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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

3.2.2.11. Wet ash handling - "Technology of the past"

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ABSTRACT

Due to various environmental, legislative and water resource constraints there has been a shift from wet to dry ash handling technologies in thermal power plants world over. There are a number of benefits in using dry ash handling, the most prominent being huge reduction in water consumption and significantly lower operational expenditure. This eliminates the need for ash lagoons, water storage, recirculation and treatment systems resulting in lower impact on the environment. Ash obtained from a dry system is also easier to utilise for production of cement, mortars etc.

Since a variety of coal is used in thermal power generation and combining this with different boiler designs the ash produced from them is also different. The two major types of ash produced are furnace bottom ash and flyash. In pulverised fuel boilers bottom ash is collected under the boiler and in the past the preferred systems have included the impounded hopper and submerged scraper conveyor. In the last few years the trend has moved towards dry technologies, these utilise atmospheric air to cool the bottom ash. It also transfers the heat from the hot ash to the air entering the boiler resulting in increased efficiency.

On the contrary flyash has been handled successfully in dry systems for more than three decades in some parts of the world. Due to the temperature, good air retention properties and dust generation issues, belt conveyors are not employed to handle flyash. Other mechanical systems are limited to short distances only and normally the flyash needs to be transported 100 - 1000m. The pneumatic conveying systems have always been preferred for bulk transport of flyash. The flyash is generated at various points in the power stations i.e. preheater, economiser, ESP, fabric filter, stack etc. the properties of these ash vary substantially. Generalising these properties and designing a pneumatic conveying system to handle all different flyash can be problematic. This paper gives an insight into the basic design parameters to select the most suitable dry ash handling system.

1. INTRODUCTION

1.1. Furnace Bottom Ash

Wet bottom ash removal is still the preferred method worldwide for pulverised fuel boilers but with the growing environmental awareness and increased water shortages the trends are shifting to dry systems. The wet systems also require high maintenance and suffer from chronic corrosion and clogging issues. Impounded hopper systems are the most widely used system in the old power stations. These consist of water filled hoppers with submerged crushers to break the big lumps into small pieces and water ejector takes them out to a sump. From there the ash is pumped using slurry pumps to the ash lagoons. More modern system use submerged scraper conveyors, these consists of a chain conveyor submerged in water under the boiler and an inclined section afterwards to lift the ash to higher level. The inclined section also acts as dewatering slope before discharging the ash in a storage silo. These systems use less water than the impounded hopper systems.

In the wet system water is used to cool the ash resulting in requirement for water cooling and recirculation systems which increase the operation cost of these systems. The dry systems use the slight negative pressure in the pulverised fuel boilers to draw air over the bed of hot ash. The air moves counter current to the ash and fans the re-burn effect. This reduces the unburned carbon levels and frees up additional thermal energy which is returned to the steam generating process within the boiler. This arrangement increases boiler efficiency, reduces coal usage and CO_2 emissions [1].

1.2. Flyash

Dry flyash handling is a mature market as compared to the dry bottom ash and the technology is very well proven but in some countries there are still wet flyash handling systems in operation. A number of different types of day flyash handling systems are available in the market. Pneumatic conveying is the most common technology currently employed for flyash handling. The success of this type of system over other mechanical dry system is attributed to a number of reasons first being the small footprint requirements and ease of routing through the existing plant. Second factor is the flyash physical and chemical properties as the ash is very abrasive and mechanical systems have wear issues.

Unlike mechanical handling equipment the pneumatic conveying systems are influenced by the physical properties of the flyash. Particle size distribution and particle shape are the most important, especially for dense phase conveying as it will have a huge impact on the conveying rates achieved by the system.

1.3. Ash Classification Parameters

1.3.1. Bulk Density

Most of the ash handling systems work on volumetric bases this make bulk density a very important. Poured bulk density is used for volumetric sizing of the machine and packed density is used for structural calculations.

1.3.2. Particle size Distribution

This is one of the most influential parameter as it determines the suitability of equipment for the given ash. The bottom ash can have big lumps and both dry and wet handling systems require crushing of the lumps to a manageable lump size of < 25mm. Fine flyash can have a wide spread of particle size range and it varies with the type of equipment. Bag filters have a similar particle size on all outlets but electrostatic precipitator tends to have bigger particles on the first field.

