Material flows in foundries

Economical aspects of the handling of sands and dusts

Bernd Federhen

In foundries large amounts of various sands and dusts have to be transported over considerable distances. Transport facilities are available which, when chosen according to the properties of the materials, facilitate trouble-free, economical transport. When looking at the flow of the various materials through a foundry one can clearly recognize streams of material which are brought together, partly mixed, separated, treated, stored and discharged.

Figure 1 shows this in a simplified manner. The diagram shows that sand in various states is an important part of material handling in foundries. The sand flow forms a cycle where partial flows are added to and taken from.

The typical flow is from storage silos for new sand/used sand to mixers where the sand is mixed with liquid or solid binders and possibly additives and from where it is then transported to the moulding resp. core shop. In the casting process, the sand meets the metal flow. From the knock-out station the sand flows back to the preparation or reclamation systems, dust and waste sands being discharged and stored until they are disposed of. In used sand reclamation systems additional internal sand cycles are necessary.

As an example, **Figure 2** shows a silo group for new sand, used sand, reclaimed sand and waste sand. Filling and discharge takes place by means of pneumatic conveying. The waste sand is disposed of with silo trucks.

The space available for the necessary transport systems in foundries is very limited. It is therefore desirable to have transport systems with very small dimensions which can be easily integrated in the allowable space. Energy consumption and maintenance input should be minimal.

Table 1 shows possible transport methods for the various materials.

The transport of mixed core sand

As examples for the transport of moist sands, **Figures 3** and **4** show cars for the transport of mixed core sand to the core shooter.

Figure 3 shows a vibrating mixer from which core sand is discharged and falls into a transport hopper mounted on gimbals. The driving chain wheel of the transport car reaches into a chain at a C profile which guides the car from the vibrating mixer over the hoppers of several core shooters.

The vibrating mixer plant is located at ground level. To discharge the core sand, the transport car rises over the core shooters located on a platform.

The mixer shown in **Figure 4** is located above the hopper of a core shooter. The space between mixer and hopper allows passage of a transport car which supplies several core shooters with core sand. The transport car can also dump partial batches. It is driven by a linear motor.

The tendency of the core sands to build-up and their poor flow properties require a corresponding design and material choice of the transport buckets. Rails and transport cars are a relatively rigid system which has a strong influence on the erection of the facilities in core shops and requires considerable space.

The transport of dry, granular materials

Figure 1 shows that sand or dust handling occurs at many places in foundries. The distances and the handling capacities are sometimes considerable, and the space available for material transport is usually limited. This requires a very

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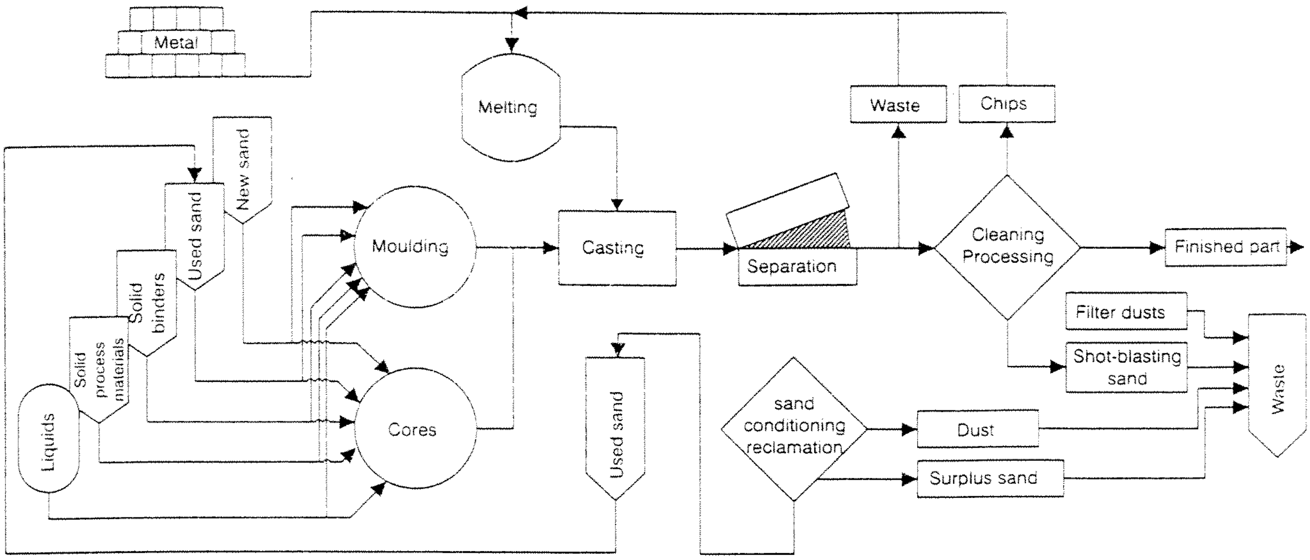


