TECHNICAL ARTICLE

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# Rules and Guidelines for Feeding, Pneumatic Conveying and Storage of Dry DSG

**Abstract**

This paper is intended as a practical guide to avoiding the pitfalls when designing medium size storage hoppers (<150m$^3$) and pneumatic conveying systems for dried DSG/FGD (flue gas desulphurisation). Recommendations for a new technology to pneumatically convey even the most challenging grades of DSG are made, bringing the associated savings in power and maintenance already established from the widespread dense phase conveying of stucco and mineral, when compared to mechanical or lean phase solutions.

**Introduction**

In recent years, problems with the storage and transport of dried DSG/FGD within gypsum plants has become apparent. These problems have mainly concerned the reliable discharge of DSG from hoppers, and reliable pneumatic conveying of different grades of DSG or mineral within the same system.

The Clyde Process range, from Schenck Process, have upgraded and replaced many poor performing storage hoppers and pneumatic conveying systems, including several for DSG, using know-how from our in-house research facility and in-plant experience.

This article describes and summarises the key points to ensure DSG can be handled reliably.

**Typical DSG / FGD Discharge from Storage Problems**

Examples of the characteristics of dried DSG are given throughout this paper, based on the materials given in Table 1.

*Table 1:*

| Description | Bulk Density | Particle Size Distribution | | |
|---|---|---|---|---|
| | | < 10% passing | < 50% passing | < 90% passing |
| Mineral Gypsum | 1000 kg/m$^3$ | 8 um | 63 um | 589 um |
| Dried DSG 1, 2 | 1019 - 1050 kg/m$^3$ | 24 - 30 um | 50 - 60 um | 92 - 110 um |
| Dried DSG 3, 4 | 1045 kg/m$^3$ | 20 - 21 um | 41 um | 70 - 90 um |
| Dried DSG 5, 6 | 810 - 860 kg/m$^3$ | 4 - 6 um | 26 -30 um | 61 - 66 um |

Gypsum plants typically use hoppers of different shapes and sizes to store DSG following drying, some of which suffer discharge problems.

These problems are normally caused by the de-aeration of the material.  This is a problem relevant to DSG, because it de-aerates very quickly, see Table 2.

*Table 2: Typical settling characteristics*

| Description | Settlement time | Settlement volume |
|---|---|---|
| Dried DSG | 4 seconds | 15% |
| Ground mineral | 4 seconds | 4% |

When DSG flows reliably, its discharge rate is slow in comparison to natural gypsum and other powders such as fly ash or cement (refer to Table 3).  This reduced discharge rate needs to be accounted for in the hopper geometry and discharge aids.  The flow rate when the DSG contains recycled scrap with paper content is reduced further, often requiring assistance to establish any flow at all.

*Table 3: Typical flow rates through aperture*

| Description | With aeration | No aeration |
|---|---|---|
| Dried DSG | 0.10 kg/sec/cm² | Erratic flow |
| Dried DSG 12% scrap | 0.06 kg/sec/cm² | No flow |
| Fly ash / cement | 0.25 kg/sec/cm² | No data |

For a simple cylindrical hopper with a conical outlet, the key geometrical features are the cone angle and the size of the hopper outlet. DSG tends to require a much steeper cone angle than mineral (see Table 4). This suggests that existing mineral bins, with cone angle selected for typical fine powders, may prove problematic for the storage of substitute DSG.

*Table 4: Typical hopper cone angles*

| Description | Cone Angle – Clyde | Cone Angle - Others |
|---|---|---|
| Dried DSG | 47° (carbon steel) | 52 [7]° (stainless steel) |
| Ground mineral | 60 ° | 55 [8]° |

To solve discharge problems, mechanical extraction such as rotary extractors, screws or bin dischargers are often used. However, through the brand of Clyde Process, Schenck Process's experience and observation of these solutions can be unreliable, requiring high levels of maintenance and have frequent periods of poor flow, sometimes resulting in unexpected modifications.

