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On the low-wear pneumatic conveyance of waste sands and similar matters

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Summary

The slug air injection procedure described herein allows the low-wear conveyance of materials, whose grain size distribution has precluded them from slow slug conveyance. The components of this system have been developed on the basis of service-proven modules. The system does without any electric control.

This new system also offers itself as a relatively low-expenditure retrofit solution for many current slug conveying installations having a propensity for sudden choking or excessive wear.

In foundries and mainly in shot-blasting installations great amounts of sands of varying grain size distribution and bulk weights use to occur. To transport these waste sands from the shot blasting installation to the dumping silos pneumatic conveyance systems are frequently used. In contrast to the pneumatic conveyance of regenerated quartz sands, waste sands often produce considerable wear of the conveyor lines. Another phenomenon frequently observed are strong conveyor line vibrations which sometimes cause the line brackets to come off the walls. The present paper explains the reasons of these incidents and presents a pneumatic conveyance system able of handling waste sands as smoothly as regenerated quartz sands.

Pneumatic conveyance of ordinary foundry quartz sands

Quartz sands commonly used in foundries are pneumatically conveyed today, in both new and regenerated condition, with hardly any major problem and low conveyor line wear. Sand transport is ensured by cycle-type conveyors. The sand forms slugs passing through the conveying line and separated by air cushions. In correctly dimensioned and adjusted conveying installations, the conveying velocities are low enough to allow the conveying lines to be made of standard-gauge steel tubes according to DIN 2448. For long conveying lines and high conveying capacities more abrasion-resistant versions are used sometimes.

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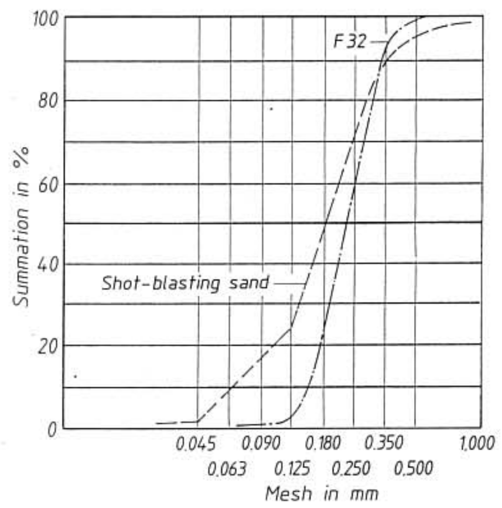


Figure 1. Screen analyses – F32 quartz sand versus shot-blasting sand

Experience in the waste sand conveyance

The pneumatic conveyance of waste sands from shot-blasting installations for example presents quite different conditions. Many such conveying systems are submitted to far greater wear than regenerated sand conveyors requiring frequent repairs with resulting process interruptions. Other installations are subject to sporadic choking or strong vibrations or concussions which cause the brackets to work themselves loose.

This is mainly due to the grain size distribution of the sands which is determined by screen analysis. **Figure 1** shows the difference between prepared sand (F32) and waste sand from the shot blasting installation. F32 sand is practically free of any dust particles of less than 0.063 mm while waste sand contains about 10% of that dust grade and is also characterized by a clearly greater percentage of fine sand fractions.

F32 sand does not contain any coarse grains of more than 1 mm in size. Waste sand, on the contrary, shows a small percentage of little "lumps" of up to 5 mm. The materials differ also in view of the packing density which is 1.5 kg/dm^3 for F32 sand and 2.3 kg/dm^3 for waste sand.

Waste sand is composed as follows:
- oversize particles
- regular sand fractions

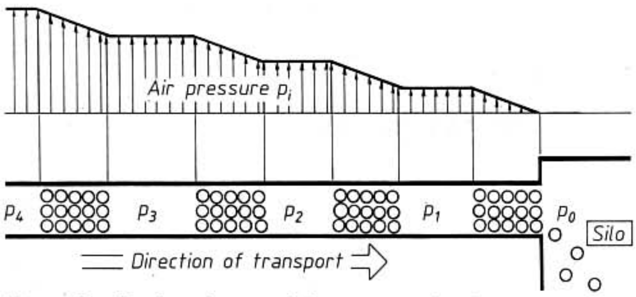


Figure 2. Basic scheme of the pneumatic slug conveyance of regenerated quartz sand

- quartz dust
- individual abrasive grains
- scale flakes
- scale dust
- bentonite in certain shot-blasting sands.