The fine flyash is classified into four groups based on it particle size.

Fine Flyash	d50 = 30 – 50 mic
Course Flyash	d50 = 70 – 90 mic
Fine Grit	d50 = 130 – 160 mic
Coarse Grit	d50 = 580 – 620 mic

Fig.1. Example of flyash classified into four groups

When pneumatically conveyed all of above grades behave differently. The spread of particle size also affects the conveying properties, ash with narrow particle size distribution is generally more difficult to convey.

1.3.3. Particle Shape

Fine flyash is predominantly spherical in shape but the sand particles have angular structure. Due to the spherical nature of the sand particles it is very easy to convey. The ash from fluidised bed boiler has higher sand content and is generally more angular hence more abrasive and difficult to convey.

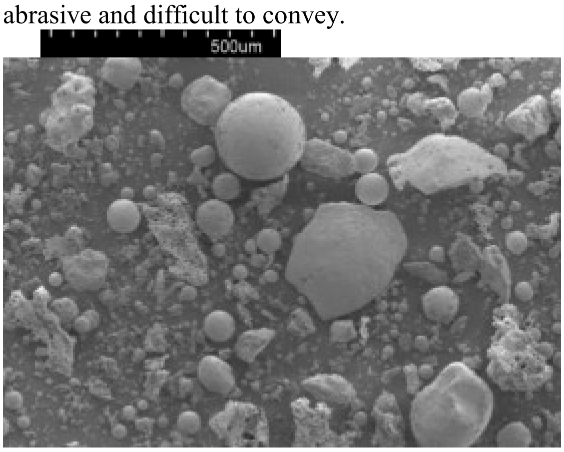

Fig.2. Spherical Flyash Particles

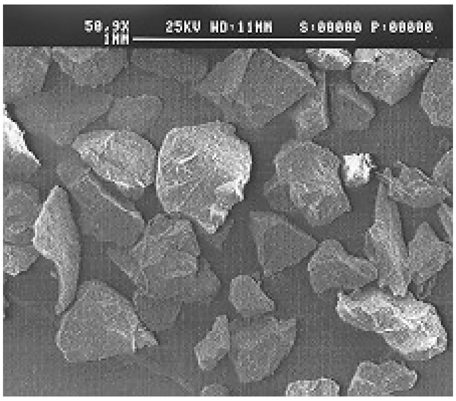

Fig.3.Angular Sand Particles [2]

2. DRY BOTTOM ASH HANDLING

The Dry Bottom system is mounted and fully sealed to the bottom of the combustion chamber (furnace outlet). Ash precipitates down from the combustion chamber onto a steel plate conveyor belt situated directly below the furnace outlet. The negative pressure inside the boiler draws ambient air in a controlled manner into the Dry Bottom ash system. Air travels in counter-flow direction along the surface of the ash activating a re-burning process of the glowing ash thus reducing unburned carbon content and releasing additional thermal energy for use in the combustion process. This basic principle is shown in figure 4 below. Heat is transferred from the hot ash into the ambient air before it enters the combustion chamber and this adds additional thermal energy to the steam generating process inside the boiler. Approx. 1% to 1.5% of the combustion air is required for the dry cooling system. This ensures that the combustion process and the exhaust gas composition are not affected. Adjustable cooling air inlets are located along the casing and the top outlet of the Dry Ash Cooling system to control the amount of air. Most of the air enters the sealed Dry Ash Cooling system at the top of the ash discharge side, to ensure maximum ash surface heat transfer. The air entering at the bottom of the sealed casing, adds ambient air to the heated air entered at the top and supports the cooling and re-burning process.

For dry bottom ash applications where large lumps are a significant problem the dry bottom ash cooling system can be fitted with Jaw Crushers between the transition chute and cooling system inlet. These crushers breakdown the large lumps into smaller more manageable size that can then be cooled and transported by the onward conveying systems. The jaw crushers can also be used as boiler / conveyor isolation if required.

