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Pneumatic Conveying of Coal and Ash

1 INTRODUCTION

Millions of tons of coal are burnt in thermal power plants around the world. Thermal power constitutes more than half of the world's electric power generation [1]. The quality of the coal used varies widely from one country to another. It can vary with the location of the coal mine, and in some cases the quality of coal can vary between the upper and lower seams in the same mine. This variation can be in terms of both the calorific value of the coal and the quantity of un-burnt residue produced when it is burnt in a boiler.

The quantity of ash generated, and its collection at various locations, is influenced by the ash content of the raw coal, the boiler operating conditions, the excess air used in the combustion process, and the soot blowing operations. Millions of tons of ash are thereby produced and the ash can have a wide range of properties as a consequence, both in terms of chemical composition and particle size.

It is important, therefore, that any system built to convey this ash should be reliably designed to take account of the properties of the conveyed material. With fly ash having little or no commercial value, however, such conveying systems are not always given the consideration that they require. A poorly designed conveying system can result in repeated plant shut down, with a very significant loss in revenue. With such a high production rate of ash it is essential that the material is reliably and efficiently removed from the plant.

1.1 Ash Generation

The coal in the "As Received" condition is first pulverized in grinding mills to obtain Pulverized Fuel (pf) or Pulverized Coal. The resulting coal dust is blown into the combustion chamber or furnace section of the boiler. In modern boiler plant the coal is required as a fine dust in order to achieve combustion rates similar to those of oil and gas.

During the burning of the coal, glassy droplets of ash are produced. Some of these particles impinge on the furnace wall, and at high temperatures the particles can fuse together to form deposits of slag.

Build up of thick layers of ash on a furnace wall increases resistance to the heat transfer process, thus reducing the thermal efficiency of the boiler. In order to minimize the effects of the ash build up, these deposits are periodically removed by means of soot blowers. The dislodged lumps fall into the ash hoppers at the bottom and this is generally referred to as Furnace Bottom Ash (FBA) or simply Bottom Ash.

The bottom ash constitutes about 8 to 15% of the total ash and consists of very coarse particles and large lumps and agglomerates. These are generally crushed to a smaller size before being mixed with water to be disposed of in slurry form.

1.1.1 Fly Ash

The remaining 85 to 92% (fly ash) is very much finer and the particles of ash are carried away with the flue gases and get collected at various locations along the flue gas path. This ash is commonly referred to as Pulverized Fuel Ash (pfa) or simply Fly Ash. The coarser fraction of this ash is collected in the economizer, air pre-heater and duct hoppers.

The finer fraction, and generally the largest percentage, is collected in the electrostatic precipitator (ESP) hoppers. This ash typically has a mean particle size varying from about 150 micron in the economizer hoppers to about 30 micron in the ESP hoppers. Figure 10.1 shows a typical layout of the ash collection points, and approximate percentages of ash collected at each location.

1.1.2 Ash Quality

The quantity of ash produced depends principally upon the quality of the coal used and whether it has been cleaned in a coal washing plant after being mined to remove shale, rock and debris. The quality is additionally influenced by the combustion process in the boiler, as well as the other operating variables mentioned above. An inefficient combustion process, for example, may result in a high level of un-burnt carbon in the ash produced.

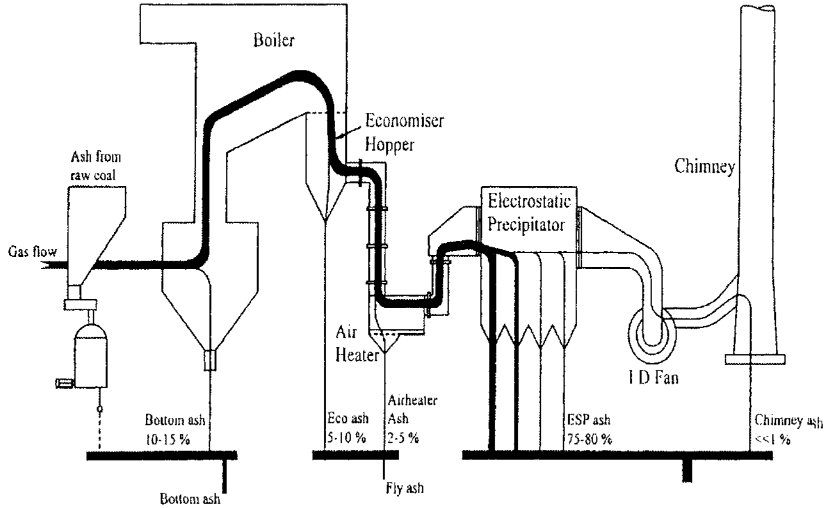

Figure 10.1 Ash accumulation points and typical ash distribution within a power plant.

Carbon in ash gives it a dark color, and as a result the ash becomes unsuitable for certain applications. The ash content in superior grades of coal can be as low as 6 to 8 %, but can be as high as 45% in poor grades.

India, for example, has abundant coal reserves, but the coal has such a high ash content that to produce 55,000 MW of thermal energy, the quantity of coal burnt produces approximately 80 million ton of fly ash every year [3]. Proper utilization, or safe disposal, of such enormous amounts of fly ash is a challenge to engineers associated with power generation. It is, therefore, inevitable that power plant requires an efficient and reliable ash handling system.

1.1.3 Ash Temperature

The temperature of the ash also decreases as it moves away from the furnace and through the gas passages [2]. Due account of this must be taken in the design of conveying equipment, not only in terms of materials of construction and for components, but in evaluating conveying air velocities and specifying air requirements, for air is compressible with respect to temperature as well as pressure.

The influence of the temperature of the conveyed material on the volumetric flow rate, and hence velocity, of air was considered in detail in Chapter 5. This took account of the solids loading ratio of the conveyed material and the temperature of the conveying air. The approximate variation of fly ash temperature with location within the boiler plant is given in Figure 10.2.

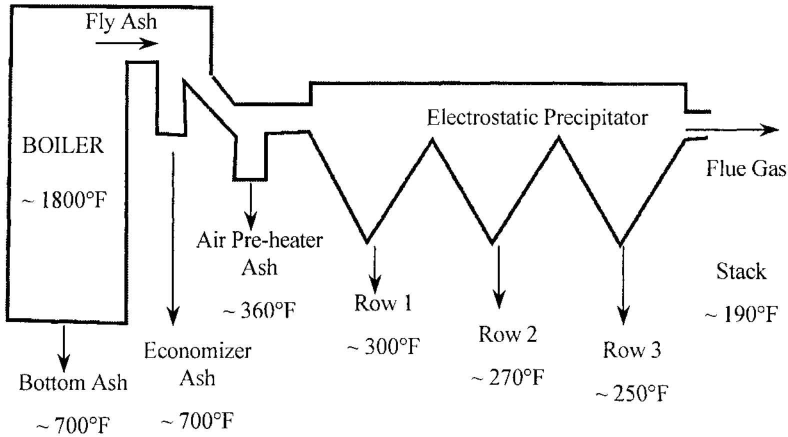

Figure 10.2 Typical ash temperatures at boiler plant hopper locations.

1.2 Properties of Fly Ash

It is important that the properties of any material that has to be conveyed should be taken into account, and that any variations in properties that are likely to occur, from any source, are also allowed for.

The chemical composition of coal, and hence of the resulting ash generated, will vary both globally and locally. This will also influence particle and bulk density. The mean particle size will vary with respect to the location of the ash hopper on the boiler plant, as well as the air flow settings on the coal grinding mills. Particle shape will be influenced to a certain extent by changes in the combustion process.

1.2.1 Typical Ash Composition

Silicon oxide (SiO_2), or silica, and aluminum oxide (AlO_2), or alumina, are the two major components in the chemical composition of fly ash. The percentage of silica can be as high as 65%, and alumina can vary between about 15 and 30%. Both alumina and silica are very hard materials, with silica having a hardness value of about 6 on the Mohs scale of hardness and that of alumina being close to 8. It is because of the high concentration of these constituents in fly ash that it is very abrasive, and can cause damage to all surfaces against which it comes into contact, whether by abrasion or impact.

In some cases the ash may also contain trace elements, such as chromium, boron and arsenic. The ultimate safe disposal of such ashes may require additional measures to be taken to prevent contamination of the soil, or the type of application to which the fly ash might be used.

1.2.2 Size Distribution

As the flue gases pass through the boiler ducting, ash is collected at numerous locations along its route from the boiler combustion area to the chimney. The particle size of the fly ash decreases as the distance of the collection point from the boiler combustion zone increases.

The ash is first collected in the economizer hoppers, and then the air pre-heater hoppers, before it enters the series of electrostatic precipitator hoppers. About 85% of the total ash carried with the flue gas is collected in the ESP hoppers. ESP's charge the dust particles and use electrostatic attraction to remove approximately 99·5% of particles from the flue gas entering.

The average or mean particle size of the ash particles collected in the economizer and air pre-heater hoppers is about 125 microns. The size of the ash particles collected in the ESP hoppers, however, is much finer. Within the various zones of the electrostatic precipitator, ash collected in the initial row of hoppers, in the direction of the gas flow, is of a higher average particle size as compared with the ash collected in the last row of hoppers.

The design of any ash handling plant will also have to take these variations in mean particle size into account. Although there is no change in the material from one location to another, the variation in particle size distribution can have a very significant influence on the conveying capability of the material. Typical values of the particle size of the ash collected in the various hoppers of a typical 200 MW generating unit are given in Figure 10.3.

1.2.3 Shape of Fly Ash Particles

Since ash particles are produced as glassy droplets, as a result of combustion in the boiler, the majority of fly ash particles are spherical in shape.

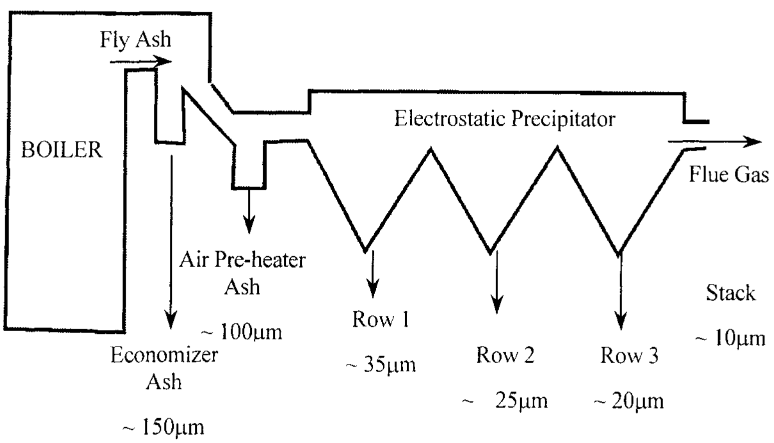

Figure 10.3 Typical ash sizes at boiler plant hopper locations.

A considerable amount of fly ash that is collected in ESP hoppers is used in the manufacture of cement. Cement, however, is produced by a grinding process and so the particles have an entirely different shape. Although the mean particle size is very similar, the conveying characteristics of the two materials can be very different as a consequence.

1.2.4 Particle and Bulk Density

In the case of materials that have to be handled in a large quantity, bulk density can be an important variable to consider. Since bulk density takes into consideration the particle density and voids in bulk storage, it is a useful parameter for the sizing of various system components.

Particle density will influence the slip velocity when the material is conveyed pneumatically through pipelines in two-phase flow. It is important, therefore, to have an idea of the typical range in which the particle density and bulk density of fly ash can vary. Most fly ashes have a bulk density of about 45 lb/ft^3 and a particle density of around 110 lb/ft^3. Bulk density will vary with location within the boiler plant and the combustion process. Particle density will vary with composition.

1.3 Ash Collection Hoppers

Since close to 75% of the total ash produced in the combustion process is collected in the ESP zone, it is necessary to consider the layout of these ash collection hoppers. The electrostatic precipitators have several fields and each field has a number of collection hoppers. A 200 MW generating unit will typically have six fields and four hoppers in each field, thus making a total of 24 ash collection hoppers. A sketch showing the layout of a typical group of ESP hoppers, and the direction of the gas stream, is given in Figure 10.4.