Figure 1. Essential material flows in foundries

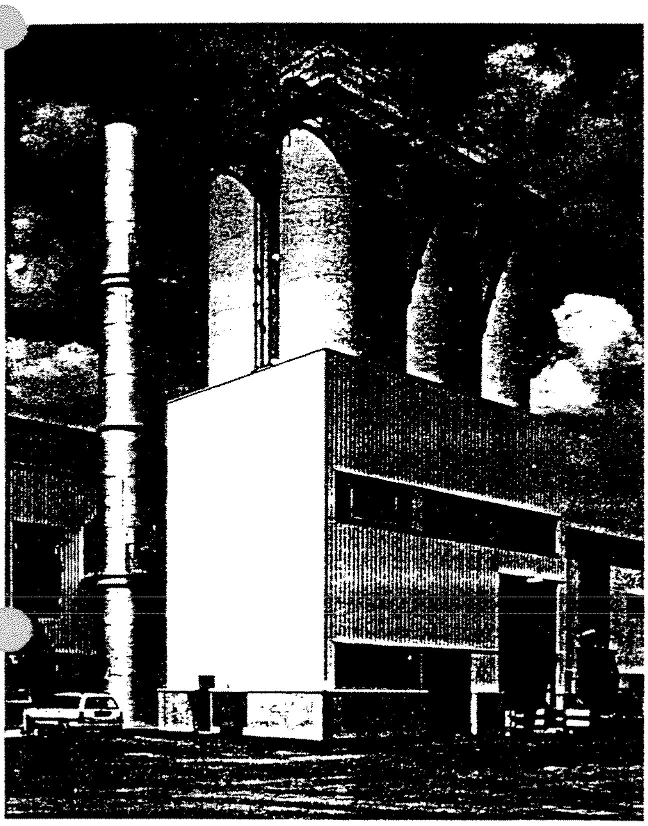


Figure 2. Silo group for new sand, used sand, reclaimed sand and waste sand *(Photo VAW)*

Table 1. Possible transport methods for the various materials

Material	Transport method (example)
Sands, moist	Mechanical transport
Dust	Pneumatic conveying, big bag
Sands, dry	Pneumatic conveying
Metal, solid	Bucket, vibrating pan
Metal, liquid	Ladle, runner
Liquids	Pipeline with pump

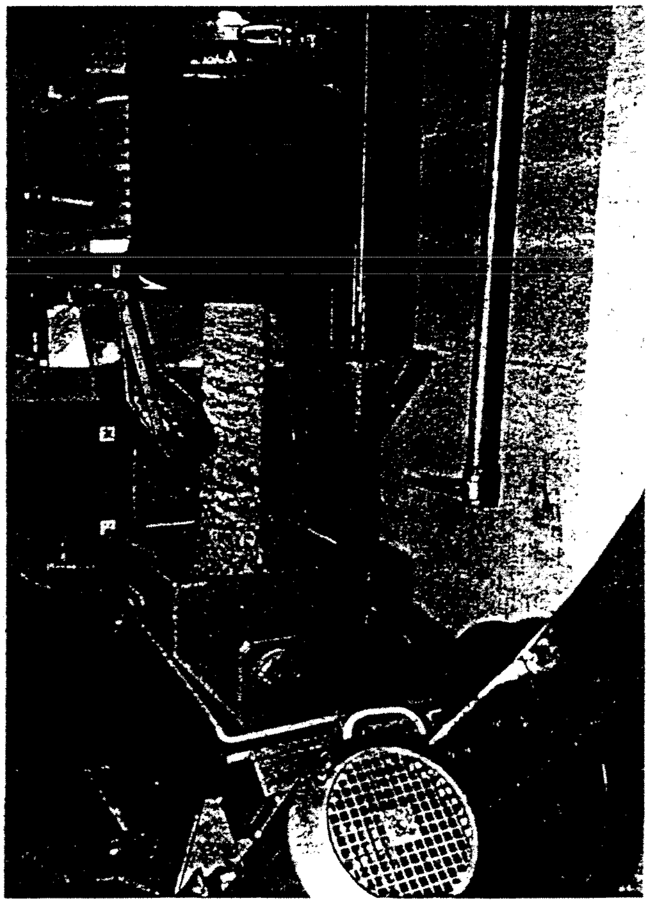


Figure 3. Transport car for mixed core sand mounted on gimbals underneath a vibrating mixer *(Photo Alb. KLEIN)*

adaptive conveying system – the pneumatic conveying system.

