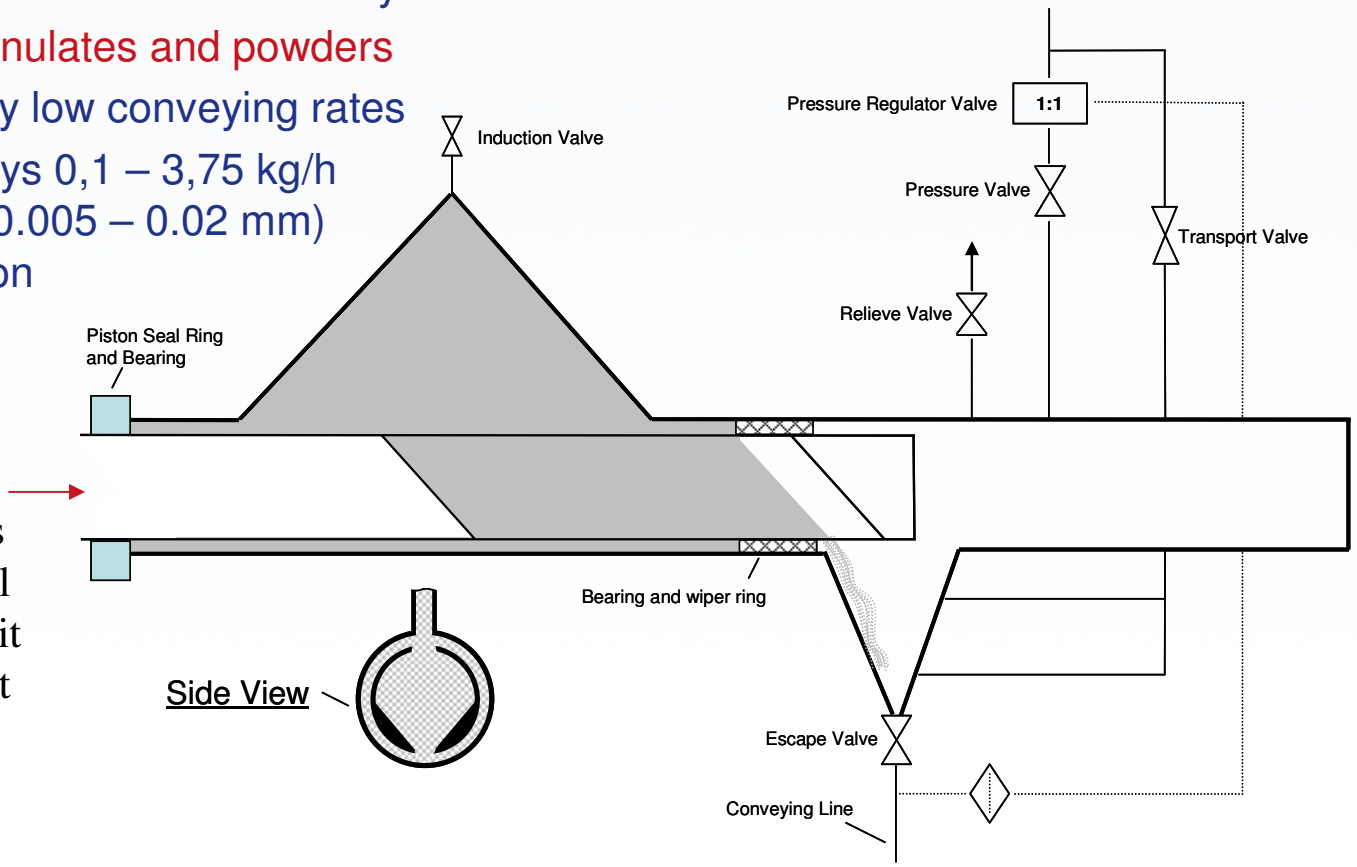
The PFD Dense Phase Conveyor

The latest development

- The third and final version of the conveyor is now available
- Conveyance of granulates and powders
- … also at extremely low conveying rates
- ‘Test facility’ conveys 0,1 – 3,75 kg/h of finest powders (0.005 – 0.02 mm) with 100 % precision

Major difference:

‘Slotted’ piston does not push the material forward, but carries it to the dropping point



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