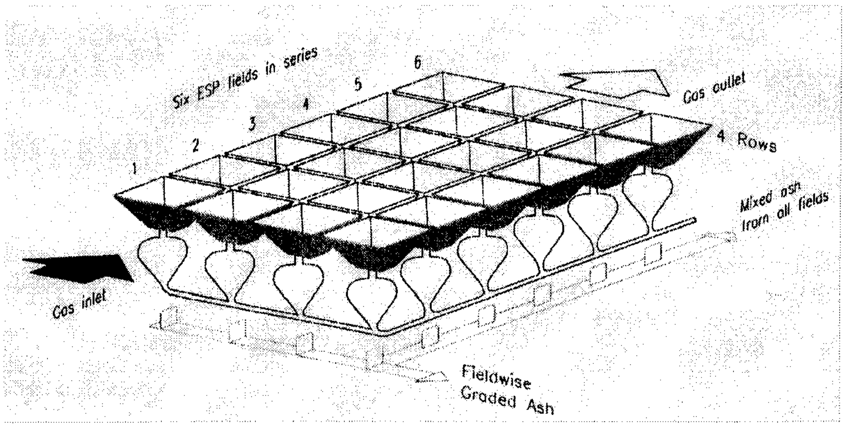

Figure 10.4 Typical arrangement of electrostatic precipitator ash collection hoppers.

The first field hoppers have the highest ash collection rate, which may vary between 70 and 80%. The rate of ash collection in subsequent fields decreases in similar proportions. As a result the ash collected in the hoppers of field 3 and onwards is minimal. If, during a failure, however, field 1 is not operational, the field 2 hoppers would have the same collection rate as the field 1 hoppers in normal operating conditions.

The capacity of the ESP hoppers is generally selected so that they are capable of storing as much ash as is generated in 24 hours of plant operation. The design of the ash handling system has to consider the time cycle for the ash evacuation, keeping in view the differences in ash collection rate in the various hoppers.

1.3.1 Off-Loading Arrangements

The removal of ash from the ESP hoppers can either be in a direction parallel to the gas flow, as shown in Figure 10.3, or across the direction of the gas flow. In the first case hoppers of various fields will be connected to each other so that the ash collected in the receiving silo will have a mixture of 'coarse' and fine precipitator ash.

In the latter option, the hoppers of a particular field will be interconnected thus making it possible to keep the 'coarse' ash of the initial two fields separate from that of the very fine ash of subsequent fields. Fly ash from the last few fields is generally preferred whenever it is required for use as a cement substitute in the construction industry.

In the case of the cross direction ash evacuation arrangement, however, the loading on the ash removal system would be non-uniform due to the large differences in the ash collection rate in the hoppers of the various fields. This factor must be taken into consideration when designing the ash removal system for such an arrangement. The choice of system depends largely upon the end utilization of the ash and the ESP plant layout.

1.4 Ash Transfer Systems

The selection of an ash removal system depends upon the nature of the ash, the quantity of ash to be handled, and if the ash has to be graded for the end utilization. Pneumatic conveying systems offer an ideal choice for the handling of fly ash in dry form. Both positive pressure and negative pressure conveying systems are widely employed. Very often both are incorporated, and air slides are also used.

Because there can be between thirty and forty individual ash hoppers to be emptied on a 200 MW boiler unit, and obviously many more on larger units, the ash handling is often split into two parts and intermediate silos are employed. Where the ash needs to be removed from the power station site, and long conveying distances are involved, this is almost essential. A sketch of a typical ash handling system for the removal of ash from the numerous ash hoppers on a boiler plant to intermediate storage is given in Figure 10.5.

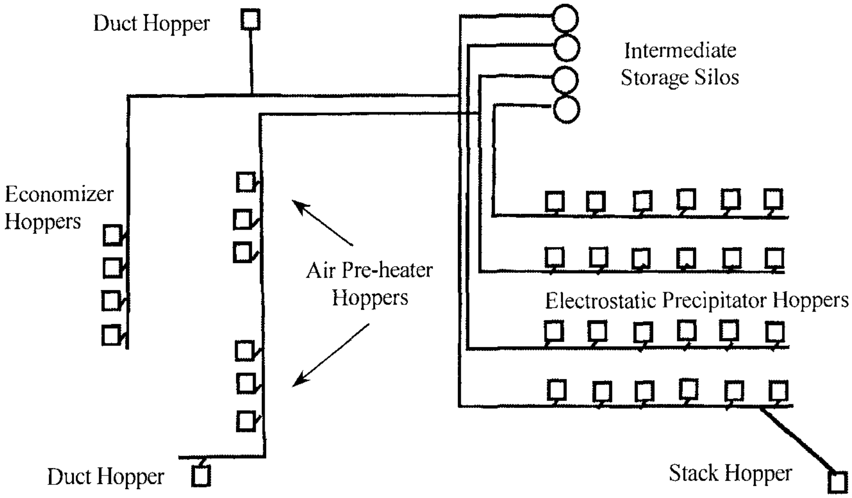

Figure 10.5 Sketch of pipeline layout for ash removal by vacuum conveying from a 200 MW power plant.

The system shown in Figure 10.5 is a vacuum conveying system. Multiple lines would be used, with an exhauster dedicated to each, and stand-by machines would also be available. The four pipelines shown would have cross-over connections and valving so that virtually any hopper could be off-loaded through any line so as to provide added security to guarantee that any hopper could be off-loaded.

Because different hoppers contain different quantities of ash, and every hopper is at a different distance from the reception silo, the main design specification for this type of plant is often that the ash produced by the boiler in an eight-hour shift should be capable of being transferred to the silos in a four-hour period. This could amount to 700 ton of ash, and so although flow rates of 50 ton/h per line would be expected, it is also the sequencing of the off-loading of the hoppers that is critical for the operation.

With a common pressure drop being available to every hopper, the ash flow rates will be very much higher for those hoppers that are close to the silo than for those that are distant. In order to maximize performance, pipeline feeders need to be able to meet the maximum potential for the location. Another problem is that the grade of ash varies from one hopper to another and this can have a marked influence on the conveying potential and capability of the system. This point is considered in more detail later in this chapter.

A sketch of a typical ash handling system for the onward conveying of the ash from the intermediate silos to site disposal silos is given in Figure 10.6. Because of the distances involved, which can be up to one mile and more, this type of duty is mostly met by positive pressure conveying systems.

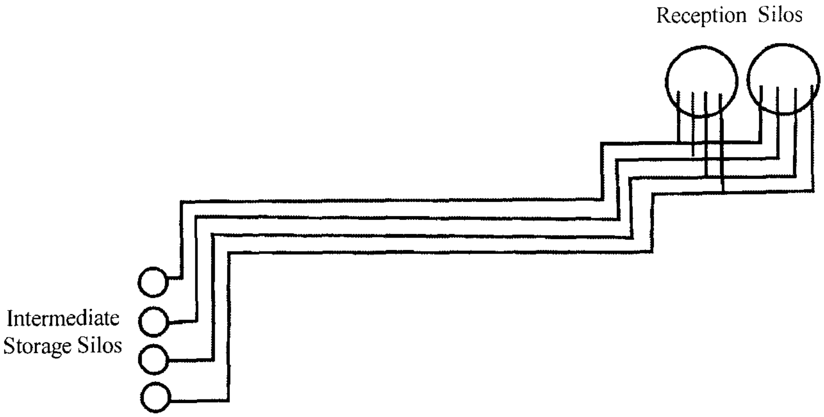

Figure 10.6 Sketch of a typical pipeline layout for the onward positive pressure conveying of fly ash to reception silos

At some power stations the fine and coarse grades of fly ash are kept separate throughout the plant and one or two of the intermediate silos would be dedicated to the coarse ash. By this means separate systems can be installed to handle the different grades for the onward transfer.

It would generally be recommended that the ESP ash be conveyed separately from the coarse ash. The difference in conveying capability between the fine and coarse grades of fly ash is such that serious consideration must be given to this situation. If the grades of ash are mixed then the conveying conditions must be carefully selected. This issue will be considered in detail later.

If the conveying distance from the intermediate silo to the disposal silo is more than about 3000 ft, high conveying air pressures will generally have to be used, or very large bore pipelines employed. Within the practical limits of the pressure drop, the material would be conveyed at a lower value of material to air ratio.

In such a situation a higher conveying line inlet air velocity has to be used. The high pressure will result in a higher exit velocity. In such applications it is generally recommended that the pipeline should be stepped to a larger bore part way along its route. This helps to reduce the velocity and improve the performance of the conveying system.

2 SYSTEM COMPONENTS

Because of the abrasive nature of the material, particular consideration has to be given to the components of pneumatic conveying systems, and this includes the pipeline and the bends. This is certainly the case with ash, for as the abrasive elements in coal do not take part in the combustion process, the ash has a significantly higher proportion of abrasive constituents. The ash can also be at a high temperature, as was illustrated in Figure 10.2, and so this also has to be taken into account.

2.1 Feeding Devices

Feeding devices that have no moving parts are the ideal choice, provided that they are capable of providing the necessary control on feed rate. The choice is then for feeders that have no pressure drop across the moving parts. Two mechanisms of wear have to be considered. One is abrasive wear and the other is erosive wear. Of the two, erosive wear is the most serious and so consideration can be given to feeders that have moving parts, provided that there is no pressure drop across them.

2.1.1 Rotary Valves

Rotary valves are rarely used on boiler plant. They can not be recommended for positive pressure conveying duties because of the pressure differential, despite the fact that they are available with wear resistant blades and liners. They can be used for feeding vacuum conveying systems, but are not popular for this duty, possibly because of the problems with hot ash. Differential expansion between moving parts and protection of bearings are particular problems.

2.1.2 Screw Feeders

The ordinary screw feeder is totally unsuitable for positive pressure conveying, because of the air leakage problem. Like the rotary valve they can be used for feeding vacuum conveying systems but are rarely used for this purpose. The simple screw feeder, however, has been developed by several companies into a device that can feed successfully into conveying lines at pressures of up to about 40 lbf/in^2 gauge.

One such device, that was manufactured by the Fuller Company in the USA, and known as a Fuller-Kinyon pump, was shown in Figure 2.11. This type of feeder is commonly used for the onward conveying of fly ash to reception silos For high pressure operation, however, the device is only suitable for materials that can be compressed, which generally restricts their use to materials that have very good air retention properties. Thus they are only suitable for materials such as pulverized coal and fine grades of fly ash.

This type of screw feeder would not be recommended for coarse grades of fly ash, and certainly not for fluidized bed combustor ash or granular coal. As a result of the high power requirements, and the fact that the screw is prone to wear and cause serious maintenance problems, this type of feeder is gradually being replaced by twin blow tank feeders operating in series and capable of continuous operation.

2.1.3 *Venturi Feeders*

Venturi feeders have limited pressure capability but are often used for the transfer of fly ash from boiler plant hoppers to intermediate storage silos. They are sometimes used also for the injection of pulverized coal into boilers, particularly on small-scale boiler plant where individual control over burners is required. Although they have no moving parts, wear in the throat area can be high because of the very high velocities and turbulence, and so wear resistant materials must be incorporated. Because they have no moving parts additional control must be provided in order to adjust the material feed rate.

2.1.4 *Trickle Valves*

These are only suitable for negative pressure conveying systems, since there is no pressure drop against which to feed. They are widely used for the vacuum off-loading of ash from hoppers on boiler plant. With no moving parts or pressure requirement they can be very cheap devices, and if thirty to forty are required on a boiler plant the overall saving can be very significant. The greatest problem with this type of feeder is that of flow rate control. This is generally achieved by calibration and adjustment on site, but this is very material dependent. A slight change in particle size, particle shape or moisture content will affect the balance of the setting for the material and change the flow rate.