Pneumatic conveying processes for dusts and sands

The conveying principle itself is based on the fact that the material is transferred into a conveying pipe, accelerated by the conveying air due to its flow resistance and transported through the conveying pipe. The greatest advantages of pneumatic conveying lie in the simplicity of the principle itself. There is hardly a simpler conveying means than a pipe through which the material is moved. It is cheap, very adap-

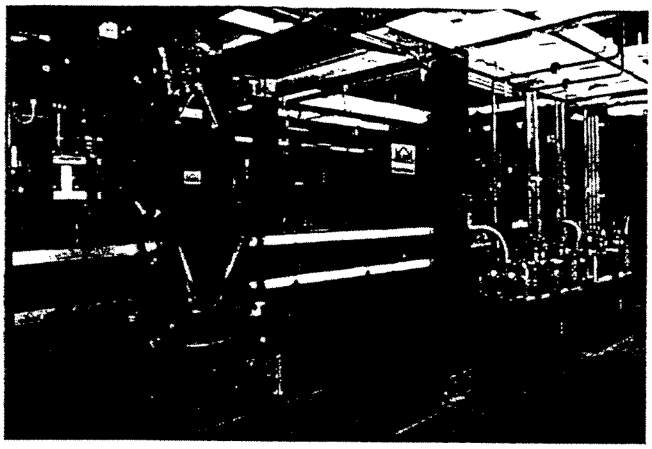


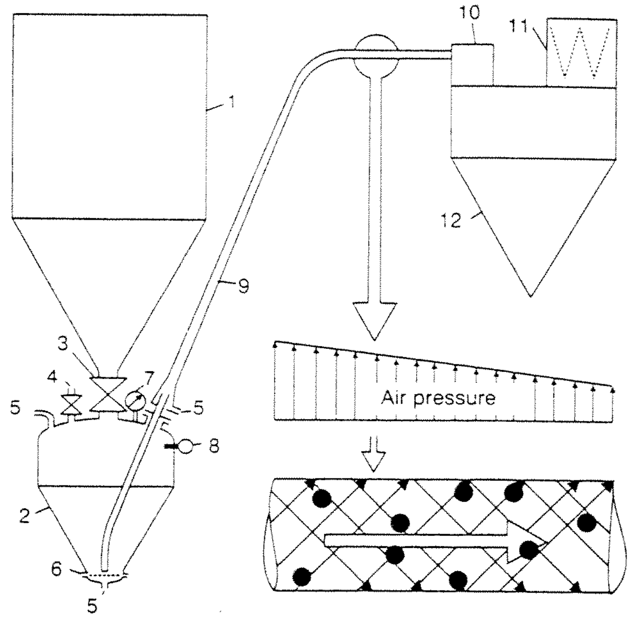
Figure 4. Transport car for mixed core sand at the mixer *(Type STATORMIX, Alb. KLEIN, Photo VAW)*

tive, space-saving, dust-tight, weather-independent and only requires little maintenance.

In foundries, pneumatically conveyed materials have widely varying conveying properties. These can be accomodated when the suitable conveying process is chosen according to the properties of the materials and when the system is equipped with rugged components [1].

Group A materials

Depending on the distance, materials of group A (**Table 2**) are transported with the dense phase or lean phase process. The air velocity is higher than 10 m/s, the air flows turbulently. The product particles move through the conveying pipe at a relatively great distance to each other. The air pressure decreases almost linearly over the conveying distance. Since the product particles only have a very small mass (dust grains), the wear on the pipes is low even with these conveying velocities despite higher ranges. The static pressure of the flowing conveying air on the dust particles acts as motive force of the product particles. If larger material accumulations form at one point in the pipe, the energy flow is interrupted at that point and the pipe will clog.



1 Primary vessel, 2 Conveying vessel, 3 Inlet closure, 4 Vent valve, 5 Conveying air feed points, 6 Fluidization bottom, 7 Pressure switch, 8 High level probe, 9 Conveying pipe, 10 Separator, 11 Filter, 12 Receiving hopper

Figure 5. Pneumatic conveyance according to the lean phase to dense phase conveying process

Conveying vessels are suitable feeding locks [2], the filling process being monitored by a level probe. The conveying process is completed when the vessel and the pipe have been emptied to an extent where only the flow resistance of the empty pipe acts on the pressure switch, i.e. the conveying pipe empties after each conveying process. The product is discharged from the vessel into the pipe by means of a fluidization bottom. To minimize the air consumption, these conveyors can be equipped with a loading control unit.

Product and conveying air are separated at the receiving hopper by means of a separator and a filter.

Figure 5 shows the general design of the pneumatic conveying systems and the process for dustlike materials of

Table 2. Classification of the pneumatically conveyable materials in foundries according to their conveying properties

Material group	Materials	Grain size	Possible conveying processes
A – dusts	Bentonite Coal dust Cement Iron oxide and similar filter dusts	< 0.1 mm, dustlike definable, constant, bulk low porosity, wide grain spectrum	Lean phase to dense phase conveyance (conveyor type S)
B – sands	New sand Chemically bonded prepared used sand and the like Croning sand	0.063 to 0.7 mm granular, dustfree, definable, constant, bulk is pourous, narrow grain spectrum	Slug-type conveyance (conveyor type T and SP 25)
C	Waste sand Used bentonite-bonded sand (dry) Blasting sand and the like	dustlike to granular, variable, bulk very low porosity, wide grain spectrum	Slug-type conveyance (PLI)

