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Conveying of High Density and Other Materials

1 INTRODUCTION

In this chapter, data on materials that do not fall into the previous four categories is presented. The main focus of the information provided here is on materials that have a high density, since there is a lot of interest in this type of material, and the capability of this class of materials for pneumatic conveying may not be fully appreciated. Several materials having fairly high densities have already been included in preceding chapters and so it may well be recognized that there is no difficulty in conveying such materials.

In Chapter 12 on “Aluminum Industry Materials” fluorspar was included and this has bulk and particle densities of about 100 and 230 lb/ft$^3$. With a mean particle size of about 66 micron the material did not have sufficient air retention capability to be conveyed in true dense phase flow. It did, however, achieve what might loosely be referred to as ‘medium’ phase conveying for at high values of pressure gradient solids loading ratios of up to about 70 were achieved and the material could be conveyed with conveying line inlet air velocities down to approximately 1400 ft/min.

Then in Chapter 13 on “Cement and Drilling Mud Powders” barite was included and this has bulk and particle densities of about 100 and 265 lb/ft$^3$. With a mean particle size of about 12 micron, however, the material was capable of being conveyed in dense phase, at very high values of solids loading ratio, and with con-
veying air velocities down to 600 ft/min very easily. In conveying barite vertically up a distance of about 15 feet from a high pressure blow tank one of the authors conveyed the material quite steadily at a solids loading ratio of over 800. For this type of material the value of solids loading ratio achieved is essentially only dictated by pressure gradient.

2 IRON POWDER

Although not the densest material to be considered here, it does represent a good starting point as the name itself generally conjures up high density with respect to bulk solids. The data presented here was obtained for iron powder having bulk and particle densities of about 150 and 355 lb/ft³. The mean particle size of the material was approximately 64 micron. The iron powder was conveyed in both low pressure and a high pressure pneumatic conveying test facilities.

2.1 Low Pressure Conveying

Conveying characteristics for the iron powder conveyed in a low pressure system, and hence in dilute phase suspension flow, are presented in Figure 14.1. The material was fed into the pipeline by means of a low pressure, bottom discharge blow tank. The pipeline through which the material was conveyed was two inch nominal bore, 115 feet long and included nine 90° bends. Air supply pressures up to 8 lbf/in² gauge were utilized and material flow rates up to about 3000 lb/h were obtained.

Figure 14.1 Low pressure conveying characteristics for iron powder conveyed through the pipeline shown in figure 4.15.
Solids loading ratios up to about six were achieved and the minimum conveying air velocity for the material was about 2800 ft/min. Provided that the minimum velocity was kept above this figure of 2800 ft/min, with due allowance for the influence of air inlet pressure on the volumetric flow rate of free air required, no operating difficulties were experienced with this material at all. With this particular material, however, there is no indication of whether there is any dense phase conveying potential at all.

2.2 High Pressure Conveying

This iron powder has also been conveyed in a high pressure conveying system and the conveying characteristics obtained are presented in Figure 14.2. The material was fed into the pipeline by means of a high pressure, top discharge blow tank. The Figure 4.2 pipeline through which the material was conveyed was two inch nominal bore, 165 feet long and included nine 90° bends. Air supply pressures up to 30 lbf/in\(^2\) gauge were utilized and material flow rates up to about 40,000 lb/h were obtained. Solids loading ratios of over 140 were achieved and the minimum conveying air velocity for the material was about 750 ft/min.

Although the mean particle size of the material was about 64 micron, the material clearly had very good air retention properties, and better than those of the fluorspar mentioned above with a mean particle size of 66 micron, so that true dense phase conveying was achieved for the iron powder with the high pressure gradients available.

![Figure 14.2 High pressure conveying characteristics for iron powder conveyed through the pipeline shown in Figure 4.2](image-url)

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3 COPPER CONCENTRATE

The data presented here was obtained for copper concentrate having bulk and particle densities of about 105 and 245 lb/ft³. The mean particle size of the material was approximately 55 micron. Conveying characteristics for the copper concentrate, conveyed in a high pressure system are presented in Figure 14.3.

This is the same pipeline as used for the high pressure conveying of the iron powder, presented above, and the same high pressure blow tank was used to feed the material into the pipeline.