2.1.5 *Blow Tanks*

Blow tanks are widely used in power plants for the pneumatic conveying of fly ash. They can be used on individual ash hoppers for the transfer to intermediate storage silos and for the onward transfer of ash to reception silos. Blow tanks can only be used with positive pressure conveying systems, but they can be designed and built to almost any pressure capability. On boiler plants and in other situations where the material is delivered to a reception point at atmospheric pressure they are generally limited to a maximum pressure of about 100 lbf/in^2 gauge, because of the air expansion problems.

For applications where material has to be fed into a reactor or vessel maintained at pressure, there is essentially no limitation on operating pressure. Fluidized bed combustor boilers have been developed that can operate at a pressure of 300 lbf/in^2 for combined gas turbine and steam turbine generation cycles. For these to operate continuously, coal must be fed into the combustor while on load, and blow tanks are the only type of feeder capable of this type of duty. There are numerous different types of blow tank, and for each type alternative configurations are possible. They can be used individually or in pairs. Some of the types commonly used on boiler plants are considered below.

2.1.5.1 Single Blow Tanks

Single blow tanks can vary in size from a few cubic feet to 1500 ft^3 and more. On boiler plants small blow tanks are generally used to convey batches of material as a single plug. Large blow tanks may take 15 to 20 minutes to convey the batch and so the material is conveyed effectively on a continuous basis for the major part of the cycle.

2.1.5.1.1 Single Plug

A sketch of a single plug conveying system was given in Figure 1.10. In this device the material is effectively extruded into the pipeline as a single plug, typically about 30 ft long. The discharged material is then blown through the pipeline as a single plug. Coal and ash can be conveyed in this type of system, as well as mill rejects.

The conveying mechanism is completely different from conventional dilute and dense phase conveying, and system performance is not so dependent upon the characteristics of the material. Wet coal, for example, can be conveyed, which would not be possible in any conventional conveying system. A sketch showing this type of blow tank fitted beneath electrostatic precipitator hoppers is given in Figure 10.7. The blow tanks will generally feed into a common pipeline, as shown, and as illustrated earlier in Figure 10.5.

2.1.5.1.2 Single Batch

Blow tanks are commonly used to convey fly ash from intermediate storage to reception silos. A 1350 ft^3 blow tank will hold about 30 ton of fly ash and with a 15 minute cycle a transfer rate of 120 ton/h can be achieved. A sketch of a typical bottom discharge blow tank was given in Figure 2.19.

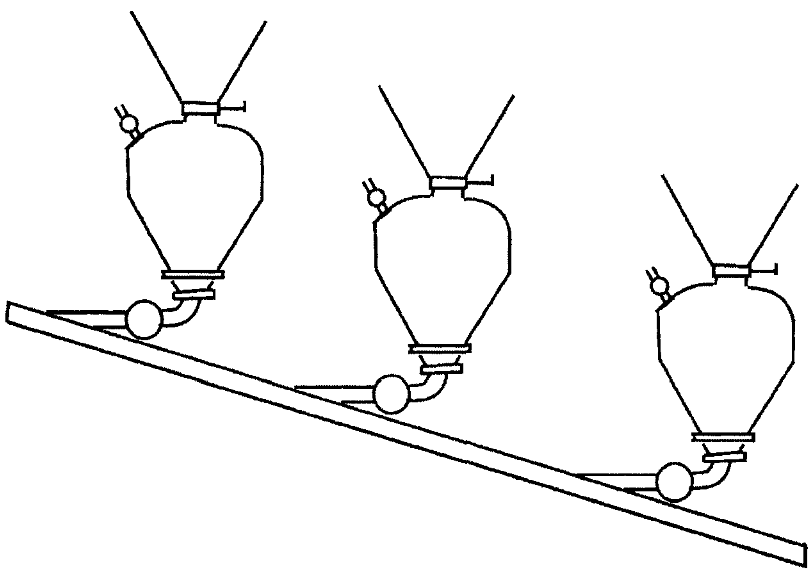

Figure 10.7 Sketch of blow tanks used for off-loading ash hoppers.

The material in the blow tank needs to be fluidized, or aerated, close to the discharge point, and material flow rate control is achieved by proportioning the air supply between the blow tank and supplementary, or conveying air. Top discharge blow tanks that have a fluidizing membrane across a flanged bottom section are also widely used, but they are prone to maintenance problems as their performance is susceptible to dust and moisture in the air.

2.1.5.2 Twin Blow Tanks

A particular problem with single blow tanks is that conveying is not continuous, as it can be with rotary valves and screw feeders. If two blow tanks are used, rather than one, a significant improvement in performance can be achieved when conveying through a single pipeline. There are two basic configurations of twin blow tanks. One is to have the two in parallel and the other is to have them in series. These were considered in some detail in Chapter 2 with Figures 2.24 to 2.27.

Twin blow tanks arranged in series are now a common option for long distance conveying. At many power stations, cement plants have been built alongside the power station in order to utilize the fly ash in the manufacture of cement. The reception silos are generally located on the boundary of the two plants. This often requires the pneumatic conveying of the fly ash over a distance of a mile or more.

2.1.6 Air Slides

Air slides are also used quite often for the off-loading of ash hoppers. Because these hoppers are generally at a high elevation, the headroom required to provide a slight slope is not generally a problem. A series of ash hoppers generally feed into the one air slide, as illustrated in Figure 10.8. Several air slides can then feed into a common air slide to transfer the ash to the intermediate storage silos.

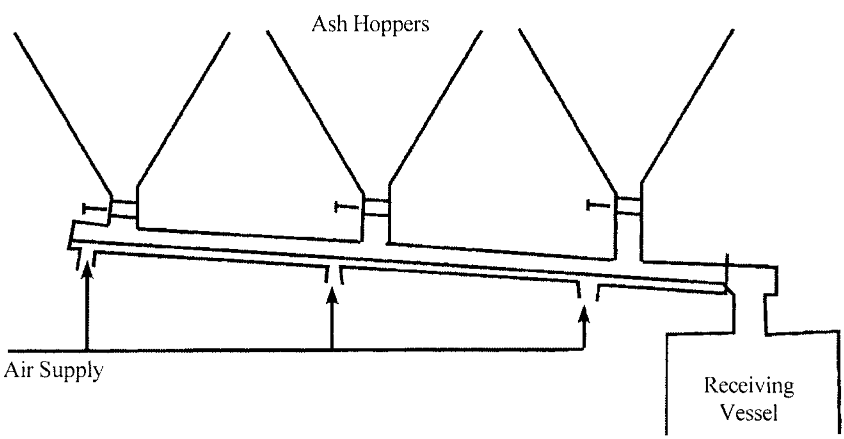

Figure 10.8 Application of an air slide to ash hopper off-loading.

2.2 Air Movers

Because of the heavy duty requirements of coal and ash handling systems it is essential that positive displacement devices are used for all blowing and exhausting duties. Because it is a potentially dusty environment, and the dust is extremely abrasive, it is essential that air intake filters are fitted to all blowers and compressors. Exhausters need to be protected from the possibility of filter bag failure by the provision of back-up filters.

The specification of exhausters is in terms of the volumetric flow rate of air drawn into the machine. Some of the ash to be conveyed can be at a high temperature, as illustrated on Figure 10.2, and so the temperature of the conveying air at entry to the exhauster must be taken into account in the specification to ensure the correct value of conveying line inlet air velocity is achieved at the material feed point.

2.3 Filters

Bag filters with reverse air jet cleaning are the industry standard for power plant. With a very high proportion of fines in fly ash, cyclone separators are not generally a viable option. Care must be taken with vacuum conveying systems with respect to their specification, for the volume of air to be handled is significantly higher than the free air value because of the reduced air pressure at which they operate.

Once again, with reference to Figure 10.2, it will be seen that the ash can be at a high temperature. Conveying air does not have a very significant effect in terms of cooling the ash and so the air could be at a fairly high temperature at entry to the filter. This will have to be taken into account in both the specification of the filter size, because of the reduction in air density, and the specification of the filter material for the expected temperature.

At times when the coal mills need maintaining, and the velocity of the classifying air is increased to compensate, the particle size of the coal will increase. The consequence of this is that combustion may not always be complete and it is possible for glowing ash particles to be deposited in the economizer hopper. When these are conveyed with air they continue to burn and these can cause serious problems with regard to filter fabrics if they come into contact.

2.4 Pipelines

Coal and ash are abrasive materials and so all pipelines need to be able to withstand the wear. To minimize down time, plant is often required to operate for periods of up to three years between planned maintenance periods. Fly ash conveyed through a normal mild steel pipeline would probably wear a hole through a 90° bend within one day of operation. Thick walled spun alloy cast iron is a normal specification for pipeline. In extreme cases is may be necessary to line the pipeline with basalt.

2.4.1 Bends

Bends provide pneumatic conveying systems with considerable flexibility with regard to routing but they are very vulnerable to wear by impacting particles. In extreme cases basalt and alumina ceramics may have to be used as lining materials. In recent years a number of alternative bend section profiles have been patented and are widely available. These are generally very short radius and so have the advantage of being relatively light and take up little space. They usually have a built-in pocket in which material is either trapped or 'circulates'. The pressure drop associated with these bends, however, is generally very much higher than radiused bends and so a penalty in energy may result if they are employed.

For normal operation either very thick wear back sections are cast into the material, or replaceable wear back sections are incorporated, and these are replaced on a planned basis, typically every six months. A sketch of typical cast iron pipe bends and fittings is given in Figure 10.9.

2.4.2 Steps

If high pressure air, or a high vacuum, is used for conveying a material, it would generally be recommended that the pipeline should be stepped to a larger bore part way along its length. This is to cater for the expansion of the air that occurs with decrease in pressure, and so prevents excessively high conveying air velocities towards the end of the pipeline. Stepped pipelines were considered in some detail in Chapter 9.

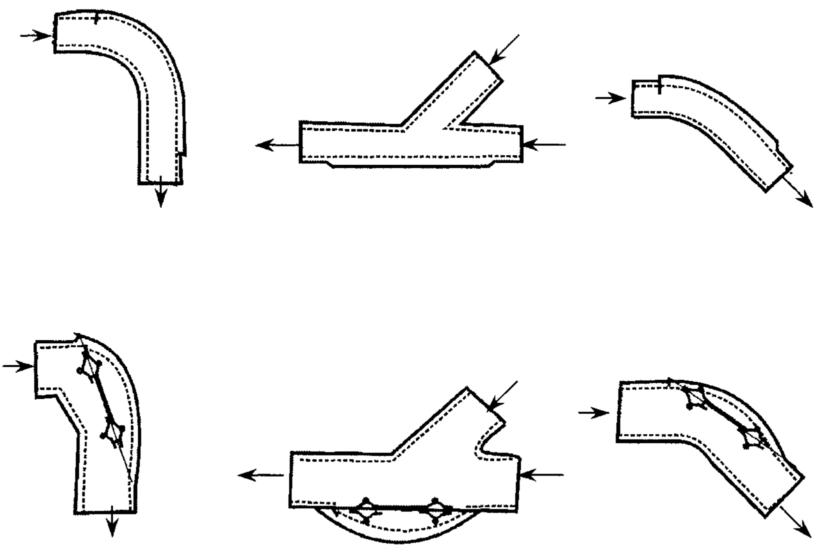

Figure 10.9 Typical cast iron pipe bends and fittings. (a) Integral and (b) replaceable wear-back fittings.

2.5 Valves

A number of different valves are needed on pneumatic conveying plant and a wide variety of different valves are available in the market place. The requirement is generally for the purpose of isolating the flow. With abrasive materials, such as coal and ash, valves should operate only in the fully open or fully closed position, and when open, the seating surfaces should be out of the flow path of the material, particularly in pipeline flow situations.

Valves should never be used in the partially open position to control the flow of material. This type of valve is also very vulnerable during the opening and closing sequences, and so these operations should be completed as quickly as possible.

