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P a r t 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.2. Ash removal

3.2.2.1. Technological options for removal of fly ash at TPPs in India

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ABSTRACT

India has large reserves of coal and hence Power generation in India is predominantly based on using coal as the fuel. However, the quality of coal used at the thermal power stations is of poor quality and contains high level of coal ash. At present, the thermal power plants in the country produce close to 120 million t of coal ash. A significant quantity of this ash is used in various activities. Construction sector is one of the major consumers of this ash. Transportation of coal ash within the power plant and to the user's site presents complex handling requirements. Moreover, the unused quantity has to be safely transported to the ash ponds. This paper considers various handling options for different grades of coal ash, which have been in use at the power stations in India.

1. BACKGROUND

Thermal power constitutes more than half of the world's electric power generation [1]. Millions of tonnes 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 be reliably and efficiently removed from the plant. The removal of ash can either be done wet in the form of slurry or dry using pneumatic conveying systems.

2. ASH GENERATION

Power generation in India is predominantly based on using coal as the fuel. However, the quality of coal used in the power stations is of poor quality and contains upto 45 % ash. The coal based power plants in the country generate close to 120 million t of flyash every year. Due to concerted efforts of the Government of India agencies, the research laboratories, manufacturing industry, power plants and regulating bodies, a significant amount of flyash is presently being used in various applications. Large quantity, however, still needs to be safely deposited in the ash ponds or the ash mounds. Utilization of ash necessitates that it must be transported over short and long distances in varying quantity.

2.1 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. These properties will also influence particle and bulk density. 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.

Silicon oxide and aluminium oxide are 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, having a hardness value close to 8 on the Mhos scale of hardness. 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 into which it comes into contact, whether by abrasion or impact

2.2 Ash Collection Hoppers

The finer fractions of he coal ash is carried away with the flue gases. Various fractions of this ash is collected at several locations along the flue gas path. A layout of the ash collection locations is shown in Fig. 1.

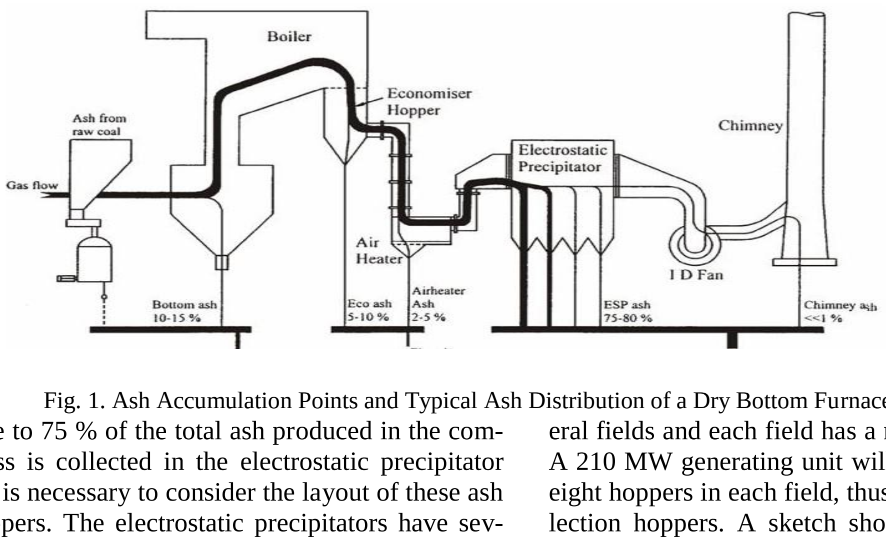

Fig. 1. Ash Accumulation Points and Typical Ash Distribution of a Dry Bottom Furnace

Since close to 75 % of the total ash produced in the combustion process is collected in the electrostatic precipitator (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 210 MW generating unit will typically have six fields and eight hoppers in each field, thus making a total of 48 ash collection hoppers. A sketch showing the layout of a typical group of ESP hoppers, and the direction of the gas stream, is