However, there are many examples of dried DSG storage where discharge problems do not occur. These successful designs tend to be premised on the following principles, which underpin the approach recommended in this paper:

a) Correct silo geometry, especially in the discharge cone
b) Avoidance of mechanical discharge aids
c) The use of well-designed aeration/fluidisation systems

**Guidelines for the Reliable Discharge of Dried DSG from Storage**

Through the Clyde Process brand, Schenck Process implements the following simple guidelines in order to ensure that the design of DSG storage bins can be operated trouble free, under normal conditions.

**Check the Material Grade**

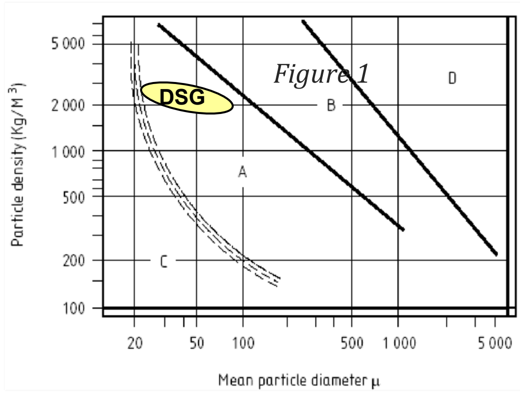



*Figure 1*

Using Geldart [2], Figure 1, Schenck Process checks that the mean particle diameter and particle density place the material in either band A or B. Materials in this band have a high likelihood of flowing well from storage.

DSG is typically in Band A, indicating the material responds well to aeration.

Materials within band C require special attention to ensure reliable discharge. These materials are outside the scope of this paper.

**Silo Geometry**

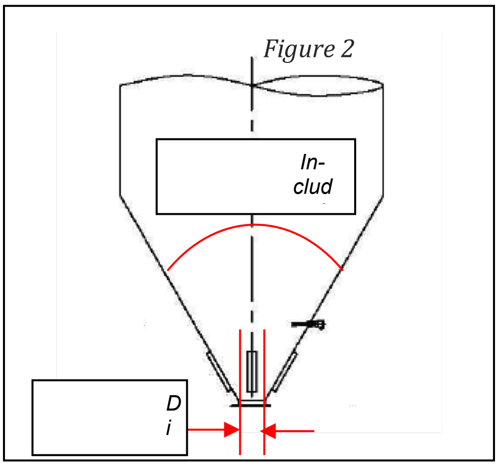



*Figure 2*

The included angle of the hopper (figure 2) should be less than 60° if the bin is aerated[1], while the discharge diameter should be at least 200mm.  Smaller discharge diameters risk bridging and rat holing problems, whilst cone angles less than 60° lead to erratic discharge.

The best position for the outlet is usually on the centre axis of the bin, to maximise the working volume and promote equilateral discharge.

Without equilateral discharge, a significant amount of material will have a high residence time, increasing the possibility the material flow properties will change in response to compaction or atmospheric moisture.

Aeration of DSG causes its volume to expand by 10-15%, therefore enough expansion space within the bin must be assured at all times (Figure 3), to prevent overfilling and subsequent damage to the silo and ancillary equipment. This is especially relevant when filling the silo pneumatically, where there is a risk of pressurisation.

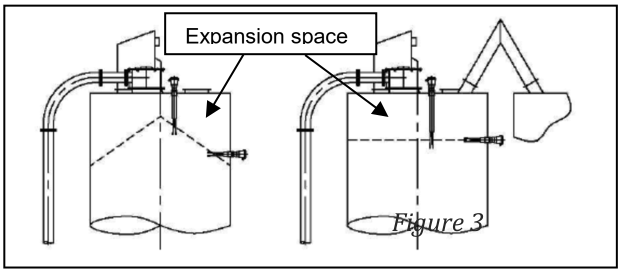


Figure 3

Square or rectangular bins should be avoided with DSG, as material tends to hang up in the corners of the hopper. Promoting its discharge is then difficult given the low corner valley angles created by the square configuration.