Conventional butterfly valves, therefore, are not appropriate. Ball valves are not generally recommended either, for as they have moving parts, fine abrasive particles can get between surfaces and they lose their air-tightness. The same situation can apply with gate valves if they have to operate at pressure.

Pinch valves are a much better proposition, as there is no relative movement between surfaces in which fine abrasive dust can lodge. These can also be opened and closed rapidly. Rubbers and urethanes also have reasonable erosive wear resistance, and so are well worth considering for this kind of duty. They will wear, however, and so they must be located in accessible positions and spares must be available.

2.5.1 Dome Valves

The dome valve is a more recent addition to the list of valves available, but it has been specifically designed for this type of duty, and is now widely used in the industry. The valve has moving parts, but these move out of the path of the conveyed material when the valve is open. On closing, the valve first cuts through the material and then becomes air-tight by means of an inflatable seal. The valve can be water-cooled and so it is capable of handling hot materials.

2.5.2 Diverter Valves

There is often a need for a pipeline to deliver material to a number of different reception points and this requirement can be conveniently met by means of diverter valves. Conventional diverter valves, however, are not generally suitable for abrasive materials and so flow diversion is generally achieved by means of using two flow isolating valves.

Dome valves are often used for this purpose, with one in each downstream pipeline. In the section of pipeline isolated, material will collect and so protect the closed valve from particle impact. There will be considerable turbulence where the diversion involves a change of direction and so all pipe-work in the region should be suitably protected from wear. The trapped material will be released when the flow direction changes and is unlikely to cause any subsequent flow problems in the pipeline.

3 CONVEYING CAPABILITY

It is well recognized that different materials can have very different conveying characteristics, and that the conveying capability of different grades of the same material can differ widely. Coal and ash materials are no different in this respect. Fly ash, as was shown in Figure 10.3, can come in a very wide range of sizes, effectively through a grading process.

Coal is a mined and quarried product and so will be found in a very wide range of sizes, depending upon the application. In boiler plant the raw coal will have a mean particle size of about one inch. For combustion, however, a mean particle size of about 50 micron is required and so it reduced in size in grinding mills.

In a large coal fired power station five million ton of coal per year might be used, but the raw coal is mostly conveyed by means of conveyor belt from the stockpiles to the boiler plant. The pulverized coal is conveyed pneumatically to the burners at the corners of the boiler, but the distance is generally very short since the grinding mills are generally located close to the boilers.

Because of combustion requirements the concentration of the coal in the air is very low and so high volume centrifugal fans are generally used for the purpose. The ash that is produced, however, is mostly cleared from the various boiler plant hoppers by means of a variety of pneumatic conveying systems.

3.1 Pulverized Fuel Ash

A power station burning five million ton of coal in the USA is likely to produce about 800,000 ton/yr of ash and, as will be seen from Figure 1, the vast majority of this will be fly ash. The same power station in India will produce about 2 million ton/yr because of the poor quality of the coal available. It is not surprising, therefore, that much research on the subject has been undertaken in India [4].

Various grades of fly ash have been conveyed at the Indian Institute of Technology in New Delhi and data from these conveying trials is presented to illustrate the conveying capability of the material. A high pressure top discharge blow tank conveying facility was used and details of the pipeline employed are presented in Figure 10.10 for reference.

3.1.1 Fine Ash

Conveying characteristics for a fine grade of fly ash, obtained from the electrostatic precipitator hoppers of a near-by power station serving the New Delhi area are given in Figure 10.11. This fly ash had a mean particle size of about thirty micron.

The conveying characteristics are presented in the usual form, of material flow rate plotted against air flow rate, with conveying line pressure drop being included as the family of curves.

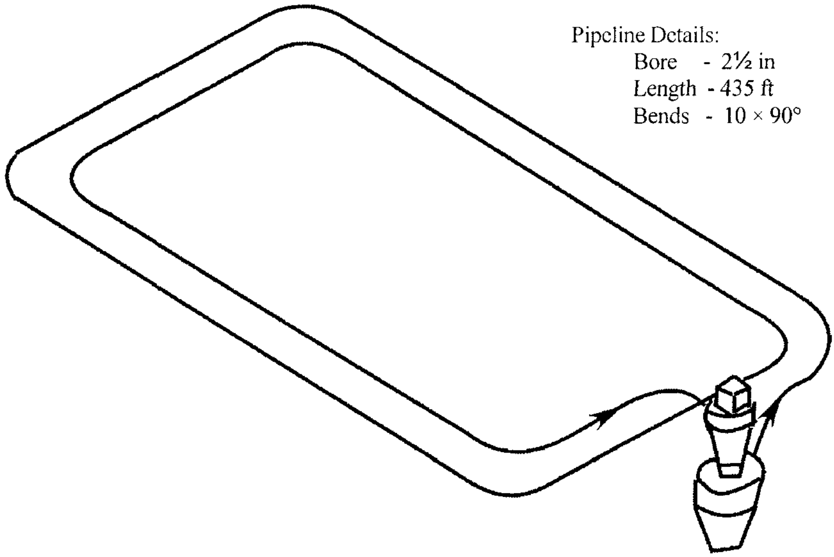

Figure 10.10 Sketch of pipeline used for conveying trials with fly ash.

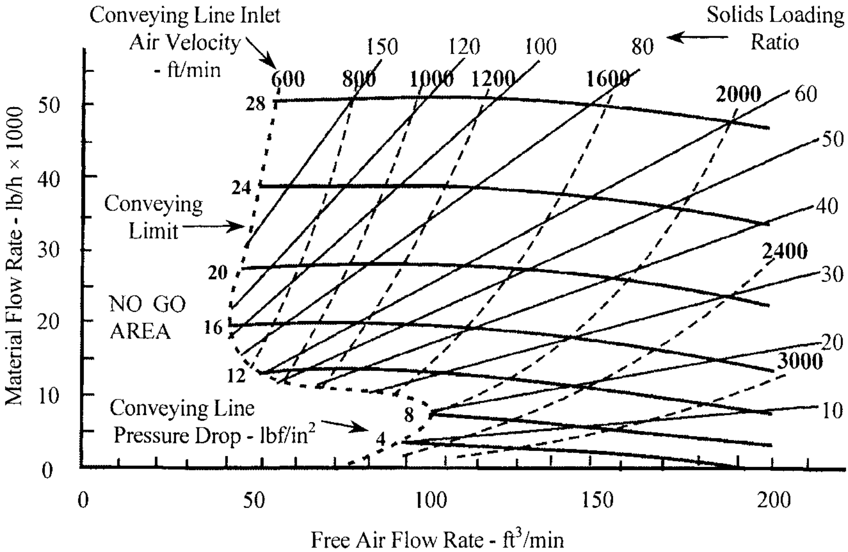

Figure 10.11 Conveying characteristics for a fine grade of fly ash.

In addition to lines of constant solids loading ratio, lines of constant conveying line inlet air velocity are plotted, and the conveying limit for the material is also identified.

It will be seen from Figure 10.11 that the fly ash could clearly be conveyed in dense phase. Solids loading ratios well in excess of 100 were achieved and conveying was possible with conveying line inlet air velocities down to 600 ft/min. Fly ash flow rates of about 50,000 lb/h were achieved with a pressure drop of 28 lbf/in^2 through the 435 ft long pipeline of 2½ inch bore.

3.1.2 Coarse Ash

Conveying characteristics for a coarse grade of fly ash are presented in Figure 10.12. This fly ash had a mean particle size of about 110 micron and was obtained from the air pre-heater hoppers of the same power station from which the fine fly ash was obtained. It was conveyed through the same pipeline as the fine fly ash. From Figure 10.12 it will be seen that this material could only be conveyed in dilute phase, suspension flow through the pipeline.

The maximum value of solids loading ratio that could be achieved was only just 15 and the minimum value of conveying air velocity at which the material could be conveyed was about 2600 ft/min. With a conveying line pressure drop of 28 lbf/in^2 the maximum value of material flow rate achieved was only about 18,000 lb/h, compared with 50,000 lb/h with the fine ash. To achieve 50,000 lb/h with the fine ash an air flow rate of about 55 ft^3/min was required, compared with about 240 ft^3/min for the coarse ash at 18,000 lb/h.

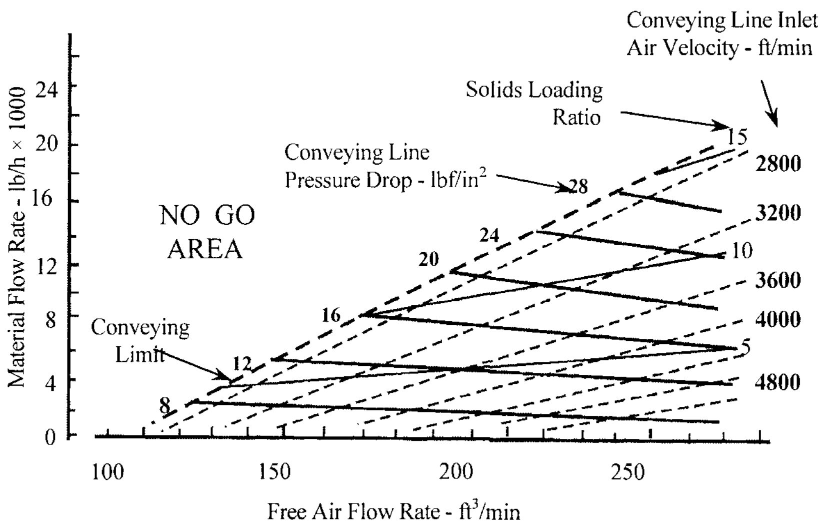

Figure 10.12 Conveying characteristics for a coarse grade of fly ash.

If these two sets of data are combined it will be seen that the specific energy required to convey the coarse ash is approximately twelve times greater than that for the fine fly ash under these conveying conditions.

3.1.3 Conveying Limits

The approximate influence of solid loading ratio on the minimum conveying air velocity for the fine fly ash is presented in Figure 10.13. Data for the coarse grade of fly ash is also given for comparison. For the coarse ash there is no significant change in the minimum value of conveying air velocity over the range of solid loading ratios possible with the material.

To visually reinforce the differences in conveying capability between these two grades of fly ash the conveying characteristics are presented side-by-side on similar axes in Figure 10.14. From Figure 10.5 it will be seen that there is often a need to convey both grades of fly ash in the same conveying system. These two fly ashes from Figures 10.11 and 12, however, are essentially completely different materials.

The minimum conveying air velocities differ widely and this means that the air flow rate requirements are very different. The material flow rates for different conveying conditions also differ and so uniform flow rates can not be expected, and the pipeline feeding devices must be able to respond to these differences.

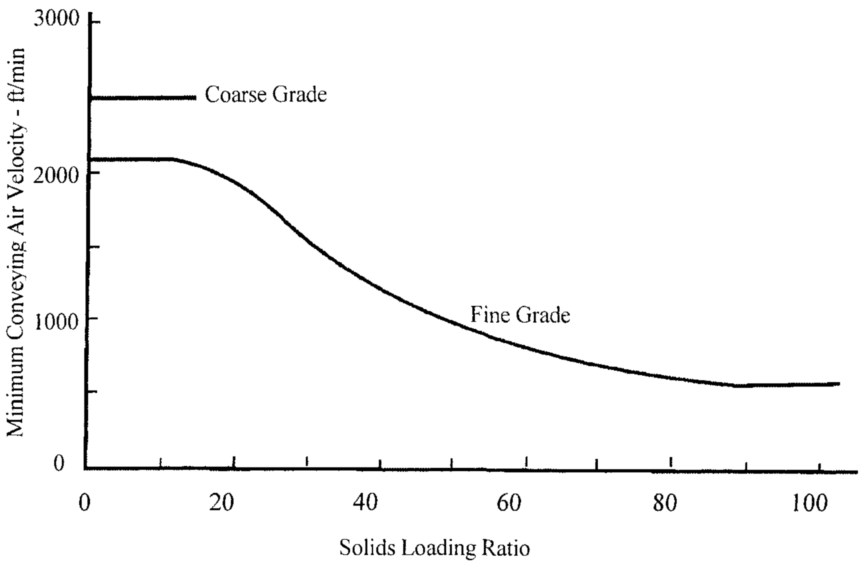

Figure 10.13 The influence of solids loading ratio on minimum conveying air velocity for fly ash.