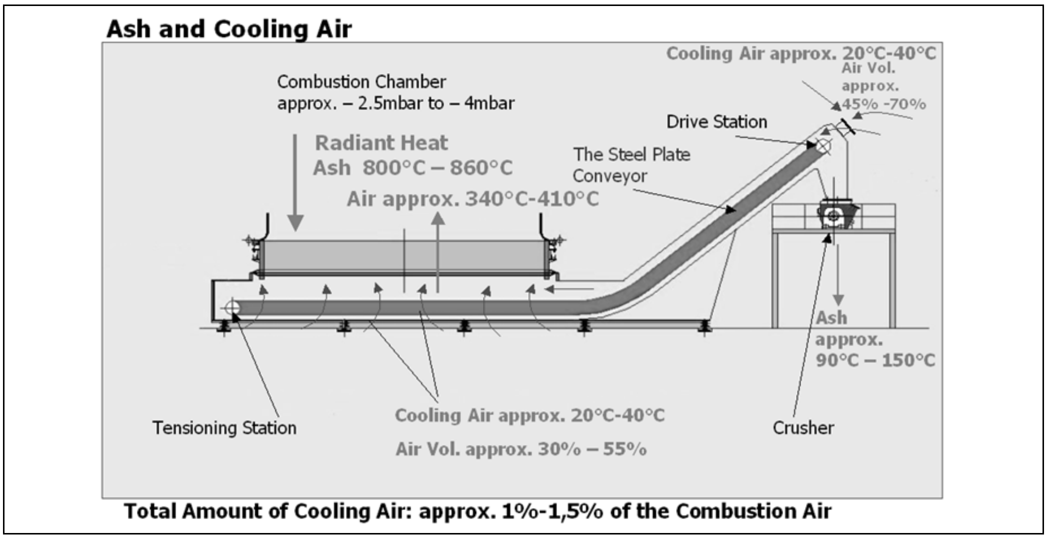

Fig.4. Basic Principle of Dry Bottom Ash Handling

2.1. Physical Arrangement

Underneath the combustion chamber a transition chute is supported from the ground floor by means of a steel structure. The transition chute or hopper is lined with concrete refractory on the internal wall to withstand the radiation heat from the combustion chamber of the boiler. A heat resistant fabric compensator is installed between the boiler/hopper outlet and the Dry Ash Cooling System intake, to compensate the movement between cold and hot condition of the boiler. The compensator is fabricated from elastic material, resistant to high temperatures. To avoid damages due to high temperatures by the radiant heat from the combustion chamber, a special protecting skirt is also provided at the inner side of the compensator. The compensator is mounted in one-piece only, to assure tightness and the required flexibility. Alternatively water sealing system similar to ones used in SSCs systems can also be used. The Dry Ash Cooling System can be put on a rail system to move it to the side whilst the boiler is out of operation; this gives free access to the combustion chamber of the boiler for maintenance and repair purpose. The Dry Ash Cooler and transition hopper can also be designed to enable storage of ash should any problem occur down-stream thus preventing a shutdown of the boiler.

2.2. Benefits of Dry Verses Wet bottom ash handling system

Dry Bottom Ash Handling	Wet Bottom Ash Handling
No water requirement	Warmed up cooling water must be cooled down
Residual unburnt carbon <5%	Residual unburnt carbon <20%
Can be mixed easily direct with fly ash	Can be mixed with fly ash only after drying
Bottom ash can be sold for a higher price (with fly ash) than bottom ash	Only usable in special cases for simple application, e. g. road construction
No water treatment processes are required	High cost for water treatment and disposal areas
The Dry Ash system is a completely enclosed system with no impact to the environment	Environmental critical product, if disposed with high content of water
Simpler and more compact system, because no need of water requirement	More equipment like water pumps, settling ponds, water treatment, etc., required
Saving energy by burning partly remaining coal in the bottom ash	Unburned content transferred to cooling water
Return of heat by warmed up cooling air introduced in the furnace	Enthalpy from the ash transferred totally to cooling water

3. PNEUMATIC CONVEYING SYSTEMS

Pneumatic conveying of ash in power station is a well-established and readily accepted method of both transporting ash. Other mechanical methods of handling of ash in and around power station are associated with dirt, noise, spillage, expensive maintenance and other problems. Using pneumatic conveying to transfer of ash within a sealed pipeline system, offers a number of advantages over the traditional mechanical methods.