**Discharge Aids**

From experience, aerating DSG with air is the most reliable discharge aid when used in conjunction with 60° cones angles. Schenck Process has found that any kind of “forced” movement of DSG leads to unexpectedly high resistance. For this reason, Schenck Process recommends avoiding the use of mechanical extraction and bin activators where possible and using hoppers with correct geometry and aeration instead.

When designing the aeration system, the following points should be considered:

a) Air should be distributed equally around the discharge close to the outlet, typically using four injection points (see Figure 4).

b) Six to eight more aeration points would be positioned equally around the hopper wall, approximately half way up the cone.

c) Silos with a volume over $40m^3$ should have a third rung of aeration points. Silo volumes in excess of $150m^3$ would need specialist attention to ensure the aeration design will be effective.

In all cases, the principle is to ensure that the design aerates the material evenly, without creating air “escape” channels that prevent further material fluidisation and consequent poor discharge.

Figure 5

Many different aeration devices are available. Those that tend to work best have a degree of mechanical agitation, such a Solimar™ pad (Figure 5). Care must be taken when using porous or sintered aeration as fine particles can pass through the pores and block the pads from behind, rendering it ineffective.

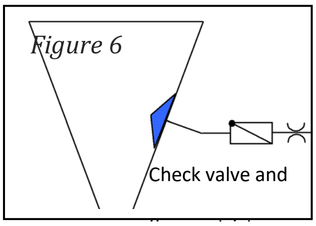


Figure 6

When designing the air supply to the individual aeration points, the flow to each must be controlled otherwise the air will short circuit through the points not covered with material. Square edged orifice plates or orifice tubes can be used to ensure aeration air flows to all points at all times (Figure 6).

By controlling the air addition in this way, the likelihood of air locks, or pockets or highly fluidised material being formed is much reduced, improving the repeatability of material discharge.

Schenck Process investigated a poor performing storage hopper. Each aeration point did not have a flow restrictor and most of the air was escaping without fluidising much material. By adding flow restrictors to each aeration point, Table 5 shows the improved performance:

*Table 5: Effect of Controlling Fluidisation Flow*

| Description | Aeration operating without flow restrictors | Aeration operating with flow restrictors |
|---|---|---|
| Time to fill $4m^3$ vessel from $40m^3$ silo | 35-40 seconds, variable | 22 seconds, repeatable |

To ensure the hopper discharges properly, Schenck Process would recommend an aeration flow sufficient to replace 50% of its volume in 20 minutes. For example a $150m^3$ silo would need an aeration flow of approx 4 $Sm^3/min$. For a hopper of $10m^3$ volume, the aeration flow would be 0.25 $Sm^3/min$. The air supply pressure would be 300 to 500mbarg [1].

To achieve reliable discharge, it is often necessary to vent air from the filling point back into the hopper (or another suitable location). This ensures that the displaced air in the receiving vessel does not have to vent back up through the material at the feed point, slowing the discharge. It also vents away any trapped air pockets, which will cause erratic flow.

Frequently the aeration only operates when the hopper outlet valve is opened for discharge. This prevents material aerating, as the air will escape through the outlet without ever passing through the material.
It is recommended to continuously aerate the hopper at least 10 minutes before material discharge is required. The effect in practice of not aerating material in advance of discharge is shown on Table 6.0:

*Table 6: Effect on silo discharge of Aeration Time*

| **Description** | **Aeration operating continuously** | **Aeration operating only when silo must discharge** |
|---|---|---|
| Time to fill 4m$^3$ vessel from 40m$^3$ silo | 22 seconds, repeatable | 60 seconds, erratic |

**Guidelines for the Reliable Transport of DSG**

Generally speaking, Plant Operators need pneumatic conveying systems to:

a) Operate with the lowest possible energy costs
b) Be tolerant of different grades of DSG and convey ground mineral with no adjustment
c) Have high levels of availability, i.e. low wear and low maintenance
d) Minimise dust emissions to maintain the quality of the environment

In order to deliver all of these benefits, Schenck Process recommends that self-adaptive dense phase conveying technology be used, described below.

