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Full Length Article

Beneficial effects of dry bottom ash extraction and recycling in modern PCF power plants

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ABSTRACT

The article describes the operational experience of the first industrial application of the Magaldi Ash Recycling (MAR®) system. That installation was commissioned in 2007 at a 2 × 320 MW pulverized coal-fired (PCF) power plant in Italy.

The MAR® system is a recycling process that transforms bottom ash into fly ash by returning the "dry" bottom ash to the boiler combustion chamber.

The dry bottom ash is removed from beneath the boiler using the MAC® Magaldi Ash Cooler. This technology, with more than 200 installations worldwide on boilers generating more than 70,000 MW, extracts and cools down the bottom ash by means of a small amount of ambient air. Then, the MAR® system conveys the ash back to the coal feeders where it is mixed with coal, milled and reintroduced into the furnace.

The effects of the bottom ash reinjection, including the results of a 2-year site investigation, will be discussed in the present paper. The benefits of the MAR® system for PCF power plants are remarkable and can be summarized by the following achievements:

1. Conversion of all bottom ash into saleable fly ash.
2. Complete elimination of costs associated with bottom ash disposal or dedicated slurry system to a bottom ash pond.
3. LOI content reduction in fly ash due to the dilution effect of dry bottom ash (~8% reduction on average).
4. Fly ash in compliance with international standards: EN 197-1 (cement) and EN 450-1 (concrete) in the EU.
5. Environment respect: mixing fly ash with cement, CO_2 emissions decrease. Around 0.9 tons of CO_2 are generated from the production of a ton of Portland cement.

1. Introduction

Coal combustion residuals (CCRs), commonly referred to as coal ash, are the materials that remain after burning coal for producing electricity. CCRs include bottom ash that generally accounts for 10–20% of the total ash production. CCRs management always represents a critical point for both environmental protection and sustainability of power generation from coal.

Conventional wet technology, referred to as Wet Bottom Ash Systems (WBAS), uses water to quench bottom ash generated by a boiler [3,7,12,13]. It is based on two main methods: Water Impounded Hopper (WIH) systems and Submerged Chain Conveyor (SCC) systems. But growing concerns about water scarcity, environmental regulations, equipment reliability and increasing awareness of the overall cost savings due to dry system, are some of the reasons why utilities are selecting the dry ash handling technology.

The MAC® (Magaldi Ash Cooler) technology [7–9,13], introduced by Magaldi over 30 years ago, overcomes the limitations of conventional WBAS thanks to a "dry" cooling process to remove hot bottom ash from both small and large pulverized coal-fired boilers. To date, more than 200 dry bottom ash handling systems have been supplied worldwide under utility and industrial boilers, of any size and burning any type of solid fuel [4] Picture 1.

Downstream the MAC® system, the "dry" bottom ash can be beneficially reused as an "inert material" in some applications (e.g. road construction, brick manufacturing, cement production) to replace raw materials removed from the earth, thus conserving natural resources.

The "dry" bottom ash can be also recycled back to the boiler through the Magaldi Ash Recycling (MAR®) system. In that case, all bottom ash is transformed into fly ash, a more valuable by-product that can be beneficially reused as an "addition" [2] for cement and concrete production to replace Portland clinker, generally up to 35% and even

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Picture 1. MAC® System Installations Worldwide.

more in case of pozzolanic cements.

The present paper reports the main benefits of the dry bottom ash extraction and recycling gained in a 2 × 320 MW PCF power plant located in Italy, burning imported coals and equipped with the MAC® system since 2003 and the MAR® system since 2007.

2. Dry bottom ash removal

Conventional WIH systems [7,12,13] Fig. 1 use large amounts of water for cooling and conveying, involving extensive water treatment systems, significant power consumption, high O&M costs and environmental pollution. Big lumps frequently cause crusher blockages, requiring manual intervention and risk for operators.

Conventional SCC systems [7,12,13] Fig. 2 need water treatment systems and recirculation pumps. Wear and corrosion problems, due to water presence and friction among scrapers, chain, bottom plates and wet ash, are unavoidable. Visual inspection for maintenance activities cannot be safely performed during operation. Unpredictable failures of the chain are possible. High power and frequent chain tensioning are required. Particles floating in the water bath as well as fines suspended in the water generate operational problems. Sudden failures or necessity for repairs, associated with the above risks, can lead to production losses or high O&M costs.