When preparing new quartz sands and regenerating used sands particular care is being taken to minimize the grain size distribution variation of such sands. This means that the product to be transported is always basically the same so that the pneumatic conveyor, once correctly adjusted, will continue to operate under the same conditions.

Waste sands from shot-blasting installations, however, are of varying consistency. The grain size distribution and bulk weight varies constantly as a result of casting program changes, steel casting shot-blasted for descaling after annealing or the use of naturally clay bonded sands. The conveyance process strongly depends on such factors.

Slug-type conveyance of prepared quartz sands

Figure 2 illustrates the basic functioning of the pneumatic conveyance of normal prepared quartz sand: The sand forms individual compact slugs which are transported from the pressure vessel to the receiving silo via the conveying line. The slugs are separated by air cushions having a pressure of p_i which decreases as the slug approaches the end of the conveying line. This pressure decrease is due to the fact that the air expands and flows through the pores of the preceding slug to reach the lower-pressure air cushion ahead of it.

In **Figure 3,** the beginning of a new conveying cycle is shown which is best illustrated at the end of the conveying line.

The air coming from the last air cushion and passing through the pores of the preceding slug with a pressure of p_1 loosens the slug thus reducing the wedge effect between the individual grains and the conveying line walls so that pressure p_1 is sufficient to shift the slug towards the silo. While the slug moves towards the silo the air pressure behind it drops almost to the silo air pressure level of p_0 as the air expands and flows towards the silo through the pores of the preceding slug. The sand is not accelerated any more but enters the silo calmly and at low speed. Now the following slug is moved in the same way by pressure p_2 of the air cushion behind it. This process is repeated until all plugs in the conveying line are moving and sand flows in from the vessel.

Practicians know that H32 quartz sand for example is conveyed far more smoothly and evenly than F36 sand for example. This is due to the low porosity of the F36 material which prevents the air from flowing freely through the slug. The slugs tend to stop whenever they encounter a major resistance, as at a baffle for example, until pressure has built up again behind them. The slugs then use to accelerate jerkily and to dissipate their kinetic energy by impacting against the next obstacle. At the end of the conveing line the slug pops into the silo accompanied by a loud expansion noise.

Slug-type conveyance of waste sands

With sands containing great amounts of dust, the pores between the bigger grains can get clogged or at least strongly narrowed. The air from the air cushion behind the slug is not allowed to pass through it freely. As shown in **Figure 4,** the slug gets wedged in the line and the conveying process either breaks down completely or takes place sporadically only. This is a phenomenon which makes itself heard: phases of quiet conveyance are followed by loud transportation noises and isolated hard impacts.

For corresponding measurements, a conveyor was installed on an electric balance whose output signal indicated the momentary conveying capacity. When interpreting the curves recorded by a multi-channel chart recorder it must be remembered that the sand flow from the vessel is not a constant but a cyclic one with sand slugs and air cushions alternating. And that is how the measuring equipment records the process so that the actual conveying capacity is an average value.

Among others, the conveying pressure has also been recorded using an electronic pressure gauge. **Figure 5** shows the conveying pressure and the momentary conveying capacity during one conveying cycle, using F32 quartz sand. Each maximum value in the capacity curve represents a slug leaving the vessel and entering the conveying line. Each time this curve drops to zero and does not start rising again shortly afterwards, the conveying line is