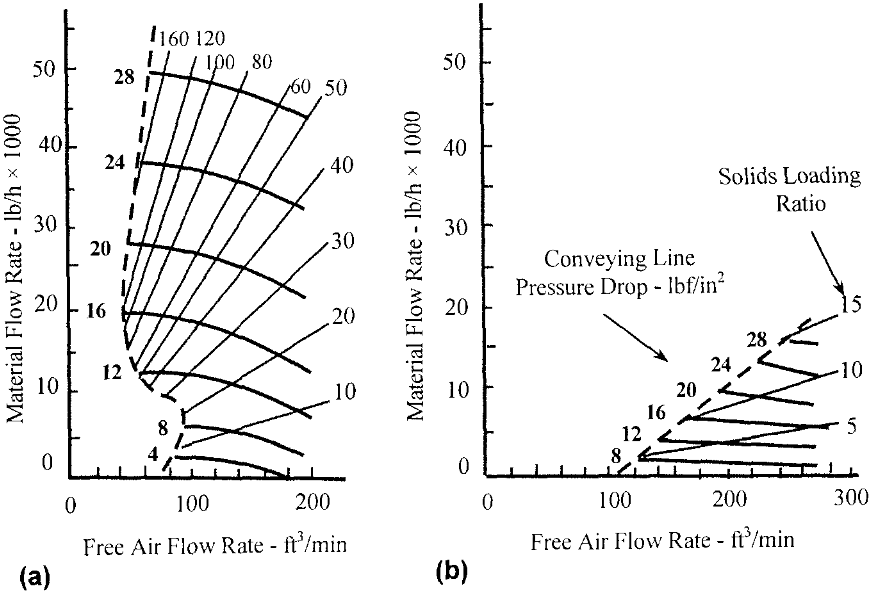

Figure 10.14 Comparison of conveying performance for (a) fine and (b) coarse grades of fly ash.

From Figure 10.6 it will also be seen that a mix of the two grades often need to be conveyed through a common pipeline. It is unlikely that the two grades would be intimately mixed to give a material having a uniform size distribution.

3.1.4 Particle Size Influence

Since there is a large difference in the material flow rate, for a given conveying line pressure drop, apart from the major influence on mode of conveying, a number of fly ash samples having different mean particle sizes were conveyed in order to investigate the influence of particle size on flow rate capability [5]. A single reference point was taken for the subsequent comparison. Because the coarse grades of fly ash could not be conveyed at low velocity, an air flow rate of 240 ft^3/min and a pressure drop of 23 lb/in^2 were selected. The results from the range of fly ash grades tested are presented in Figure 10.15.

From Figure 10.15 it would appear that there could well be an optimum value of particle size at which the material flow rate is a maximum, and this could well occur in the range of mean particle size at which the transition from dilute to dense phase conveying capability occurs. It is suspected that there will be little further reduction in material flow rate with mean particle size above a mean particle size of about 120 micron [4].

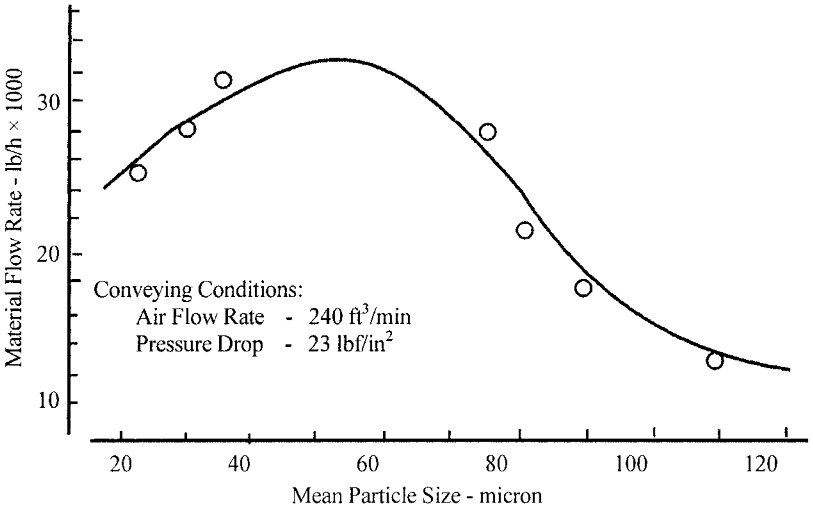

Figure 10.15 Influence of mean particle size of fly ash on material flow rate achieved for given conditions.

The entire range of particles considered on Figure 10.15 is appropriate to power station fly ash. It is interesting to note that the conveying capability of the coarse grades of fly ash change so markedly, and that even the different grades of fine ash, from different fields of the electrostatic precipitator hoppers, also show different conveying capabilities. Insufficient tests have been carried out with coal to say whether these trends are repeated, but it will be seen from the data presented later on coal that particle size does have a marked effect.

3.2 Material Characterization

Certain material characteristics can be used to predict the potential behavior of a material when pneumatically conveyed. These are mostly based on bulk properties of the material that relate to material-air interactions, such as fluidization, air retention and permeability [6]. This was considered in Chapter 4 with Figure 4.22.

4 CONVEYING DATA

Further conveying data for fly ash, and a number of other ash and coal products, is presented below for comparison and reference. Data on both granular and pulverized coal is given, together with additional data on fine fly ash and fluidized bed combustor ash. Fluidized bed boilers are becoming more popular because of their capability of burning a wider range of fuels, with better control over emissions, and the very high pressure combustion capability. The ash produced, however, can have a mean particle size of 0·1 in and above and has a very wide particle size distribution in addition.

4.1 Low Pressure Conveying

Details of a pipeline used to obtain low pressure conveying data are given in Figure 10.16 for reference. The various materials tested were fed into the pipeline by means of a bottom discharge blow tank. A blow tank was used since it has no moving parts, which is a definite asset when conveying such abrasive materials. A positive displacement blower was used to provide the air supply. The blow tank was a low pressure design, with a similar pressure rating to that of the blower, and so it did not need to be a coded vessel.

Data for a fine grade of fly ash, obtained from electrostatic precipitators, and conveyed through this pipeline is presented in Figure 10.17. This material is capable of being conveyed in dense phase, but the conveying system only had a low pressure capability. The conveying distance, however, was very short and so the pressure gradient available was sufficient to convey the fly ash at solids loading ratios of up to about sixty. As a consequence the conveying limit for the material in this pipeline takes the form shown.

The locus of the conveying limit is dictated by the data for the fine fly ash presented in Figure 10.13. If the data is checked it will be seen that the limit at a pressure of 2 lbf/in^2 is about 60 ft^3/min of air, because at a solids loading ratio of seven the minimum velocity is about 2100 ft/min. At a pressure of 5 lbf/in^2 the limit is at about 35 ft^3/min, because at a solids loading ratio of 60 the minimum conveying air velocity is approximately 800 ft/min.

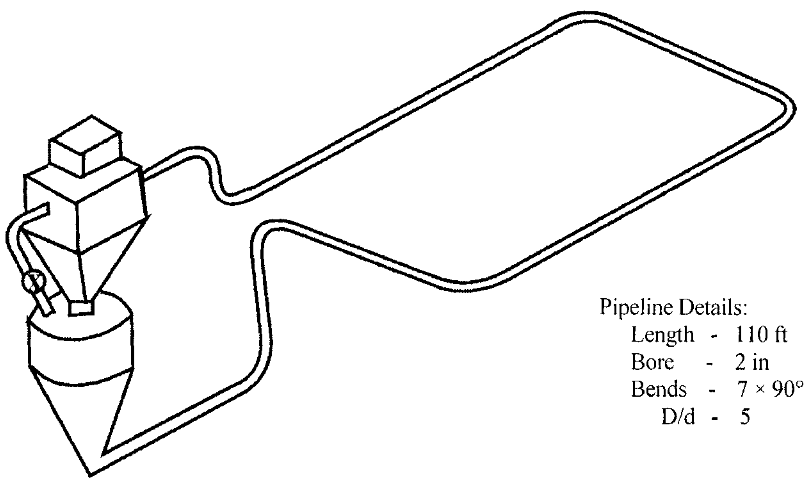

Figure 10.16 Details of pipeline used for low pressure conveying trials.

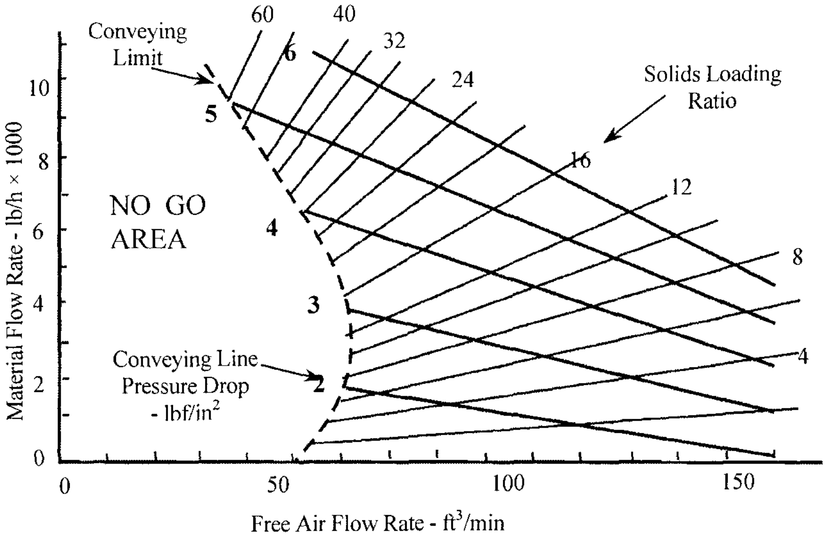

Figure 10.17 Low pressure conveying characteristics for a fine grade of fly ash.

Data for fluidized bed combustor ash conveyed through the Figure 10.16 pipeline is presented in Figure 10.18.

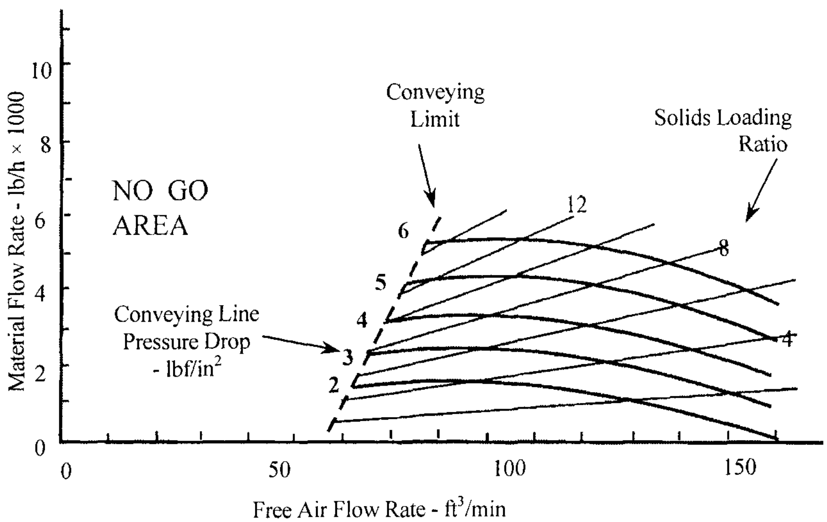

Figure 10.18 Low pressure conveying characteristics for fluidized bed combustor ash.