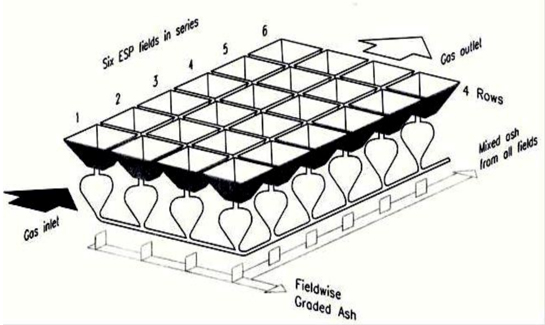

Fig. 2. Typical Arrangement of Electrostatic Precipitator Ash Collection Hoppers

given in Fig. 2.

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 very minimal. If, during a failure, field 1 were 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.

2.3 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 Fig. 2, 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 ash of the first field and fine ash from the subsequent fields. 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.

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 utilisation of the ash and the ESP plant layout.

3. ASH REMOVAL 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 utilisation. Possible ash removal systems include mechanical, hydraulic and pneumatic conveying systems. Hydraulic and pneumatic conveying of ash would be discussed separately in the following sections.

3.1 Hydraulic Conveying

Conventional hydraulic conveying systems are widely used for the disposal of ash into ash lagoons. Ash is discharged from the various ash hoppers, mixed with water and transported through open channels into the ash sump. From the sump the ash is conveyed in slurry form to the ash lagoons, which could be located up to several kilometers from the plant. In countries like India, where ash generation is so enormous, and applications for utilisation not fully explored, slurry disposal of ash is still practiced at most power stations. The recent trend is to go in for high concentration (up to 70 % ash) slurry instead of dilute slurry having only 20 % ash content. Such high concentration slurry should result in savings of water, specific power consumption and ease of maintenance of the ash ponds. A major advantage of slurry disposal is that the distance of conveying is not a limitation as in the case of dry flyash handling through pneumatic conveying systems.

Environmental problems associated with ash lagoons in many countries, however, are starting to have an impact on the viability of this method of disposal. Legislation is also coming into force in a number of countries, which is setting gradually increasing targets for the practical use of fly ash, with the aim of reducing the quantity of ash that has to be disposed of. For most applications it is desirable that the ash must remain dry and so the use of pneumatic conveying systems is gradually increasing.

3.2 Pneumatic Conveying

Pneumatic conveying systems offer an ideal choice for the handling of fly ash in dry form. Pneumatic conveying systems broadly fall into two categories: the suction system and the pressure system. Air slides can be considered to be an extreme form of pneumatic conveying wherein very high material transfer rates can be achieved by employing the advantage of gravitational flow aided by artificial fluidisation of the material Fig. 3.

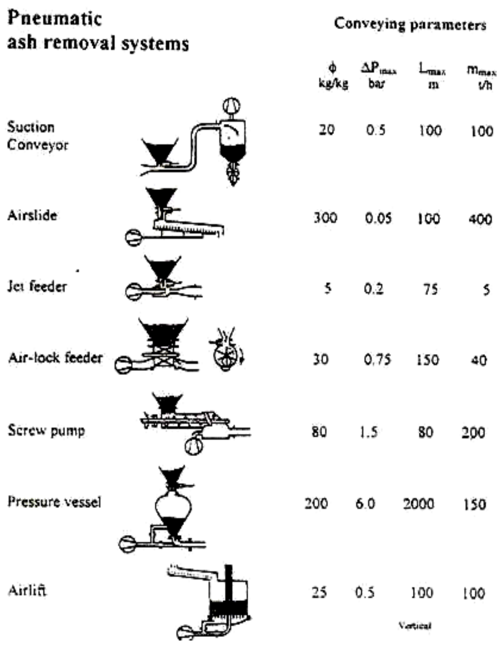

Fig. 3. Pneumatic Ash Removal Systems with Conveying Parameters Indicated

Harder [1] has presented an overview of the systems available to convey fly ash. Fig. 4 shows some possible alternatives that can be used for the transportation of ash. Typical values of the conveying parameters associated with these systems are also marked against them. Each system has its own limitations in terms of the conveying air velocity, the maximum achievable pressure drop, distance of conveying, and the concentration, or solids loading ratio, at which the material can be conveyed.