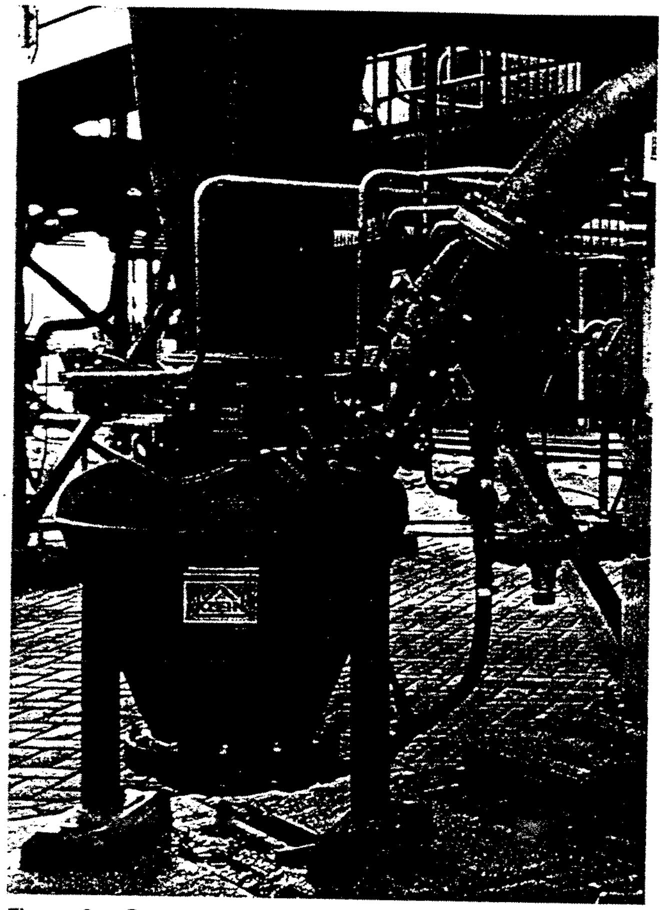


Figure 6. Dust conveyor at the discharge point of a filter *(Photo Hoogovens)*

group A. **Figure 6** shows two pneumatic dust conveyors at a filter as a typical application.

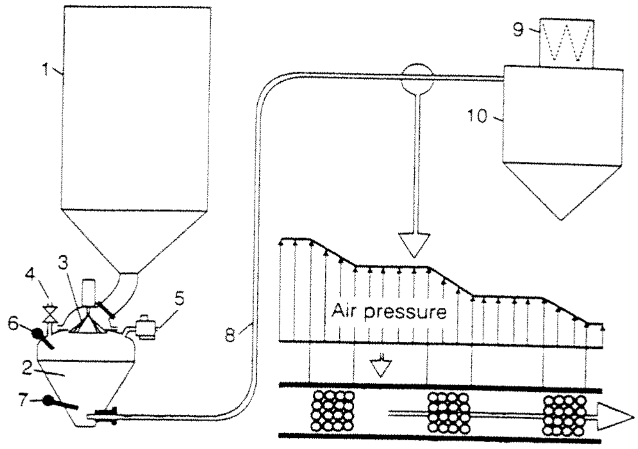
Group B materials

When transported at high velocities, as necessary for group A materials, group B materials cause considerable wear due to their hardness, grain shape and the relatively large grain mass. Wear occurs at bends, pipes and the sand grains themselves and causes interruptions in operation and high replacement parts costs. Wear of the sand grains increases the percentage of fines in the sand, thus extending its surface, and consequently increases the binder consumption with all its known negative influences. For that reason, everything possible must be done to carefully transport moulding and core sands.

The slug-type conveying process shown in **Figure 7** facilitates trouble-free transport of these materials when their properties are taken into account [3].

The dustfree grain composition results in great porosity of these sands, through which the conveying air flows, even if slugs form in the conveying pipe and move through it relatively slowly. The air flows from one air cushion through the slug into the air cushion downstream and loosens the slug to where it can easily shift in the conveying pipe. The air flowing in the spaces between the sand grains produces a static pressure on them, which is sufficient for the transport.

The velocity of the sand slugs is below 5 m/s, characteristic conveying pressures being between 5 and 6 bar. Coarser sands, e.g. sand H32, result in a more uniform, smoother



1 Primary vessel, 2 Conveying vessel, 3 Inlet closure, 4 Conveying air feed point, 5 Vent valve, 6 High level probe, 7 Low level probe, 8 Conveying pipe, 9 Filter, 10 Receiving hopper

Figure 7. Pneumatic slug-type conveyance of sand according to the conventional slug-type conveying process *(conveyor type T)*

conveying process than fine-grain sands, e.g. F35. Up to a PLI number of approx. 300, new sands can be transported very uniformly and carefully by means of the usual slug-type conveyance. The PLI number is a value resulting from experience and can be calculated easily from a sieve analysis.