**Self-Adaptive Dense Phase Pneumatic Conveying Technology**

Clyde Process self-adaptive dense technology was developed in response to calls from several industry partners to solve ongoing problems with conventional dense phase systems provided by our competitors, whose machines were based on mineral gypsum know-how, but were being used to transport dried DSG. Their problems were proving very costly and are summarised below:

*Transport Capacities Below Expectations*

When switching from mineral gypsum to DSG, it was discovered that both lean phase and dense phase systems have a much-reduced conveying capacity. With lean phase systems, it was possible to partially address this issue by increasing the available air supply. However with dense phase systems, it proved far more challenging, if not impossible, to restore the necessary conveying rates.

*Frequent Pipeline Blockages*

Through test work and plant experience, it discovered that different grades of DSG convey very differently in dense phase systems, refer to table 7.

Difficulties with dense phase conveying of DSG begin to arise especially when the mean particle size is greater than 35 microns (refer to Table 7).

Table 7: Differing DSG Dense Phase Conveyability

| **Descrip-tion** | **Bulk Density** | **Mean particle size um** | **Findings** |
|---|---|---|---|
| Mineral Gypsum | 1000 kg/m$^3$ | 63 | Self adaptive dense phase re-quired |
| Dried DSG 1,2 | 1019 - 1050 kg/m$^3$ | 50 - 60 | Self adaptive dense phase re-quired |
| Dried DSG 3,4 | 1045 kg/m$^3$ | 41 | Self adaptive dense phase re-quired |
| Dried DSG 5, 6 | 810 – 860 kg/m$^3$ | 26 - 30 | Conventional dense phase or self adaptive OK |

The use of self-adaptive dense phase technology allowed all grades of DSG to be handled, thereby significantly increasing the possible sources of DSG available to the plant.

**Innovative Dense Phase Technology**

The main features of the adaptive system are a special pipeline with an internal air bypass feature, and using algorithms to control the pressure in the pipeline by adjusting the material loading.

Internal By-Pass – “Autoflow”

The internal by-pass arrangement comprises of a small inner pipe mounted within the main conveying pipeline. The Autoflow functions by allowing air to escape from behind material plugs, thereby relieving excessive pressure that may lead to a blockage. The design of the internal by-pass was refined for DSG use, especially relating to the spacing between the inner pipe features, the position and diameter of the inner pipe and by adding small amounts of air at various locations and at various quantities throughout the pipe length.

*Line pressure control – "D-Pump".*

Figure 7

DSG exhibits a tendency to fill the dense phase pneumatic conveying pipeline almost completely. This means that blockages occur frequently. To address this property of some grades of DSG, Schenck Process adjust the pipeline loading to maintain a pre-set conveying pressure, using proprietary D-Pump technology (Figure 7).

The combination of internal by-pass pipe work, and line loading control, resulted in a conveying system that can dense phase convey all grades of dried DSG and mineral gypsum, without any adjustments to the machine configuration or control software.

**Benefits of Dense Phase Conveying with Adaptive Technology**

The Clyde Process self-adaptive Dense Phase conveying technology for DSG has now been operating trouble-free at several plants for over 18 months, which compares well to other dense phase systems that require constant attention and a dedicated maintenance team. The benefits of this technology are summarised below:

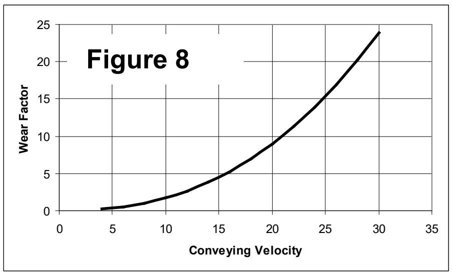
Zero Set-up Time
When changing the grades of DSG or mineral, no alterations to the self-adaptive conveying system are required for reliable transport.