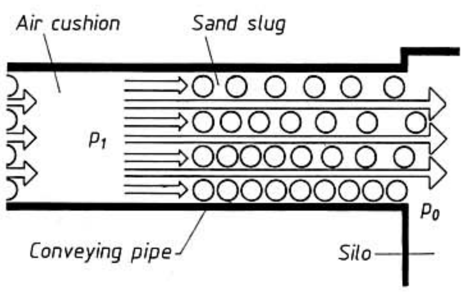


Figure 3. Influence of conveying air on regenerated quartz sand slug

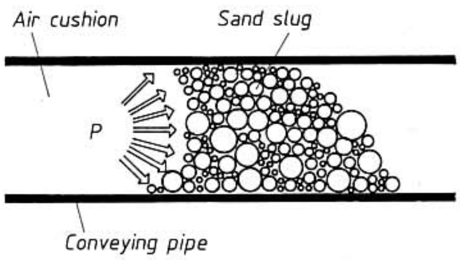


Figure 4. Influence of conveying air on shot-blasting sand slug

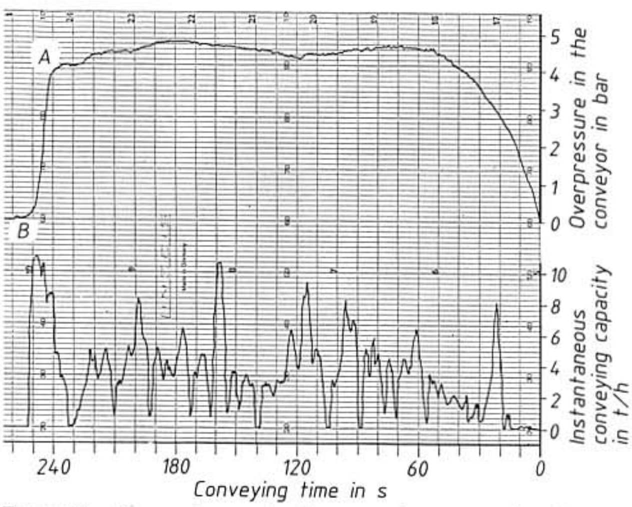


Figure 5. Conveying cycle diagram of a conventional pneumatic slug conveyor using F32 sand

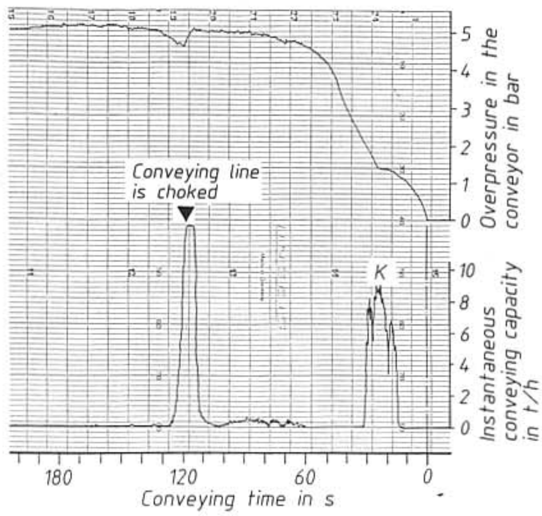


Figure 6. Conveying cycle diagram of a conventional pneumatic slug conveyor using shot-blasting sand

choked. The higher the peak, the greater the momentary conveying capacity. At point A in **Figure 5,** the vessel is empty. This condition is signalled by a minimum probe. The conveying air valve closes and the exhaust air valve of the vessel opens resulting in a steep pressure decline between points A and B. The sand still contained in the conveying line remains there until the next conveying process begins. The system starts up automatically when the conveying air from the vessel flows through the unmoving slug.

Figure 6 shows the same system and process using sand from the shot-blasting installation this time. After some sand has flown into the conveying line at the beginning of the cycle (point K) the line gets choked after a conveying time of as little as 30 seconds. The vessel pressure increases to mains pressure but there is practically no conveying action. After about 110 seconds, another small quantity of sand flows from the vessel. Then the conveying line is completely blocked.

Energy exchange between the conveying air and the material to be conveyed

The particles in the conveying line must be supplied with energy to make them move. In pneumatic conveying systems this energy is transmitted by the air.

Dispersed conveyance. During dispersed conveyance, the particles move through the conveying line at a great distance from each other. The air velocity being far higher