PLI number = AFS number × (% of parts smaller than 0.125 mm)

Examples (according to sieve analyses of bagged material)

Type of sand	approx. PLI number
H 32	46
H 34	132
F 32	116
F 35	740
F 36	1 215

Sands with splintery grain shape and those with a rougher surface, e.g. sand on which bentonite particles were calcined in a thermal reclamation system, are more difficult to convey than spheroidal new sand. This results in a higher specific air requirement and lower conveying capacities.

Optimization of pneumatic sand conveying systems

Pneumatic conveying systems for sand are generally supplied with 6 bar overpressure from the company's compressed air system. The most economical operation is achieved when the air pressure is utilized and the air volume is kept minimal. Thus, the energy of the compressed air is used and the conveying velocity remains small.

In order to reach the required conveying capacity over a given distance with a minimum of wear, it is therefore important to determine the optimum combination of conveying pipe cross section and air velocity.

The influence of air velocity on the conveying capacity

Figure 8 shows measured values for the dependency of the conveying capacity on the air velocity at the end of the conveying pipe. The air velocity results from the measured

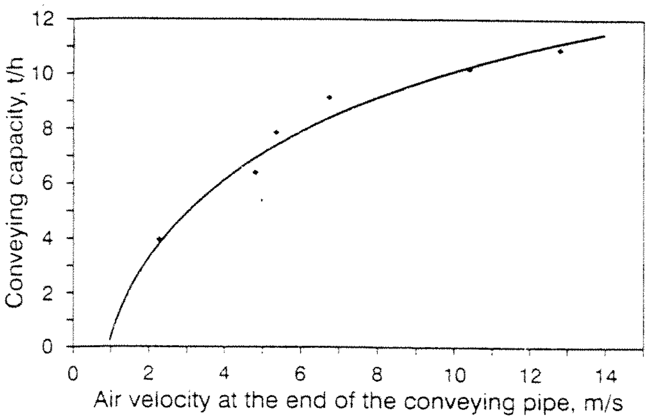


Figure 8. Dependency of the conveying capacity on the air velocity at the end of the conveying pipe *(Conveyor type T,* Sand F 32, Conveying pipe DN 80, Conveying distance 40 m)

air quantity, the measuring time and the cross section of the pipe. The sand slugs reach approximately half of the air velocity. The smoothing of the drawn regression curve shows that the air requirement and thus the energy consumption increase overproportionally with increasing air velocity. Since the wear also increases overproportionally with increasing air velocity [4, 5], it is clearly better to use larger pipe cross sections for higher conveying capacities than to work with higher velocities. This must also be taken into consideration when existing conveying systems are extended.

If the conveying air velocity is increased to more than approx. 8 m/s at the end of the pipe, the sand slugs in the pipe produce hammering in the pipe; a part of the energy contained in the conveying air is thus converted and causes wear instead of transport.

The influence of the discontinuous operation of conventional pneumatic sand conveyors on air consumption and wear

Conventional pneumatic sand conveyors operate discontinuously according to the principle shown in **Figure 7** [6]. In this state the sand runs from the primary vessel (1) through the inlet closure (3) into the conveying vessel (2) until the high level probe (6) responds. The inlet closes, and air is fed into the vessel through the connection (4). The conveying pipe (8) still contains slugs from the previous cycle. The air flows through the sand in the vessel into the conveying pipe, through the sand slugs up to the receiving hopper (10). The sand slug which is closest to the receiving hopper is fluidized by the conveying air and transported to the receiving hopper. When it has fallen from the conveying pipe into the receiving hopper, the air pressure which has built up in the vessel is higher than necessary for moving the remaining sand slugs in the pipe. Therefore, all sand slugs are then moved towards the receiving hopper, and the air flowing through the vessel to the conveying pipe carries sand from the vessel into the pipe where a new slug forms. This process is repeated until the low level probe (7) is reached, the conveying air supply is interrupted and the vent valve (5) for reduction of the pressure is opened. The conveying vessel can then be refilled. During the filling time there is no movement in the conveying pipe.

Before the conveying movement restarts, the air must penetrate all the sand remaining in the pipe from the previous cycle. This requires time. With regard to wear, it would be impractical to blow the conveying pipe empty after each cycle in order to shorten the next starting process.

Thus, with discontinuous pneumatic sand conveyors only a part of the cycle time is available as actual conveying time. The complete conveying capacity must occur in that time, i.e. higher velocities and correspondingly higher energy conversion and wear occur. Continuously operating pneumatic sand conveyors do not have these disadvantages.

A special conveyor for continuous pneumatic sand transport

With the continuous pneumatic conveyor a well seasoned unit for the transport of sand is available [7]. Compared with conventional units, it offers striking advantages:
- continuous transport process
- considerably lower conveying air consumption
- lower transport velocity
- less wear
- lower space requirement
- lower burden on filter
- very good accessibility of the components
- suitable as measuring unit for sand consumption

Figure 9 shows this conveyor (left) by comparison with a conventional pressure vessel conveyor with the same conveying capacity (right).