No Blockages
When the Autoflow pipe-work is used in conjunction with line pressure control algorithms pipeline blockages are avoided, in the experience of the operators using the Clyde Process technology.

Maintained Transfer Rates
With different grades of DSG or mineral, the adaptive technology will maintain the conveying rates without modification to the conveying systems. This gives maximum flexibility on raw material sourcing.

No Caking or Material Build Up inside of Pipe-work
The dense phase system operates at conveying start velocities of 3-5 m/s, much lower than the speed where DSG adheres to pipe and bends (a common problem in lean phase pipe work). As a consequence, maintenance issues associated with this are avoided.

Much Reduced Pipe-work Wear




The start conveying speed of the dense phase system is 3-5 m/s, compared to 15 to 20 m/s lean phase. Figure 8 [5] shows the wear in the Clyde Process dense phase will therefore be approximately 10 times less than the equivalent lean phase system, with a corresponding increase in component life.

Lower Power Consumption
The difficulties with dense phase conveying DSG have forced many operators into lean phase solutions over recent years.

| TABLE 8 | **DSG** | **DSG** |
|---|---|---|
| Conveying Mode | Lean Phase | Dense Phase |
| Average Conveying rate | 20 tph | 20 tph |
| Conveying pressure | 0.50 barg | 2.5 barg |
| Minimum conveying velocity | 20 m/s | 3 - 5 m/s |
| Absorbed power | 60 kW | 42 kW |

As can be seen from Table 8 above [4], the self-adaptive dense phase solution when handling 20tph of DSG would use 18 kW per hour less than the lean phase technology, representing a 30% saving in power.

**Practical Alternative to Mechanical Systems**

Many gypsum plants around the world avoid pneumatic conveying systems because of unpredictable performance and pipeline blockages arising with certain grades of dry DSG. Mechanical systems are often used to avoid this unpredictability, but bring the following disadvantages:

- Restrictions on plant layout
- High maintenance costs
- Limited or costly upgrades or expansion to feed additional points, or convey at higher capacities
- Dust contamination

The emergence of the Clyde Process dense phase technology, from Schenck Process, now offers a real alternative to plants currently favouring mechanical transport. The Clyde Process pneumatic technology offers the following improvements when compared to mechanical alternatives:

- Reduced maintenance cost
- Dust containment leading to clean working environments
- Increased flexibility of plant layout
- Flexibility of future plant design

## Conclusions

The shift to DSG, as a substitute for mineral gypsum, has strong environmental and commercial merits for plant operators. However, problems with the storage and handling of DSG within the gypsum plant have led to a shift to either lean phase pneumatic conveying of more coarse grades of DSG (away from dense phase), or a shift to mechanical handling to replace all pneumatic conveying options.

However, the use of mechanical or lean phase conveying solutions have brought their own problems. The associated high maintenance costs, plant layout or expansion restrictions, and unexpectedly high power consumption can impact negatively on the competitiveness of the respective producer.

In this paper recommendations for the geometry and aeration of hoppers have been provided, which are grounded in the practical experience Schenck Process has obtained from working at many gypsum plants.

An innovative self-adaptive dense phase conveying technology has also been described, which allows plant operators to convey any grade of DSG, without suffering any of the problems recently experienced by many users. Conveying distances of 150m have been proven in practice, with distances up to 600m possible, giving far greater levels of flexibility for the future gypsum plant arrangement.

This adaptive technology is now proven within the industry and allows DSG users to return to the wide benefits offered by dense phase pneumatic conveying, when compared to lean phase or mechanical handling solutions.

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