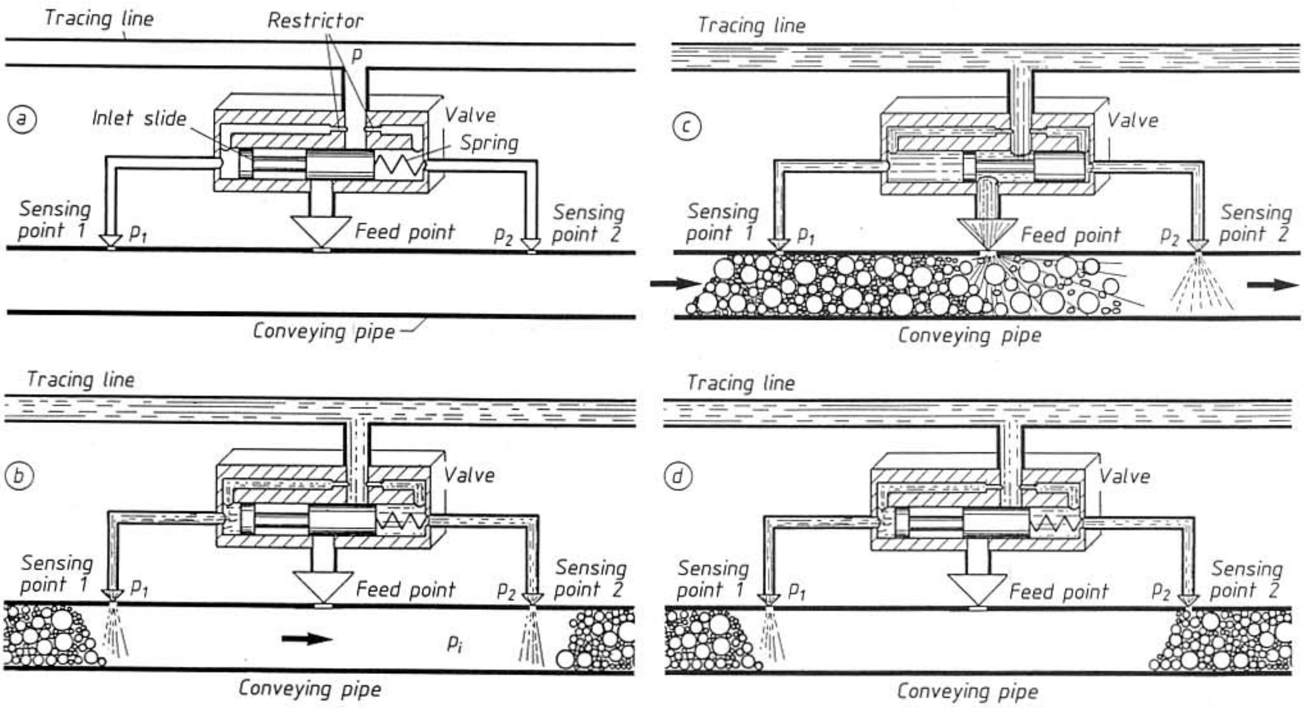


Figure 7. Slug detector: a) Basic scheme; b) Basic position: no slug at sensing point 1; $p_1 = p_2$; no air injection; c) Switch position: a slug is at sensing point 1; $p > p_2$; air is being injected; d) Basic position: no slug at sensing point 1; $p_1 \leq p_2$; no air injection

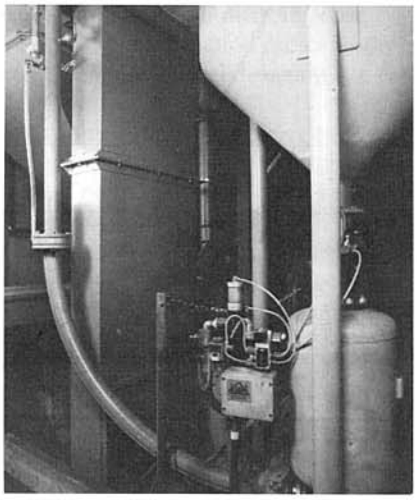


Figure 8. Slug air injection system with probes, conveying line and tracing line *(KSB photo, Pegnitz)*

than the particle speed, the particles are driven by the flow forces. Due to the great distance between the individual particles the air is allowed to pass almost undisturbed from the inlet to the outlet of the conveying line and to transmit energy to the dispersed particles at any time and at any place in the line. If a particle is decelerated by a baffle for example, the speed difference between the particle and the air flow increases resulting in a higher propulsion force. The particle is accelerated again and the material flow continues undisturbed.

Slug conveyance. Slug conveyance relies on the differential pressure of the air cushions next to the slug. By flowing through the slug pores, the air reduces the friction between the slug and conveying line walls and completes the energy reserve of the downstream air cushion. Whenever a slug is not sufficiently permeable, the downstream air cushions do not receive the amount of air required to ensure the pressure forces and diffusion processes needed for smooth conveyance and the conveying line gets choked.

Common remedial measures during waste sand conveyance

If products whose grain size distribution actually precludes them from slug conveyance are to be transported by slugs, it is possible to increase the amount of conveying energy by feeding additional air into the conveying line through so-called aerating flanges or activators installed in the line. Through these devices, air is constantly injected, that is the air flow and thus the conveying speed is continuously increased towards the end of the conveying line. As a compensation, the conveying line diameter could be gradually increased. To do so, however, the respective amount of air injected would have to be known.

In practice, the line diameter remains unchanged, often resulting in high slug conveying speeds with a correspondingly strong wear of the conveying line.

Conveyance is particularly complicated if the material does not have a uniform grain size distribution which is generally the case with waste sands from shot-blasting installations. An optimum conveying system for such materials must be fitted with sturdy devices along the conveying line to determine when and at which point of the line a slug is beginning to get blocked. Then, air must be injected into the respective area until the slug starts moving normally again. The amount of air injected must be minimized to prevent the conveying speed from increasing.