With a high value of mean particle size and a very wide particle size distribution the bed ash will only convey in dilute phase, suspension flow. The maximum value of solids loading ratio achieved was about 14 and the minimum value of conveying air velocity was about 2600 ft/min, which dictates the conveying limit with a positive slope throughout, as is usual with materials that will only convey in dilute phase.

If the conveying performance of the bed ash is compared with that of the fly ash it will be seen that the material flow rate, for a given conveying line pressure drop and air flow rate, is about half. This difference, of course, is consistent with the data presented earlier on the high pressure conveying of fine and coarse grades of fly ash. This does, therefore, reinforce the need for conveying trials to be carried out with a material, when designing a conveying plant, even for a dilute phase conveying system.

Data for granular coal conveyed through the Figure 10.16 pipeline is presented in Figure 10.19. The mean particle size of the coal was about ¼ inch. Once again there was no possibility of conveying this material in dense phase, and certainly not in a low pressure system. The minimum value of conveying air velocity for this granular coal was about 2400 ft/min and it will be seen that higher material flow rates were achieved with the coal than with the bed ash, despite the fact that the particle size was very much larger. At low values of solids loading ratio slightly higher values of conveying air velocity were required but this is probably because the top size of the material was about ¾ inch. At higher material concentrations this did not appear to be a problem.

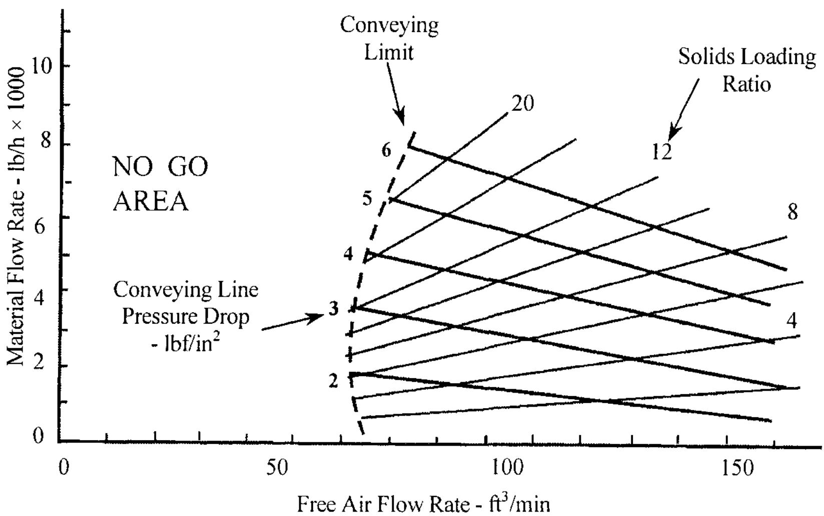

Figure 10.19 Low pressure conveying characteristics for granular coal.

4.2 High Pressure Conveying

In order to illustrate different points, and to provide data on different coal and ash materials, results from two separate sets of conveying trials are reported. In each case the materials were fed into the pipelines by means of top discharge blow tanks. Air was available at a pressure of about 100 lbf/in^2 gauge but, because of the relatively short pipeline employed in each case, the conveying trials were limited to a conveying line inlet air pressure of approximately 30 lbf/in^2 gauge

4.2.1 Group One Trials

Details of the pipeline used to obtain the first set of high pressure conveying data are given in Figure 10.20. Three different materials were tested and these were the same materials that were tested in the low pressure system reported above and conveyed through the Figure 10.16 pipeline.

Conveying characteristics for the fine grade of fly ash are presented in Figure 10.21. Because the pressure gradient was high in this test facility, solids loading ratios up to about 300 were achieved.

Conveying characteristics for the fluidized bed combustor ash are presented in Figure 10.22. Despite the fact that a very high pressure gradient was available for conveying the material, there was no reduction in the value of the minimum conveying air velocity of 2600 ft/min that was reported above in Figure 10.18 in relation to the conveying of this material in the low pressure test facility.

This reinforces the point that high pressure is not synonymous with dense phase conveying. Although relatively high values of solids loading ratio were achieved, the material was only conveyed in dilute phase suspension flow and were simply a consequence of the very high pressure gradient.

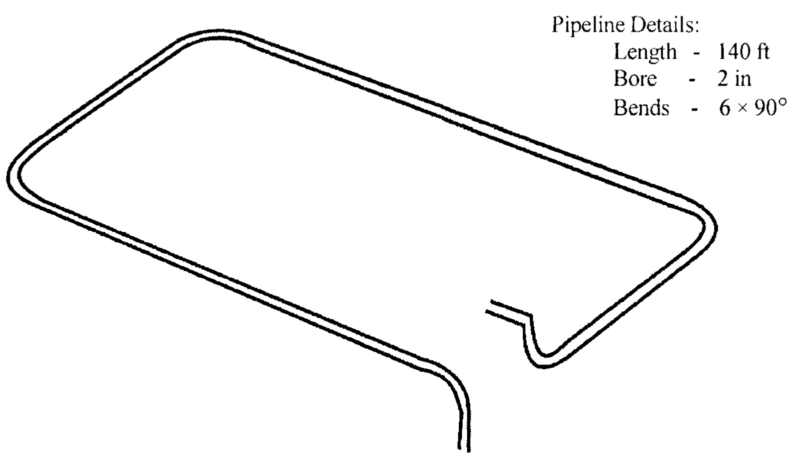

Figure 10.20 Details of pipeline used for high pressure conveying trials.

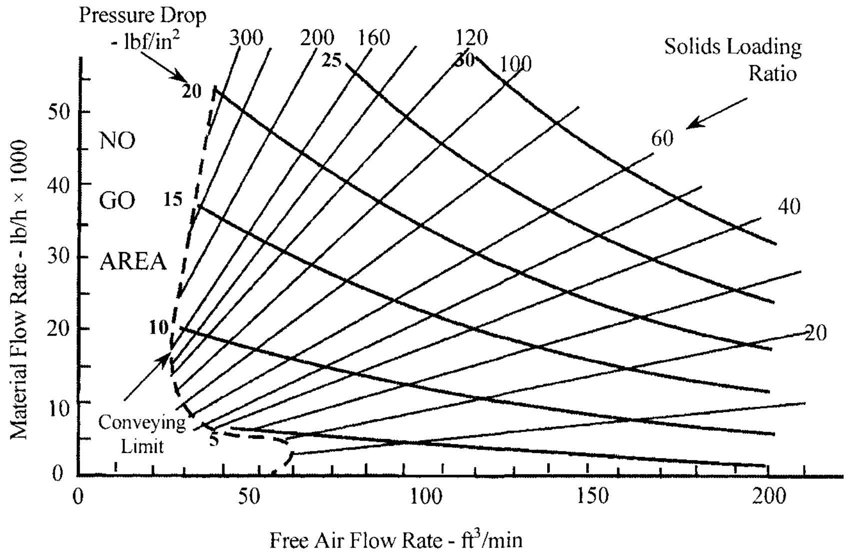

Figure 10.21 High pressure conveying characteristics for fine grade of fly ash.

Conveying characteristics for the coal are presented in Figure 10.23. Once again this is only dilute phase conveying. With a slightly lower value of conveying air velocity, and a much higher material conveying rate, compared with the bed ash, for given conveying conditions, solids loading ratios are relatively high.

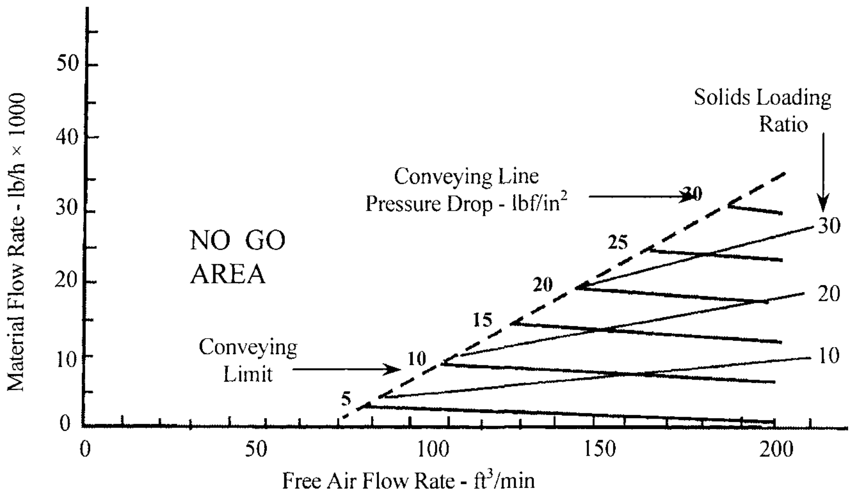

Figure 10.22 High pressure conveying characteristics for fluidized bed combustor ash.

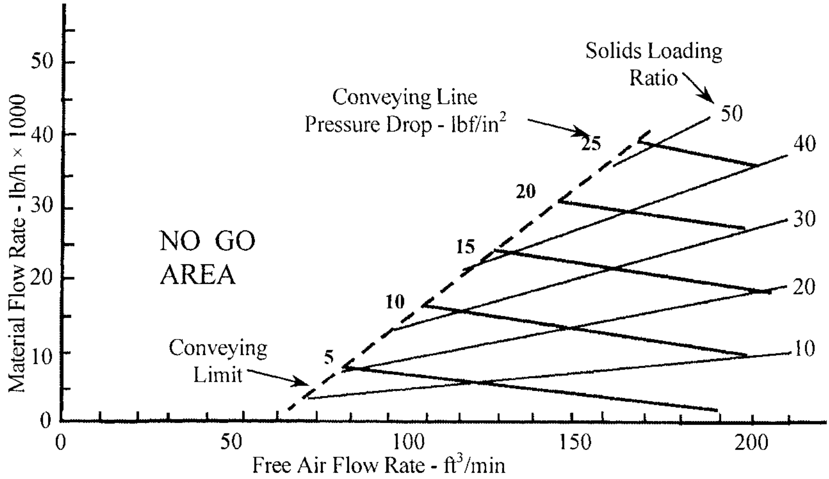

Figure 10.23 High pressure conveying characteristics for coal.

In a plant pipeline it would always be recommended that the pipeline should be stepped to a larger bore part way along its length, if high pressure air is to be used to convey a material, particularly if the material is abrasive. All three of the above materials were abrasive and the bed ash exceptionally so.

4.2.2 Group Two Trials

A sketch of the pipeline used for this set of conveying trials was given in Chapter 4 at Figure 4.2. For reference, data on a fine grade of fly ash is included, as well as data on pulverized coal. Granular coal was also conveyed through this pipeline. Coal, however, in addition to being very abrasive, is also very friable and additional data on degradation and degraded coal is presented. Data for a fine grade of fly ash conveyed through the Figure 4.2 pipeline is presented in Figure 10.24. Once again solids loading ratios up to 300 were achieved and the material would convey reliably with conveying air velocities down to 600 ft/min [7].

Data for pulverized coal is presented in Figure 10.25. The mean particle size of this material was about 80 micron and so in terms of conveying capability it was a borderline case for dense phase conveying. From Figure 10.25 it will be seen that the material could be conveyed at low values of air flow rate and these corresponded to a conveying line inlet air velocity of about 1400 ft/min, and so this was clearly dense phase conveying.

The material, however, did not have the degree of air retention necessary to allow it to be conveyed over the range of conveying conditions achieved with the fly ash in Figure 10.24. This is often referred to as medium phase conveying, but it is clearly in the narrow transitional band, because of particle size, between dilute and full dense phase conveying capability.