Vacuum or suction type systems generally require a high conveying line inlet air velocity and the maximum permissible pressure drop is typically restricted to about 0,5 bar gauge. These are well suited, however, to situations requiring multiple point pick up of the material, as in case of the evacuation of ash from ESP and other ash hoppers. The distance of conveying, however, is restricted due to the limitation on the pressure drop.

Positive pressure pneumatic conveying systems are now widely accepted for conveying fly ash at power stations. Depending upon the specific application, either dilute phase suspension flow systems or dense phase low velocity systems can be used. Several operating parameters have to be considered in making a judicious choice of the system most appropriate for a given application. The major advantage of positive pressure systems is that since high pressures can be employed for the conveying system, it is possible to convey the material over long distances. A good number of pneumatic conveying systems are in use at power stations where the conveying distance exceeds 1000 m and can go up to 2000 m. A detailed description of these systems, components and design criterion is discussed in the following chapters.

4. MODE OF CONVEYING

Much confusion exists over how materials are conveyed through a pipeline and to the terminology given to the mode of flow. First it must be recognised that materials can either be conveyed in batches through a pipeline, or they can be conveyed on a continuous basis, 24 hours a day if necessary. In batch conveying the material may be conveyed as a single plug if the batch size is relatively small.

4.1 Dilute Phase

For continuous conveying, and batch conveying if the batch size is large, two modes of conveying are recognised. If the material is conveyed in suspension in the air through the pipeline it is referred to as dilute phase conveying. If the material is conveyed at low velocity in a non-suspension mode, through all or part of the pipeline, it is referred to as dense phase conveying. Almost any material can be conveyed in dilute phase, suspension flow through a pipeline, regardless of the particle size, shape or density.

4.2 Dense Phase

In dense phase conveying two modes of flow are recognised. One is moving bed flow, in which the material is conveyed in dunes on the bottom of the pipeline, or as a pulsatile moving bed. The other mode is slug or plug type flow, in which the material is conveyed as full bore plugs separated by air gaps. Moving bed flow is only possible in a conventional conveying system if the material to be conveyed has good air retention characteristics like flyash. Plug type flow is only possible in a conventional conveying system if the material has good permeability.

4.3 Conveying Air Velocity

For dilute phase conveying a relatively high conveying air velocity must be maintained. This is typically in the region of 10 to 12 m/s for a very fine ESP ash, from 13 to 16 m/s for a coarse granular ash collected in the economizer and air pre-heater hoppers, and beyond for larger particles and higher density materials. For dense phase conveying, air velocities can be down to 3 m/s, and lower in certain circumstances [2]. Because of the fine particle size required to provide the necessary air retention properties, particle density does not have such a significant effect on the minimum value of conveying air velocity in dense phase conveying, as it does in dilute phase conveying. These influences are illustrated in Figs 4 and 5, which show the conveying performance characteristics of the precipitator and economizer ash. Within the plant, therefore, if the economizer and precipitator ash have to be handled through a common pneumatic conveying system, appropriate pipeline sizes must be selected to ensure that the minimum pick up velocity at the ash feed point is correct for that grade of ash.