Slug air injection procedure

The newly developed slug air injection system[1]) consists of so-called slug detectors mounted along the conveying line. These detectors respond to the pressure difference between the air cushions upstreams and downstreams of the slug. Whenever this pressure difference exceeds a predetermined value, air is injected from a tracing pipe into the slug at that particular place only until the slug leaves the range of the respective detector. If the differential pressure remains below the predetermined value, no air will be injected.

Figure 7a shows the basic configuration of a slug detector. The inlet slide for the admission of compressed air (pressure p) from the tracing line is closed and kept in closed basic position by a spring. Through the slide, a small amount of air is taken from two small restrictors and fed into the conveying line through sensor points 1 and 2. This air acts upon the faces of the slide. The sensing points and the feed point are protected against contamination by special non-return valves. The actual valve system consists of a modified steel slide valve which has proved good for decades and is able of sustaining millions of cycles without getting worn. Electric devices are not necessary.

Figure 7b illustrates a situation with one slug located upstreams of sensing point 1 and another downstreams of sensing point 2. The enclosed air cushion shows a pressure of p_i. The same pressure level exists at sensing points 1 and 2.

$$p_1 = p_i = p_2$$

The valve slide is kept in a closed position by the spring.

In **Figure 7c,** the slugs have moved on in the direction of the arrow. The slug at sensing point 1 impedes the sensing air flow at this place, whereas the sensing air flows freely at sensing point 2. At sensing point 1, pressure p_1 builds up which acts against the valve spring and finally

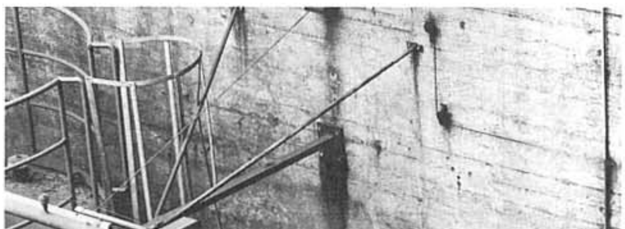


Figure 9. Slug detector at the conveying line of a slug air injection system *(KSB photo, Pegnitz)*

presses it back ($p_1 > p_2$) allowing air from the tracing line to be fed into the conveying line through the feed opening. The slug is loosened and continues to move towards the receiving silo.

When the slugs reach the position shown in **Figure 7d,** p_1 becomes $\leq p_2$. The spring closes the slide valve which cuts off the air supply at this point.

Figure 8 shows the pressure vessel, conveying line and the beginning of the tracing line. The slug detector is shown in **Figure 9.**

Conveyance data

In **Figure 10,** a conveyance cycle using shot-blasting sand has been plotted. As can be seen, the conveyance process is almost as regular as with F32 quartz sand (compare **Figure 5).**

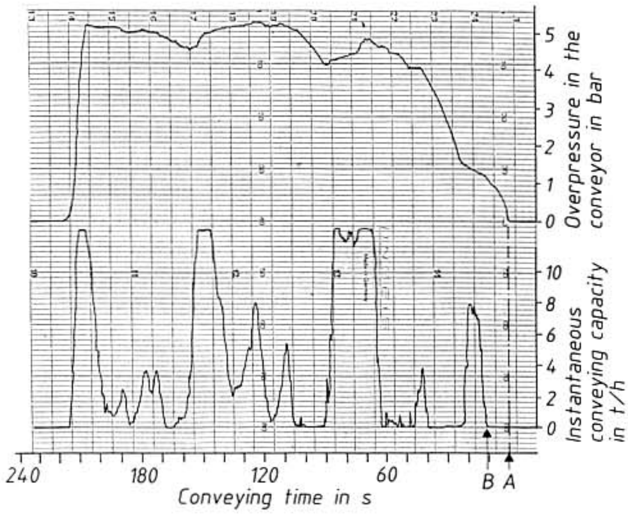
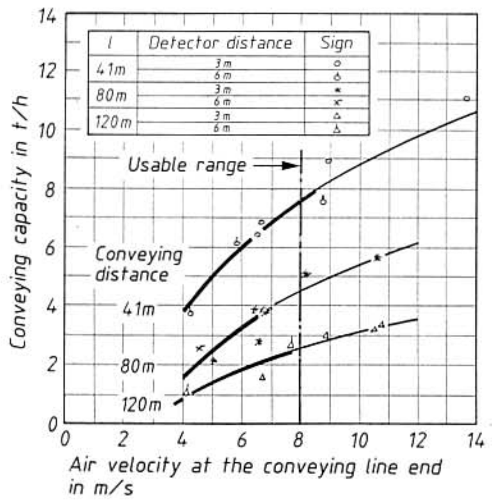
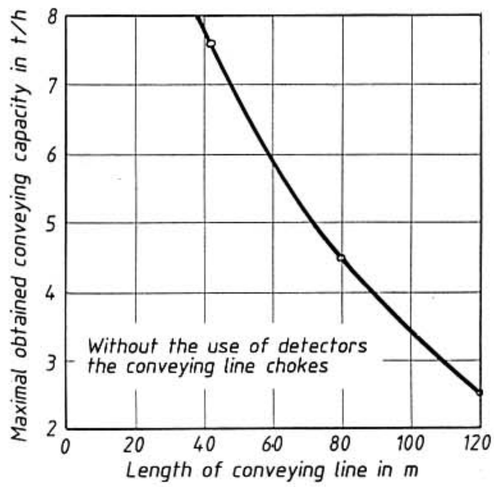