A comparison of the conveying characteristics for the two materials will show that the iron powder could be conveyed at a slightly higher flow rate than the copper concentrate, for a given value of conveying line pressure drop. Air supply pressures up to 40 lbf/in² had to be employed to convey the copper concentrate at 40,000 lb/h.

It should be noted that mean particle size is not a good indicator of the transition from dilute to dense phase conveying capability for a material. Although it does tend to occur in the 50 to 100 micron size range, it is the air retention capability of a material that is a better indicator. Air retention is additionally influenced by particle size distribution and particle shape, and so this particular bulk property does provide the best parameter for the purpose of assessing conveying capability at the present time.

![Figure 14.3](image)

**Figure 14.3**  High pressure conveying characteristics for copper concentrate conveyed through the pipeline shown in [Figure 4.2](#).
4 ZIRCON SAND

The data presented here for this material was obtained for zircon sand having bulk and particle densities of about 160 and 285 lb/ft³. The mean particle size of the material was approximately 120 micron. Conveying characteristics for the zircon sand conveyed in a high pressure system are presented in Figure 14.4.

This is also the same pipeline and conveying system that was used for the high pressure conveying of the previous two materials and so direct comparisons are possible. The first thing that will be noticed, however, is that the material has no natural air retention properties and so could not be conveyed in dense phase and at low velocity. The minimum value of conveying air velocity was about 2600 ft/min and the maximum value of solids loading ratio achieved was only about 16. Although a solids loading ratio of only 50 could be achieved with the copper concentrate, the minimum value of conveying air velocity was about 1500 ft/min.

Material flow rates achieved are very much lower than those obtained with both the iron powder and copper concentrate and as a consequence the material flow rate axis was halved for these conveying characteristics in order to magnify the data. In order to convey the material with high air supply pressures it was also necessary to use much higher air flow rates.

Despite these differences the material conveyed very well and high air supply pressures can be employed if required. As with any material that can only be conveyed in dilute phase, however, power requirements will be very much higher because of these limitations.

![Figure 14.4](Image)

**Figure 14.4** High pressure conveying characteristics for zircon sand conveyed through the pipeline shown in Figure 4.2.
5 SILICA SAND

This material is widely conveyed in foundries and glass making. The most notable thing about the material, however, is that it is extremely abrasive. Because it is relatively cheap, and readily available in a wide range of particle sizes, it is ideal for research purposes. The authors have much experience of steel pipeline bends failing due to erosive wear while conveying this material. In dilute phase conveying, under quite normal conveying conditions of velocity and solids loading ratio, it is not unusual for a steel bend to wear through after just two hours of service. This subject is considered in some detail in Chapter 20.

5.1 Low Pressure Conveying

Silica sand typically has bulk and particle densities of approximately 90 and 160 lb/ft$^3$, and the data reported here is for sand having a mean particle size of about 260 micron. Low pressure conveying data for the sand conveyed through the 115 ft long pipeline of two inch nominal bore is presented in Figure 14.5.

The minimum conveying air velocity for the sand was about 2600 ft/min. As a consequence of this, and the conveying line pressure drop being 8 lbf/in$^2$ as a maximum, the maximum value of solids loading ratio achieved was only about ten, despite this being a relatively short pipeline. Data on numerous other materials has been presented for this pipeline, including a group of four in Figure 4.14 and a comparison of seven different materials in Figure 4.16 which showed the sand to be one of the poorest performers.

![Figure 14.5](image-url) Low pressure conveying characteristics for silica sand conveyed through the pipeline shown in figure 4.15.
5.1.1 Material Degradation

This silica sand, conveyed through the Figure 4.15 pipeline, is another material for which data on degradation as a result of pneumatic conveying is available. Similar data on the degradation of sodium chloride and soda ash was presented in section 2.2 of Chapter 11, and for coal in section 5 of Chapter 10. As with these other materials the approximate minimum and maximum values of conveying air velocity were 3400 and 4400 ft/min, and the solids loading ratio was about five.

The sand was conveyed through the Figure 4.15 pipeline for the purpose of determining the potential degradation of the material. Fresh material was loaded into the test facility, it was circulated a total of five times and samples were taken during each run. Samples were taken by means of a diverter valve positioned near the end of the pipeline. A size analysis of all the samples, obtained from the fresh material and each of the five times the material was re-circulated, was carried out and the results are presented in Figures 14.6 and 4.7.