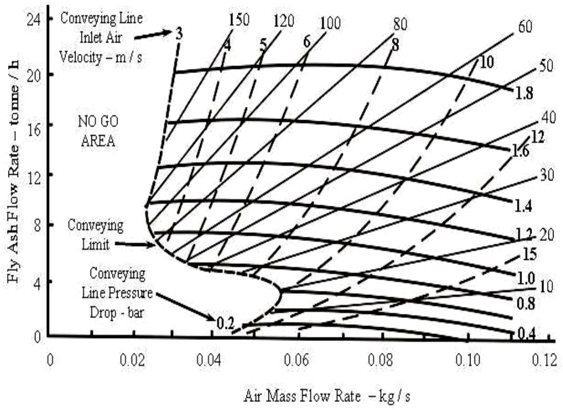

Fig. 4. Conveying Characteristics for Fine Grade of Fly Ash with Conveying Line Inlet Air Velocity Data Superimposed

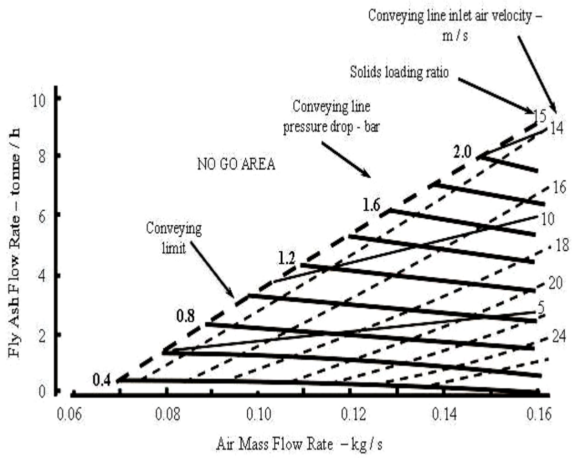

Fig. 5. Conveying Characteristics for Coarse Grade of Fly Ash with Conveying Line Inlet Air Velocity Data Superimposed

4.4 Solids Loading Ratios

The solids loading ratio, or phase density, is a useful parameter in helping to visualise the flow. It is the ratio of the mass flow rate of the material conveyed divided by the mass flow rate of the air used to convey the material. It is expressed in a dimensionless form. For dilute phase, maximum values that can be achieved are typically of the order of 15, although this can be a little higher if the conveying distance is short. For moving bed flows, solids loading ratios of well over 100 can be achieved if materials are conveyed with pressure gradients of the order of 20 mbar/m.

5. POWER STATION ASH HANDLING LAYOUT

The dry fly ash handling system at thermal power stations consists of two stages. The ash from the economiser hoppers, air pre-heater hoppers and the ESP hoppers is first evacuated to a number of buffer silos. These silos are typically located within a distance of 150 m from the last field hoppers of the electrostatic precipitators. If required, it is possible at this stage to separate the very fine ash, such as that in fields 3, 4 and 5, from the coarser ash in fields 1 and 2. From the buffer silo the ash is generally transported to another silo from where the ash is ultimately cleared from the site. The distance of the disposal silo from the buffer silo could be between 800 m and 2000 m. A typical layout of this arrangement is shown in Fig. 6.