Operational characteristics

The pneumatic conveyor takes the sand from the silo batch-wise and conveys it to the receiving hopper continuously. Each cycle consists of 5 stages. These are shown in **Figure 10.**

Filling stage. The inlet valve is open. The discharge valve flap is closed by a leaf spring and the air pressure in the conveying pipe **(Figure 10a)**. The sand flows through the connecting sleeve and into the pressure vessel. A sight glass in the inlet housing facilitates the determination of the required filling time, which can then be set accordingly.

Closing stage. A bellows cylinder forces the inlet cone up to its seating, the valve area being simultaneously flushed with air from a ring of nozzles. This ensures airtight closing of the inlet valve with a minimum of wear **(Figure 10b)**. The discharge valve remains closed, with compressed air still flowing in the conveying pipe.

Conveying stage. After the inlet valve has closed, compressed air continues to flow through the nozzle ring and builds up pressure in the pressure vessel. When the pressure in the vessel exceeds the pressure in the pipeline, the discharge valve opens and sand flows from the vessel into the conveying pipe **(Figure 10c)**.

Transfer stage. When the pressure vessel is empty, a leaf spring closes the discharge flap onto its seat and, in doing so, actuates the inductive low level probe. The air still flowing out of the pressure vessel cleans the sealing surface in the discharge valve. The compressed air feed into the pressure vessel is interrupted and the pressure in the inlet valve bellows cylinder is exhausted **(Figure 10d)**.

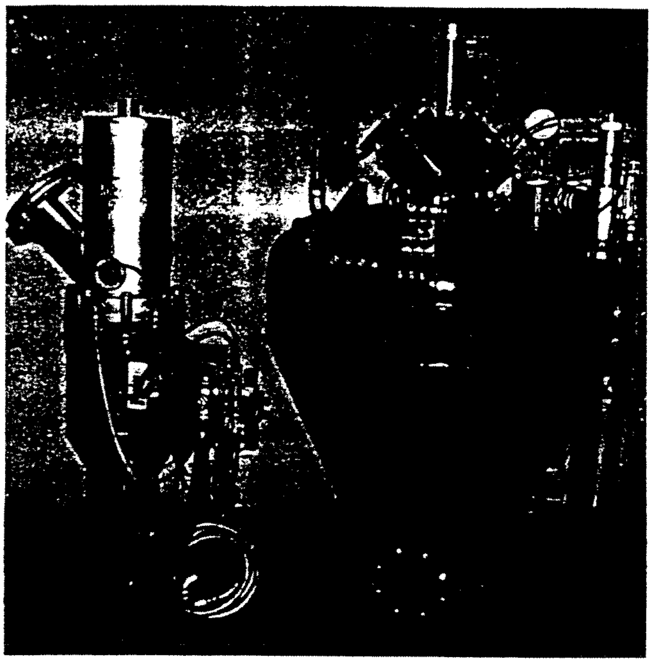


Figure 9. Comparison of a conventional pneumatic conveyor for sand (right) with the continuous pneumatic conveyor with the same conveying capacity (left) *(Type SP 25, Photo Alb. KLEIN)*

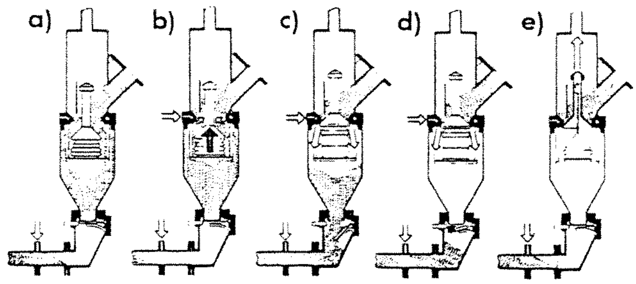


Figure 10. Function of the conveyor with continuous slug-type conveyance: a) Filling stage; b) Closing stage; c) Conveying stage; d) Transfer stage; e) Exhaust stage

Exhaust stage. The pressure remaining in the pressure vessel at this point collapses the bellows cylinder and holds the inlet valve cone on its seat **(Figure 10e)**. This causes the exhaust valve to open and the pressure in the pressure vessel to fall until the inlet cone opens under its own weight and allows a clear passage for refilling.

Possibilities to save conveying air

The continuous conveying process conveyor results in significant possibilities to save conveying air.

Figure 11 shows the comparison with a conventional conveyor. It states the air consumption per metre conveying distance in relation to the conveying capacity. The considerably lower air consumption of the new conveyor is quite apparent.