From Figure 14.6 it will be seen that degradation of the silica sand is quite significant. A noticeable effect has been recorded every time the material was conveyed and re-circulated. Despite the material being extremely hard and abrasive it is clearly brittle and friable.

In Figure 14.7 the degradation is presented in terms of a change in mean particle size. To provide a basis for comparison, data for degradation of both the sodium chloride and soda ash, from Figure 11.7 conveyed through the same pipeline and under identical conveying conditions, has been added.

![Figure 14.6](image-url)

**Figure 14.6** Influence of conveying on the degradation of silica sand

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5.1.2 Influence of Conveying Distance

Conveying characteristics for the sand conveyed through a longer pipeline are also available. A second loop was added to the Figure 4.13 pipeline to make the new pipeline 225 ft long, with the addition of four bends. A sketch of the pipeline is given in Figure 14.8.

![Figure 14.8](https://example.com/figure14_8.png)

**Figure 14.8** Details of longer pipeline used for low pressure conveying trials.

It is interesting to note that there appears to be little difference in the rate of degradation of any of these three materials. Material degradation is a subject that is considered in some detail in Chapter 21.

![Figure 14.7](https://example.com/figure14_7.png)

**Figure 14.7** Influence of material conveying on mean particle size.
Conveying characteristics for the silica sand conveyed through the Figure 14.8 pipeline are presented in Figure 14.9. The same conveying facility was used, as for the single pipeline loop data in Figure 14.5 and the conveying trials were carried out over the same range of air supply pressures and air flow rates in order to generate the data.

As expected, with an additional 110 feet of horizontal pipeline and four additional bends, the maximum material flow rates, for the same range of conveying line pressure drop values, are significantly lower. It must be recognized that if a pipeline is extended in this way then a reduction in conveying performance must be expected, if the same air supply pressure is to be utilized.

By the same token, if material is fed into an extended pipeline at the same rate as in the original pipeline, then a very much higher conveying line pressure drop will result for the extended pipeline. If that higher pressure is not available, then it is likely that the pipeline will block as a consequence. This type of situation is considered in more detail in Chapter 19.

It will be noted, by comparing Figures 14.5 and 14.9, that the material flow rates, for given values of conveying line pressure drop and air flow rate, have not halved as a result of a doubling of the conveying distance. This is because scaling from one pipeline to another has to be in terms of equivalent lengths and so vertical lift and pipeline bends also have to be taken into account.
The number of bends, for example, has increased from eight to twelve and so this has not doubled. The equivalent length of bends is relatively high, as will be recalled from Figure 8.14. Account also has to be taken of the difference in air only pressure drop values between the two pipelines. This type of scaling is considered in more detail in the next chapter.

5.2 High Pressure Conveying

Conveying characteristics for the silica sand conveyed through the 165 ft long Figure 4.3 pipeline of two inch nominal bore are presented in Figure 14.10. 200 ft³/min of free air was available to this conveying facility and so it was possible to use conveying line inlet pressures up to about 35 psig.

With a mean particle size of 260 micron, however, this material was far too granular to be capable of low velocity dense phase conveying in the conventional test facility used. The minimum value of conveying air velocity at which the sand could be conveyed was about 2600 ft/min, and so this dictated the maximum conveying limit in terms of air supply pressure with the 200 cfm limit on air flow rate, despite the fact that air at a pressure of 100 psig was available to the conveying facility.

With a conveying line pressure drop of 30 lbf/in² the sand was conveyed at about 17,000 lb/h. The barite in Figure 13.10 was conveyed through this same pipeline and with the same pressure drop the material was conveyed at about 50,000 lb/h. The limit with the barite was not pressure, but the fact that the discharge capability of the blow tank used had reached its limit at 50,000 lb/h.

![Figure 14.10](image-url) High pressure conveying characteristics for silica sand conveyed through the pipeline shown in Figure 4.2

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6 COKE FINES

Petroleum coke is a material that is becoming widely available and is relatively cheap. As a consequence it is being used for firing furnaces and kilns in place of natural gas and oil, where energy costs are a high proportion of the cost of the final product. It is available in a wide range of sizes from dust to coarse granular and so, like many similar materials such as fly ash and alumina, has an extremely wide range of conveying capabilities.