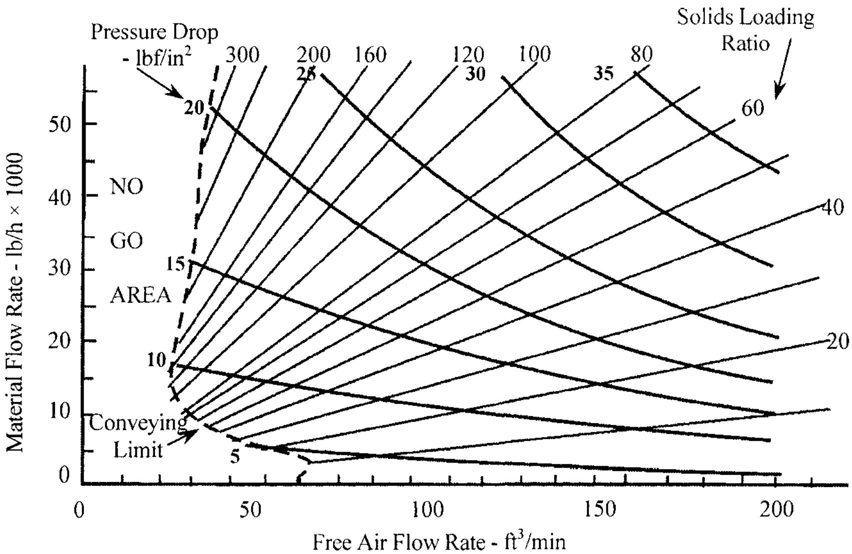

Figure 10.24 Conveying characteristics for a fine grade of fly ash.

Data for granular coal is presented in Figure 10.26. This coal had a mean particle size of about 0·05 in (about 1 mm). As a consequence the material could only be conveyed in dilute phase, suspension flow.

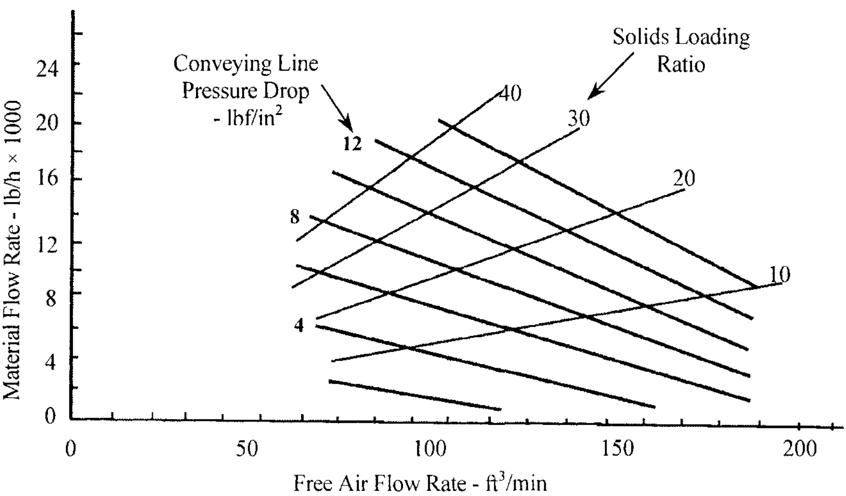

Figure 10.25 Conveying characteristics for pulverized coal.

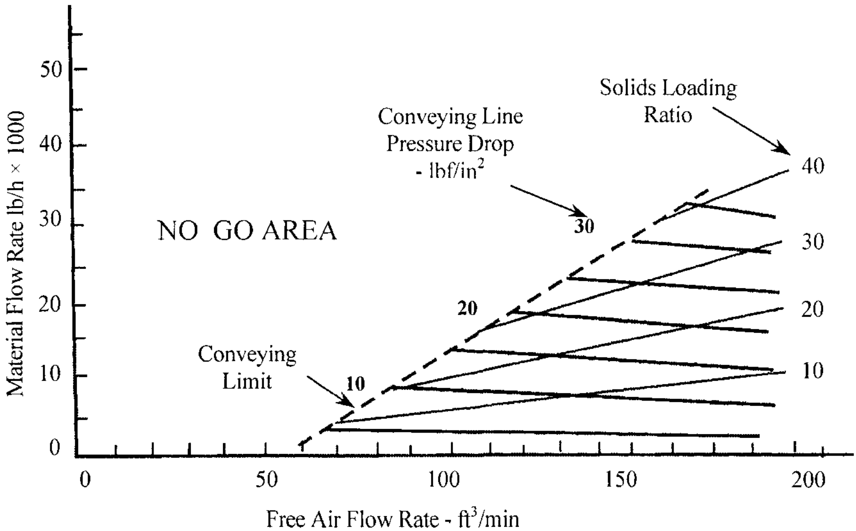

Figure 10.26 Conveying characteristics for granular coal.

The minimum conveying air velocity for the granular coal, however, was about 2200 ft/min, which is relatively low and so, with a very high pressure gradient, solids loading ratios of up to about forty were achieved.

5 DEGRADATION OF COAL

Coal is a very friable material. Any handling operations with coal are likely to result in degradation of the material. Pneumatic conveying, therefore, is likely to cause more damage to coal than any other bulk handling operation.

5.1 Free Fall Damage

To illustrate the potential damage that can result to coal as a consequence of handling, free fall tests were carried out with a sample of coal [8]. The coal was allowed to fall a distance of 20 ft onto a steel plate at an angle of 90°. The coal was retained during its fall in a large diameter steel pipe. In other tests the pipe was angled to the vertical so that the additional influence of pipeline surface effects could be investigated.

Data for the coal is presented in Figure 10.27. The data is presented as a comparison of particle size distributions. The fresh 'as received' material had a mean particle size of about 0·40 inch. After circulating the material three times the mean particle size had fallen to about 0·34 inch.

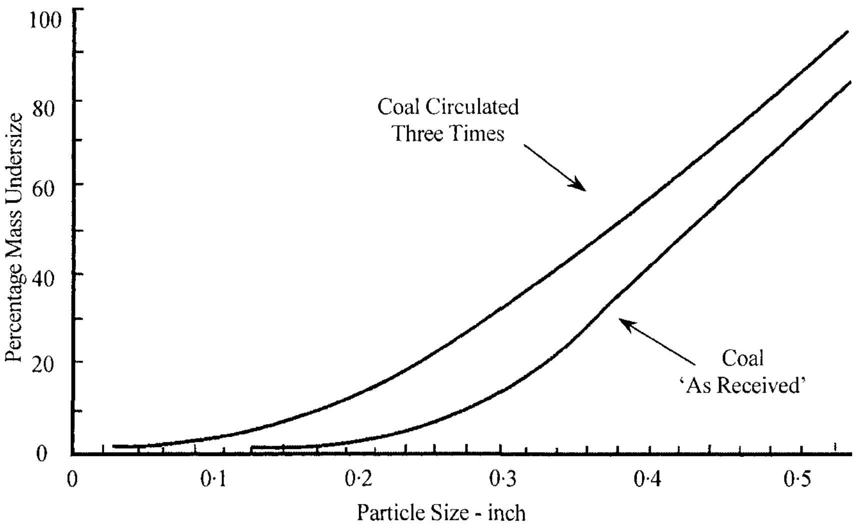

Figure 10.27 Degradation data for coal in free fall test facility.

A particular problem is the generation of fines in this process. Apart from the health hazards associated with coal dust, there is always the potential of a dust explosion with the -200 μm (80 Mesh) fraction. In any safety survey on a plant, therefore, the potential changes that could result to a material, as a consequence of handling operations, must always be taken into account.

5.2 Pneumatic Conveying

The same coal, as reported above in the free fall tests, was pneumatically conveyed in the low pressure conveying facility reported above. The pipeline was shown in Figure 10.16. The coal was re-circulated a total of five times, under identical conveying conditions, through the 110 ft long pipeline that incorporated seven 90° bends. Material was collected for analysis at the end of each test run by means of a diverter valve in the pipeline just prior to the reception hopper [8].

A size analysis of the coal was undertaken on all five samples collected and this data is presented in Figure 10.28, along with the particle size distribution for the fresh 'as supplied' material. Despite the material being conveyed only once between samples the lines for each sample on Figure 10.28 are widely spaced.

5.3 Conveying Characteristics

The influence of material grade on conveying performance was illustrated with respect to fly ash in Figure 10.14 with the fine and coarse grades presented. The conveying characteristics of coal are similarly influenced by grade.

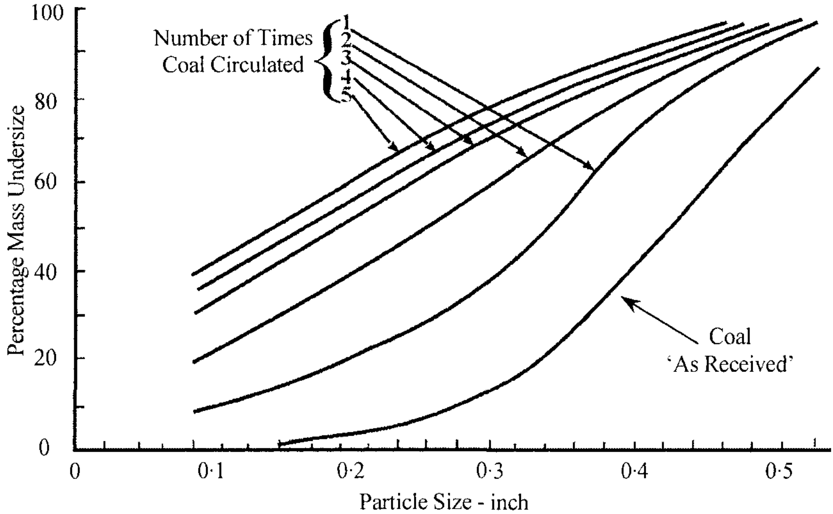

Figure 10.28 Influence of pneumatic conveying on degradation of coal.

This will be seen by comparing the pulverized coal in Figure 10.25 with that of the granular coal in Figure 10.26. With the mean particle size of coal changing so dramatically with re-circulation it is likely that the conveying characteristics of the coal could also change. Conveying characteristics for granular coal having a mean particle size of 0·05 inch (1·2 mm) were presented in Figure 10.26. This coal was conveyed through the Figure 4.2 pipeline. After the Figure 10.26 data was obtained the coal was re-circulated many times until the mean particle size had reduced to about 260 μm (60 Mesh). The conveying characteristics for this degraded coal were then determined and they are presented in Figure 10.29.

If the data in Figures 10.26, for the 'as supplied' material, having a mean particle size of about 0·05 in (1·2 mm), is compared with the data in Figure 10.29, for the degraded material, having a mean particle size of about 260 μm (60 Mesh), it will be seen that there has been a significant change in performance. With a conveying line pressure drop of 30 lbf/in^2 the 'as supplied' coal could be conveyed at a maximum of about 26,000 lb/h but this increased to almost 41,000 lb/h with the degraded coal. This influence of mean particle size on the conveying capability of the material is very similar to that reported for the fly ash in Figure 10.15.

The change in performance, however, is mainly with respect to the conveying capability of the material for given conveying conditions. There is little change in the value of minimum conveying air velocity required, but with the mean particle size of the degraded coal being 260 μm it is still very 'granular' and a significant change in this parameter would not be expected.

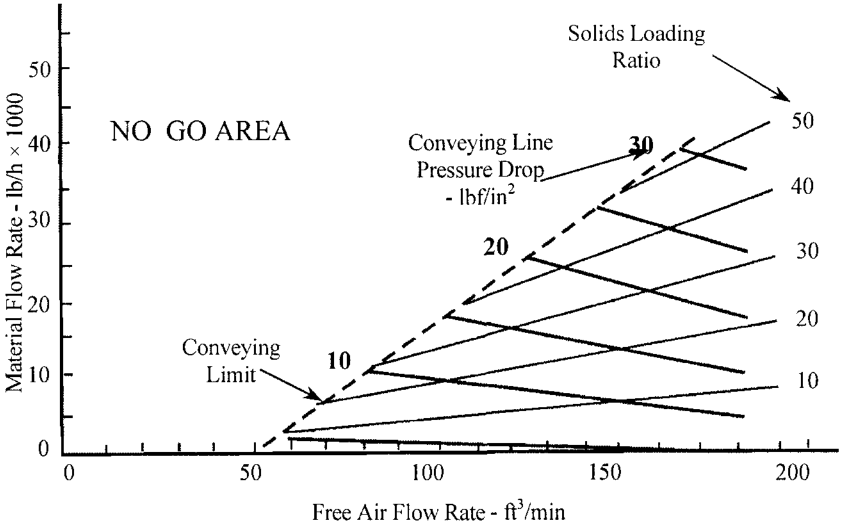

Figure 10.29 Conveying characteristics for degraded coal.