Influence of the quasi-continuous conveying process on wear

Practical experience and laboratory examinations show the overproportional influence of the particle velocity on

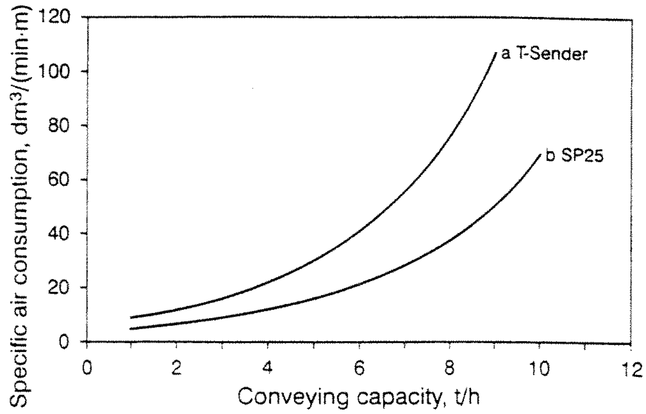


Figure 11. Comparison of the specific air consumption: a) conventional conveyor; b) SP 25

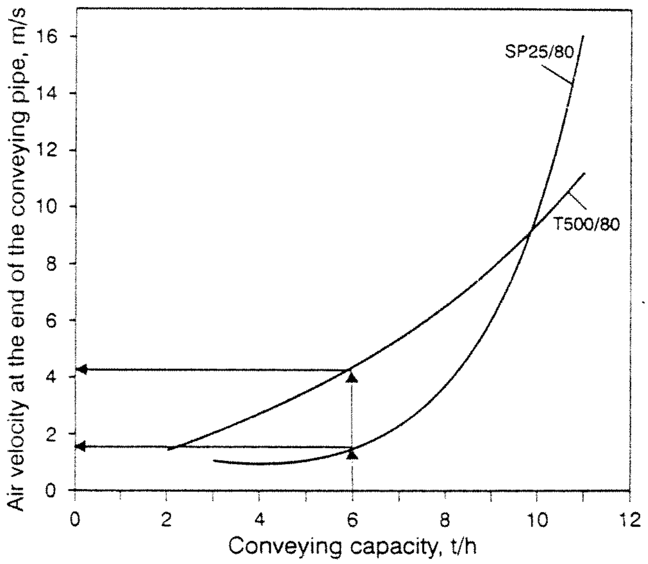


Figure 12. Comparison of the required air velocities at the ends of the conveying pipes at the conventional conveyor and at the conveyor Type SP 25, dependent on the conveying capacity (sand F 32, conveying pipe DN 80, conveying distance 40 m); example: conveying capacity 6 t/h, conventional conveyor approx. 4.2 m/s, SP 25 approx. 1.5 m/s air velocity at the end of the conveying pipe

wear [4, 5]. Therefore, the transport velocity of the sand in the conveying pipe is very important for the trouble-free operation of pneumatic sand conveying systems. With the quasi-continuous conveyor a required capacity can be reached at clearly lower air velocities **(Figure 12)**.

Application of the conveyor for high transport capacities

Increasing demands on capacities necessitated an extension of the capacity range of this pneumatic conveyor. By combining two single conveyors to form a tandem system, the possible transport capacity could be increased considerably. During the filling time of one conveyor the other one transports material. The conveying process is absolutely continuous and very gentle.

The two conveyors discharge into a common intermediate housing to which a conveying pipe up to a size of DN 125 is connected. **Figure 13** shows such a tandem conveyor.

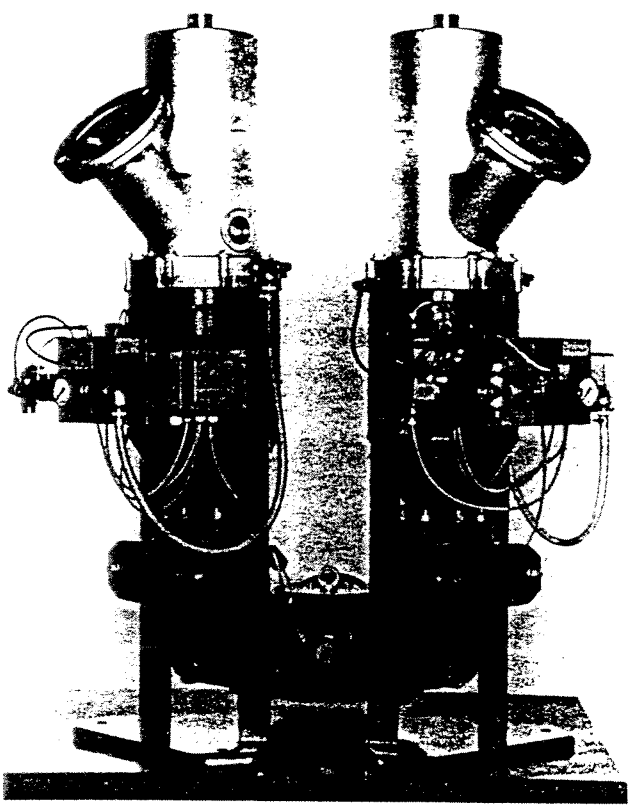


Figure 13. Tandem system for the gentle, energy-saving transport at high conveying capacities *(Type SP 25, Alb. KLEIN)*