- Pipelines are usually much easier to route and support than mechanical conveyors, offering flexibility in the location of the reception and storage facilities.
- The sealed pipeline ensures a dust free environment which is in keeping with modern environmentally conscious power station design.
- Moving parts are limited only to the collection or distribution points of the system and hence are far fewer than with traditional mechanical plant, minimising potential maintenance areas.
- Prime movers, i.e. air compressors, blowers or vacuum pumps can be located away from any harsh environmental conditions, thus promoting longevity and again minimising maintenance.

3.1 System Types - Positive and Negative Pressure

Pneumatic conveying systems can be conveniently split into two groups. Positive Pressure Systems which effectively blow the material along a pipeline, and Negative Pressure Systems which convey materials by means of suction. In general, positive pressure systems are extremely versatile with a capability to handle both low product throughputs over short distances and large products throughputs over long distances. Negative pressure systems tend to be more limited in their application, concentrating on relatively short conveying distances and low product throughputs. These systems can be sub divided into three operating regimes.

- Lean (Dilute) Phase - positive pressure or vacuum
- Dense Phase - positive pressure

3.1.1 Lean Phase System

Traditionally, dilute phase conveying systems have been employed and it is true to say that almost any material that can be fed into a pipeline, can with careful consideration of the airflow and pressure be conveyed in such a system. In general these systems will operate with conveying air pressure less than 1 bar and with air velocities of between 15m/s and 30m/s. These can be either positive or negative pressure (vacuum type), and generally rely upon the material being discharged either continuously, or in small batches into a continuous mixing air stream where the material particles are carried along individually in the air stream to their destination. Large volumes of low pressure air are used as the motive force for this type of system, supplied either from a low pressure blower, or a vacuum exhauster.

In order to transport materials in a 'lean-phase' mode, the material particle pick-up, or start velocity must be achieved by the air stream and is generally in the order of 15 to 30 m/sec. All material particles travel individually through the pipe and in addition to particle to particle collisions will also impact with the pipe at any change in direction. Due to the high conveying velocities and low suspension densities the wear rate on these systems is very high [4]. The positive pressure systems have never been very successful in handling flyash due to multiple pick up point requirement as multiple rotary valves air leakage is a major issue and educator type system cannot work with multiple pickup points. The vacuum conveying systems have had limited success due to the ease of having multiple pickup points on one conveying line and low wear on the pickup points. But the pipe and bend wear is similar to positive pressure system. The major drawback with this system is that only 500 mbar pressure differential can be utilised for conveying, this however severely limits the rates and distance for these systems.

3.1.2 Dense Phase System

Dense phase systems have always been preferred for handling flyash due to the potential benefits this method of conveying offers with respect to reduced power consumption, reduced particle degradation, erosive wear of pipeline, bends and fittings. These systems are also always of a positive pressure type, and again use a blow tank to collect the material before it is transferred into the pipeline in batches. Dense phase conveying systems generally operate with conveying air pressures in the range of 2…5 barg with air velocities between 2 - 10 m/sec and mostly operate in batch mode but options of continuous mode in dense phase are also available. Air pressure is much higher than a lean phase system but the air volumes are greatly reduced. These systems can be used to convey fine flyash up to 1500m in single stage [3]. Air can be supplied from either a high pressure or medium pressure compressors through an air receiver and unlike lean phase it is possible to run multiple systems with a single compressor.

Flyash properties influence the dense phase conveying and can vary the conveying rates substantially. Fine and coarse flyash are easily conveyed but the fine grits depending on the particle size distribution may require air injection on conveying pipes to convey reliably. This limits the maximum conveying distance of this material up to 1000m. Since the system work at high solid loading ratios >20 the material convey in plug flow this reduces the wear on the system [5]. As the majority of the material travels as a 'plug' pipeline wear is only limited to frictional effects rather than particulate impact.

4. CONCLUSION

Dry ash handling technologies have successfully been employed on coal ash all over the world. The dry bottom ash technology is relatively new but with the increased number of installation it has been proven to be the technology to move forward with. The dense phase flyash technology has been proven for three decades. Combining both technologies eliminate the use of water previously required for hydraulic conveying of ash. Promising results have already been obtained to reutilize bottom ash mixed with flyash from coal combustion using it for structural embankments, drainage media or milling and mixing it with the fly ash to utilize both together in the cement production instead of dumping this product in disposal areas.

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