The coke fines, for which data is available here, are also those of petroleum coke. The material was minus one mm in size (18 Mesh), with a very wide particle size distribution and was very granular. As a consequence the material had very poor air retention capability and a very low permeability. The material was conveyed through the 165 ft long Figure 4.3 pipeline of two inch nominal bore and the conveying characteristics are presented in Figure 14.11.

The conveying characteristics are very similar to those for silica sand conveyed through this pipeline and presented in Figure 14.10. The minimum conveying air velocity for the material was slightly higher at about 2900 ft/min and this has meant that the maximum value of air supply pressure that could be utilized for conveying, within the 200 cfm air flow rate limit, was 30 psig. For a given value of conveying line pressure drop, maximum values of material flow rate were about 25% greater for the coke fines than for the silica sand.

Figure 14.11 High pressure conveying characteristics for coke fines conveyed through the pipeline shown in Figure 4.2.
PEARLITE

Pearlite probably has the lowest density of any material reported in this Handbook. The data presented here was obtained for pearlite having bulk and particle densities of about 6 and 50 lb/ft\(^3\). The mean particle size of the material was approximately 158 micron. Pearlite is an exfoliated material and hence the large difference between particle and bulk density values.

7.1 Low Pressure Conveying

Conveying characteristics for the pearlite conveyed in a low pressure system, and hence in dilute phase suspension flow, are presented in Figure 14.12. The data relates to conveying through the 115 ft long Figure 4.15 pipeline of two inch nominal bore.

As a result of the low particle density and the shape of the particles, the pearlite conveyed very easily in dilute phase and the minimum value of conveying air velocity was about 2100 ft/min. Because of this low value of velocity, solids loading ratio values up to about 24 were achieved in this pipeline. This, however, is also partly due to the relatively high material flow rates achieved.

The iron powder in Figure 14.3 and the silica sand in Figure 14.5 were also conveyed through this Figure 4.15 pipeline. With a conveying line pressure drop of 8 lb/in\(^2\), 3500 lb/h was achieved with the iron powder, 5000 lb/h with the silica sand and, as will be seen above in Figure 14.12, 8500 lb/h was obtained with the pearlite.

![Figure 14.12](image-url) Low pressure conveying characteristics for pearlite conveyed through the pipeline shown in figure 4.15.

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This, once again, illustrates the wide difference in conveying capability that can be obtained in dilute phase conveying. In order to dispel the idea that this conveying performance might simply be related to material density, the 8 lbf/in² conveying line pressure drop line for these three materials, together with a number of other materials that have also been conveyed through this pipeline, were presented earlier for comparison in Figure 4.16. This is reproduced here in Figure 14.13 for reference.

With additional materials it will be seen that the conveying performance, in terms of material flow rate achieved, does not correlate with material density. Soda ash, as mentioned before, has something of a reputation for being a difficult material to convey, and this may be due, in part, to the fact that it is little better than iron powder. Soda ash has a bulk density of about 70 lb/ft³. Pulverized fuel ash, with a bulk density of about 45 lb/ft³, had the best performance of the materials tested.

7.2 High Pressure Conveying

The pearlite has also been conveyed through the 165 ft long pipeline of two inch bore and the conveying characteristics are presented in Figure 14.14.

It will be seen that with a much higher pressure gradient the material is now capable of being conveyed at very much higher solids loading ratios and lower air flow rates. Conveying with high pressure air, however, was not possible with this material because the conveying limit was about 25,000 lb/h.

![Figure 14.13](image.png)

**Figure 14.13** Comparison of performance of different materials conveyed through the pipeline shown in figure 4.15 with a conveying line pressure drop of 8 lbf/in².
Figure 14.14 High pressure conveying characteristics for pearlite conveyed through the figure 4.2 pipeline.

It was reported above, in relation to the high pressure conveying of silica sand through this pipeline, that the conveying limit with barite was about 50,000 lb/h and that it was the discharge capability of the blow tank that was responsible. Because of the very much lower bulk density of the pearlite it is suspected that the limit is imposed by the blow tank once again.