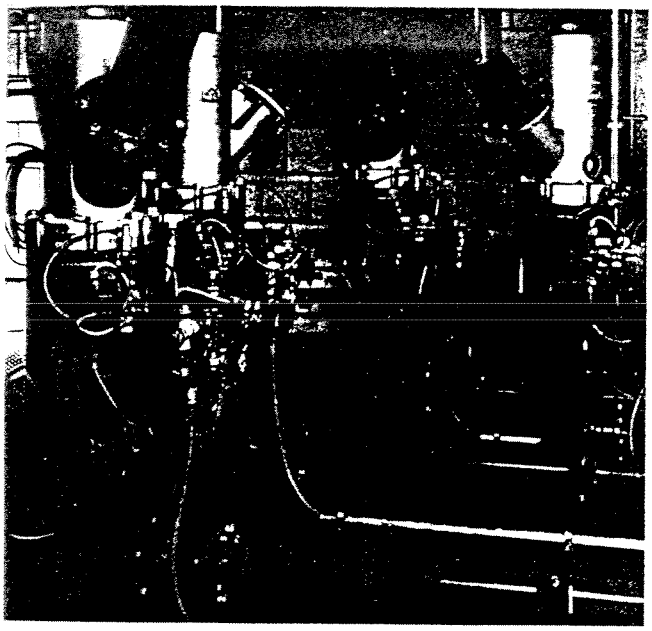


Figure 14. Group of conveyors for the transport of new sand and thermal reclaimed sand *(Type SP 25, Photo VAW)*

Possibilities arising from the small size of the conveyor

As **Figure 9** shows, the conveyor requires much less space than conventional conveyors. Therefore, well accessible plants can be built even with restricted space.

Figure 14 shows a distribution station for new sand and thermally treated reclaimed sand. All conveyors of this type are easily accessible and easy to maintain. The conveyor in **Figure 15** transports the cooled used sand from a continuously operating fluid-bed cooler-sifter. The low inlet height of the conveyor allows its attachment without pit. The conveyor in **Figure 16** is integrated into the second stage of a mechanical sand reclamation system. It is used for the internal transport of material from a centrifugal cleaner to a fluid-bed sifter. ■

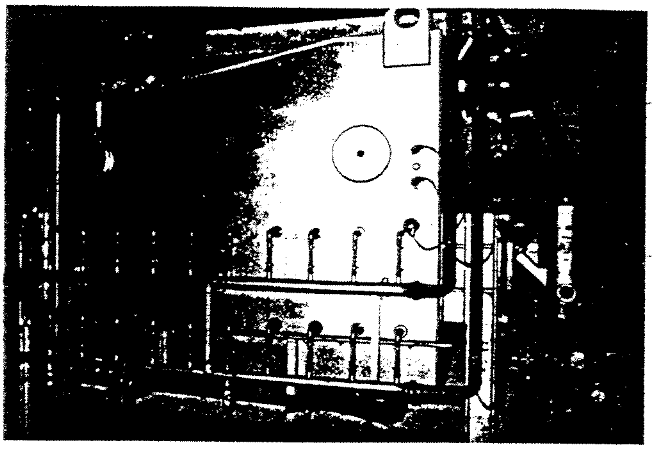


Figure 15. Conveyor for the transport of cooled used sand *(Type SP 25, Photo Kunming Machine Tool)*

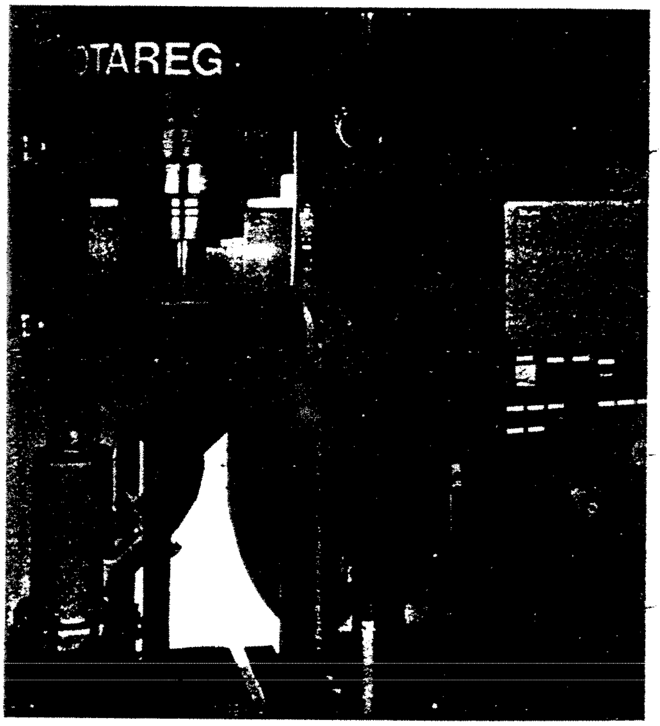


Figure 16. Conveyor, integrated in the second stage of a mechanical reclamation plant *(Type SP 25, Photo KLEIN)*

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