6 APPLICATIONS

Although power generation probably represents the greatest use of coal, and is responsible for the greatest amount of ash generation, the coal has to be transported to power stations and the ash has to be removed from site. Mining, therefore, is a major industry worldwide that involves considerable conveying of coal and ash, and are quite likely to increase considerably during this century as oil and gas reserves diminish and alternative non fossil fuel power generation alternatives are slow to develop.

6.1 Mining

Much of the coal burnt in power stations has been obtained from deep mines. With mechanization of coal face operations in the 1970's the mining capability often exceeded that of the hoisting capability of winding gear and so additional means had to be found of extracting the additional capacity. The alternatives considered at that time were the sinking of additional shafts, hydraulic conveying and pneumatic conveying. Pneumatic conveying was by far the cheapest option. Although the operating cost was the highest, the capital cost of the equipment and its installation was the lowest. This soon became widely adopted as a means of hoisting coal from deep mines.

A particular problem with mining operations is that of subsidence of the ground above. It is, of course, now a requirement that mined-out areas should be back-filled. An ideal material for this purpose is fly ash. Although it is a considerable added cost it is now being more widely considered as the best option on environmental grounds for the disposal of fly ash. The use of ash ponds for this purpose is gradually being restricted by governments on a world-wide basis.

6.1.1 Ash Disposal

Where power stations are located close to coal mines a logical solution to the problem of disposal is to return the fly ash back underground for stowing. This may involve a vertical drop of 1000 ft or more down the mine shaft. If the fly ash is conveyed at a high solids loading ratio, the pressure generated at the bottom of the shaft can be high enough for the material to be automatically conveyed onward to underground workings an equivalent distance horizontally [9].

Data on the conveying of fly ash vertically down was presented in Chapter 8 with Figure 8.12. A particular problem here, however, is that the pressure generated could be so high that the conveying air velocity in the following horizontal section of pipeline could be too low to support conveying and the pipeline could block. In this case the pipeline would need to be reduced in diameter, rather than increased, in order to increase the conveying air velocity.

The horizontal section of pipeline would need to be expanded to a larger diameter along its length in the usual way, as it would be discharging material to atmospheric pressure [10]. Details of a possible conveying system were presented in Chapter 9, with a sketch of a pipeline for such an application given in Figure 9.20 and velocity and pressure profiles for the pipeline system given in Figure 9.21.

6.1.2 Coal Hoisting

Onley and Firstbrook [11] reported on tests undertaken at Horden Colliery in the UK having an 8 in bore pipeline with a 1380 ft vertical lift. With minus one inch coal, 90,000 lb/h was achieved with a conveying line pressure drop of 25 lbf/in^2, although with wet shale of the same size only 50,000 lb/h could be achieved with the same air supply pressure. 40,000 lb/h of minus two inch dolomite was conveyed with a conveying line pressure drop of 20 lbf/in^2.

At Shirebrook colliery in the UK the pipeline bore was 12 in and the vertical lift was 1070 ft [12]. In this case there were horizontal runs of 330 ft from the feed point and 175 ft to the reception point. 145,000 lb/h of minus one inch coal was conveyed with an air supply pressure of 11 lbf/in^2. 7800 ft^3/min of free air was used and the motor power required to drive the blower was 700 hp.

Since the size of coal to be conveyed can vary from zero to four inch lumps, conveying is essentially in the dilute phase mode, although with the vertical distances involved and air supply pressures employed, conveying could only be in very dilute phase because of the pressure gradient available. Systems operate at up to 20 lbf/in^2 gauge, although 10 to 12 lbf/in^2 gauge is more usual, with air provided by positive displacement blowers. For air supply pressures of 20 lbf/in^2 gauge, twin blowers in series are normally used.

Rotary valves are generally used for pipeline feeding in this type of application but are built more substantially than rotating airlock feeders. The valves are usually powered by a direct drive hydraulic motor that can produce sufficient torque to shear lumps of rock should they become jammed. Should, however, a rock prove too strong to shear, or if tramp material should become trapped, the rotor should instantly stop, with the hydraulic circuit by-passing to a tank.

6.2 High Pressure Coal Injection

The case of feeding coal into a high pressure fluidized bed combustor boiler was mentioned earlier in relation to blow tanks operating in series and having essentially no limit on operating pressure. A much longer established application of feeding coal into a high pressure system has been that of feeding granular coal into blast furnaces.

Coal is injected into blast furnaces in order to reduce the amount of coke required to melt the iron ore. Coke is expensive to produce, but the quantity required can be reduced significantly by injecting granular coal into the blast furnace in the region of the tuyeres. This is the area where the hot air, typically at 1800 to 2200°F, is blown in for combustion. The pressure in this region, however, is 20 to 40 lbf/in^2 gauge and so blow tanks are generally used for this purpose.

Apart from the temperature and pressure, a particular problem is that the coal needs to be injected at multiple (typically 12 to 16) points around the perimeter in this region. The hot combustion air is injected by means of nozzles from a ring main. This is not appropriate for gas-solid flows and so a separate small diameter pipeline is used for each injection point. A common pipeline is generally fed from the blow tank and then at a point conveniently close to the blow tank the flow is split into the 12 or 16 separate lines. It is necessary, therefore, to balance the resistances in these lines such that a reasonably uniform flow of coal is achieved through each.

6.3 Long Distance Conveying

Both coal and ash are conveyed over long distances. With ash most long distance duties are generally associated with power stations.

6.3.1 Fly Ash

The conveying of fly ash over distances of a mile or more has now become fairly common, particularly with the drive towards the utilization of the material and the move away from slurry conveying.

One of the early systems was at Ropar in India where a cement plant was built alongside the power station in order to utilize the fly ash in the manufacture of cement. The reception silos were located on the boundary of the two plants. This required the pneumatic conveying of the fly ash over a distance of 5100 ft. Four parallel pipelines were used, each with its own twin blow tank system, and each one conveys about 85,000 lb/h over this distance. Air at a pressure of about 35 lbf/in^2 gauge is used and the pipeline is stepped twice to a larger bore along its length.

6.3.2 Coal

Mehring [13], reports on a system conveying pulverized coal over a distance of 8330 ft. The coal is conveyed from a central grinding mill to a coal firing system at a cement works and employs a parallel twin blow tank feeding system. The coal is conveyed in batches, with a 15 minute conveying cycle (ten minutes actual conveying), at about 35,000 lb/h. The conveying line pressure drop is 13 lbf/in^2, the conveying line inlet air velocity 1500 ft/min and the pipeline bore is 10 in. The solids loading ratio was reported to be about five. The pipeline incorporated 14 bends.

6.4 Multiple Grade Conveying

Not all pneumatic conveying systems are dedicated to the conveying of a single material. There is often a need for a system to transport a number of different materials. In power plant there is generally a requirement to convey different grades of fly ash, as was illustrated in Figure 10.5. The conveying requirements of different grades of ash, however, can differ widely, as was clearly shown in Figure 10.14.

There are many solutions to the problem but probably the simplest and most effective method is to use pipelines of different bore for the different materials. This technique was considered in general terms in Chapter 9 with Figures 9.12 and 9.13.

By this means the same air mover and filtration plant can be used and each material can be conveyed with its own optimum conveying line inlet air velocity. It is possible that the two pipelines could be brought together for a common entry to the reception hopper if required.

The situation is illustrated with regard to different grades of fly ash with a typical plant layout sketch in Figure 10.30. A negative pressure conveying system has been chosen for the purpose to illustrate the fact that stepped pipelines are just as appropriate for high vacuum systems as they are for high positive pressure systems.

The velocity profiles for the flow through the two pipelines, for a free air flow rate of 635 ft^3/min, is presented in Figure 10.31. A vacuum of 11 lbf/in^2 has been taken and minimum conveying air velocity values of 1200 and 3200 ft/min have been assumed for the fine and coarse grades of ash respectively [14].

Although this system is shown with a common pipeline entering the reception silo, this is not a necessity. In some cases it might not be possible or appropriate for the two pipelines to join together, particularly if a step is required in the low velocity pipeline. A very similar situation will exist for a positive pressure conveying system.

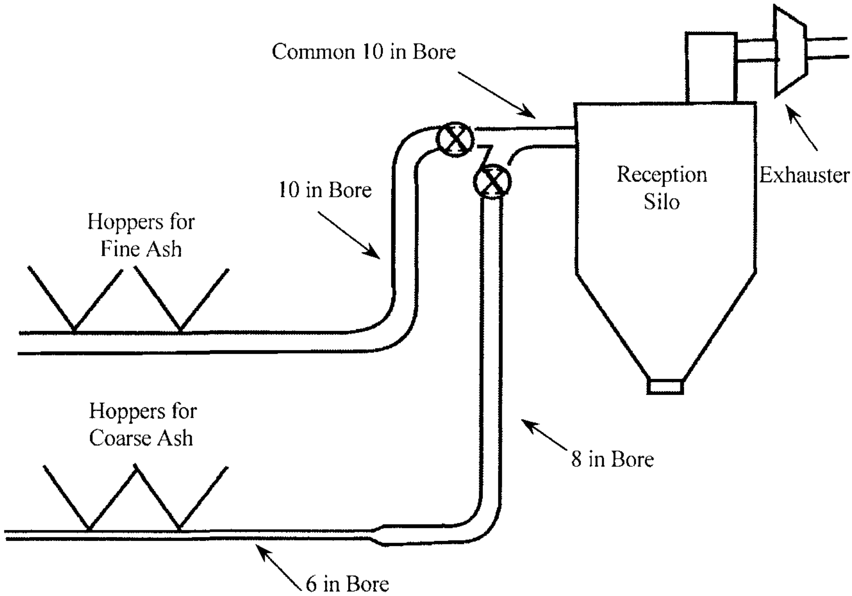

Figure 10.30 Sketch of negative pressure conveying system for conveying both coarse and fine grades of fly ash.

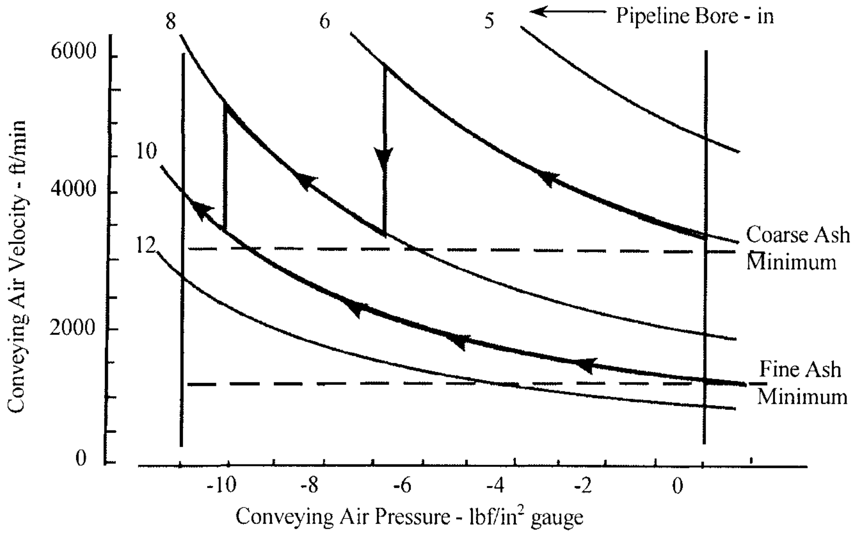

Figure 10.31 Velocity profiles for coarse and fine fly ash in common negative pressure conveying system.

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