Figure 10. Conveying cycle diagram of a pneumatic conveyor with a slug air injection system using shot-blasting sand



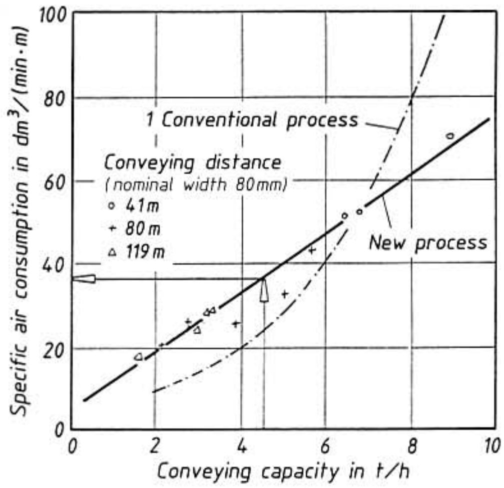
Conveyor:	T/S 500 with slug detectors
Material:	shot-blasting sand
Pressure:	5.5 bar (overpressure in the conveyor and tracing line)

Figure 11. Relationship between conveying line and average air velocity at the conveying line end



Conveyor:	T/S 500 with slug detectors; 3 m distance; DN 80
Material:	shot-blasting sand
Pressures:	conveyor: 5.5 bar (overpressure) detectors: 5.5 bar (overpressure)

Figure 12. Relationship between the conveying capacity and conveying line length ($\bar{v}_l$ = 8 m/s)



Conveyor:	T/S 500; DN 80; detector distance: 3 m
Material:	shot-blasting sand
Pressures:	conveyor: 5.5 bar (overpressure) detectors: 5.5 bar (overpressure)

Curve 1: F32 quartz sand conveyance with common thrust conveyor and without slug detectors

Example: Conveying distance 70 m; conveying capacity 4.5 t/h; specific air consumption approx. 35 $dm^3/(min \cdot m)$; air consumption per minute: 70 m $\cdot$ 35 $dm^3/(min \cdot m) \cdot 1000$ = 2.45 m^3/min

Figure 13. Relationship between the specific air consumption and conveying capacity

The slug detector and additional air injection systems allow to convey waste sands from shot-blasting installations in the same low-wear manner as new sands. The system is equally well suited for the conveyance of sinter dust and finest sands.

The conveying capacity of slug conveyors depends, among others, on the amount of air injected. The relationship of the air quantity injected per second and the conveying line cross section indicates the mean air velocity. **Figure 11** shows this relationship for three different conveying distances.

According to pertinent experience, the maximum average air velocity for quartz sands in 8 m/s at the conveyor line end. The maximum conveying capacity as a function of the conveying line length is given in **Figure 12.**

Figure 13 shows the specific air consumption as a basis for the estimation of the amount of conveying air required. This diagram has been plotted specifically for shot-blasting sands and therefore can be used as a comparative tool only for other types of sand. For comparison, specific air consumption for the conveyance of F32 quartz sand with a convential conveying system has been plotted as well[2]. ■

Translated from Giesserei 76, 1989, No. 7, pp. 210–215.

References

[1]) DE PS 36 44 119.
[2]) *Federhen, B.:* Giesserei 73, 1986, No. 24, pp. 701–705.