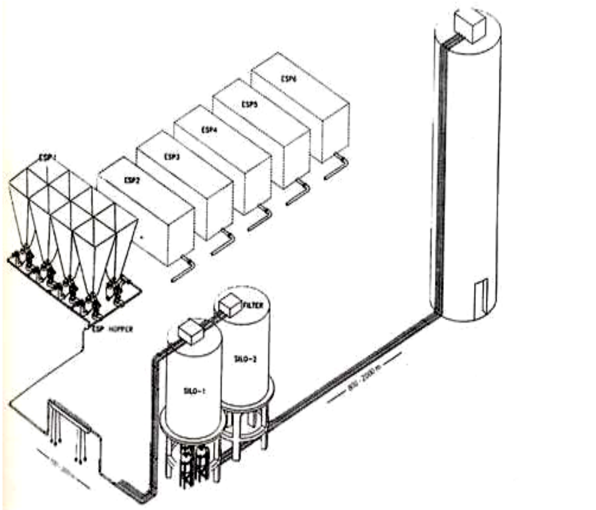

Fig. 6. Typical Dry Fly Ash Handling Arrangement at a Power Station

For evacuation of ash from the economiser and air preheater hoppers either positive or negative pressure conveying systems can be used. For the second stage of long distance conveying from the buffer silo to the disposal silo, however, only positive pressure conveying systems can be used. It has been experienced that a small percentage of coarse material could be carried along with the fine material. If the quantity of coarse material is significant, however, the operating variables must be so selected that the design caters for the worst conveying conditions. In a power plant, it is desirable to handle the economiser ash separately from the ESP ash.

If the conveying distance from the buffer silo to the disposal silo is more than 1000 m, high conveying air pressures will generally have to be used. 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.

At some power stations, dry flyash for utilisation can be given from the buffer silo itself. Arrangements are made to load trucks or tankers from under the buffer silo. In case there is no demand for the dry flyash, the ash is mixed with water and taken to the sump for subsequent slurry disposal.

6. TRANSPORTATION OF FLYASH TO THE USER'S SITE

In some cases the plant where flyash is intended to be used may be located in the close vicinity of the power station itself. Cement grinding units to manufacture pozzolanic grade of cement is one such example. In such cases it is possible to install another pneumatic conveying system to transfer ash from the power plant silo to the grinding unit.

Most applications requiring dry flyash may, however, be located in far off locations. In some cases this distance could well be a few hundred kilometers or even more. There are two possibilities of transporting ash over such distances. If the user has a dedicated and long term requirement of dry flyash on a continuous basis, closed road tankers having a capacity of 8 to 10 tonnes can be deployed. These tankers are filled from under the storage silo by gravity. At the other end, the contents of the tanker are discharged into a storage hopper by means of compressed air. It means that the pneumatic conveying system principles can be used to off load ash from the tankers.

6.1 Bagging of flyash

If the demand of dry flyash is of intermittent nature, the flyash from the silo can be filled into bags. The users can pick up ash stored in bags as per their requirement. Bag filling equipment is available, which is capable of filling bags varying in any capacity from 30 kg to 1000 kg. Such a range of bag capacity can serve the needs of small quantity users as well as the users who may require relatively large quantity. It must, however, be ensured that the filled bags are stored safely to prevent moisture from entering into the bags.

The bags at the other end can either be discharged directly into the mixing application or can be emptied into a storage hopper and used as per the requirement.

7. CONCLUSIONS

It is apparent from the information presented in this paper that the coal ash several fractions which have different properties. As a result the selection of the most optimum mode of conveying/handling of a particular grade of coal ash will be dictated by its properties. An overview of possible alternatives to handle various grades of ash is presented in Fig. 7. This includes options available for conveying ash within the plant as well as to the user's site located at some distance from the power plant.

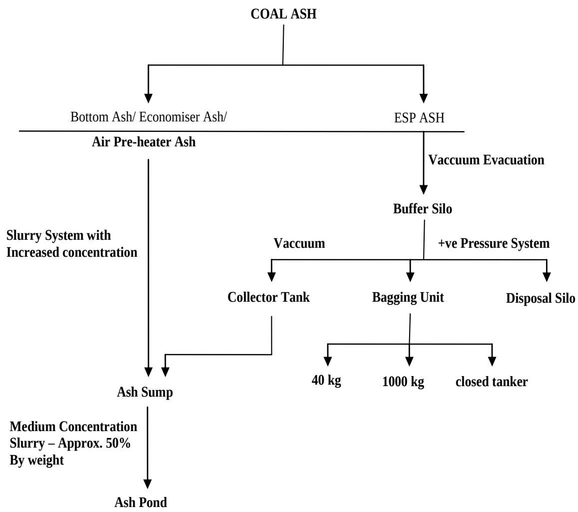

Fig. 7. Recommended Options for Coal Ash Handling and Safe Disposal

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