The MAC® system overcomes those limitations thanks to a “dry” cooling process and the dependable Magaldi Superbelt® technology. All water related problems, both operational and environmental associated with dewatering bins, waste water treatment, pumps, heat exchangers or pH control, corrosion, water leakages, hot water splashing or vapor explosion, risk of ice in cold climates, pollution from ponds and so on, are completely eliminated [3,8].

The MAC® system’s very reliable operation is witnessed by millions of trouble-free operating hours. That is ensured by the MAC® construction and the use of the Magaldi Superbelt®, allowing safe collection and transport of extremely hot, abrasive and dusty ashes, no matter if containing very big lumps. High temperatures and tear issues are resolved thanks to the patented method of connecting the pans to the mesh belt, that leaves all elements free to expand in any direction. The Superbelt® damage-tolerant design eliminates any risk of sudden failures, otherwise always present, especially with hot and abrasive materials, in the case of conveyors using chains.

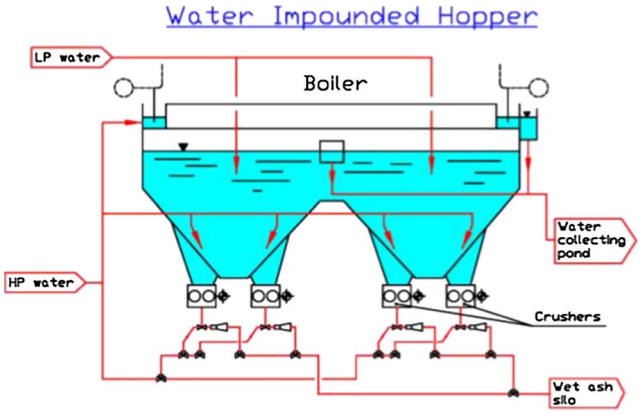

Fig. 1. Water Impounded Hopper (WIH).

In the MAC® extractor, the Superbelt® conveyor is made of stainless steel and driven through a variable speed drive by the friction between the belt mesh and the head pulley. Belt tension is maintained by a pneumatic take-up system mounted at the tail pulley. No risk of derailment of the Superbelt® is possible, as in the case of conveyors using chains and sprockets.

Wear in the MAC® system conveyors is negligible, since ash is slowly conveyed with no relative motion against steel parts. Maintenance is very easy: all idler supports are installed outside the casing, allowing simple inspection at any time and lubrication with the belt in operation. The other elements are designed for continuous operation and can be checked during preventive maintenance, over a multi-year schedule.

The MAC® system is generally comprised of Fig. 3:

- A mechanical seal, to connect the boiler to the MAC® system, allowing free furnace expansion.
- A refractory-lined hopper, or a transition chute, between the furnace and the MAC® extractor.
- A set of bottom doors, normally open; if necessary, the doors can be closed to store the bottom ash inside the hopper.
- The MAC® extractor for the bottom ash removal from underneath the boiler.
- A primary crusher for size reduction of large ash lumps.
- A secondary conveyor, so called Magaldi Ecobelt®, to take the crushed ash to a silo, while extending the cooling effect.

3. Improving boiler efficiency

In the MAC® technology ash cooling is carried out by ambient air, naturally drawn into the system by the furnace negative pressure. A limited amount of ambient air enters the system through accurately sized inlet valves located along the equipment. The system is designed to maximize the counter-current bottom ash cooling. Following the air/ash heat exchange, sensible heat from the ash is effectively transferred to the air.

For the above reasons, one of the most important effects related to the use of the dry bottom ash technology is its positive impact on the boiler efficiency [1,6,11]. When the MAC® system is used instead of a conventional wet bottom ash system, the overall efficiency of the boiler has been demonstrated to improve, primarily because of the use of air as the ash cooling medium rather than water. High temperature air creates an oxidizing atmosphere inside the system, that strongly promotes the reduction of any unburned carbon contained in bottom ash by post-combustion [5,10]. Flame radiation through the boiler throat is not lost into the water bath, as in conventional wet systems, but is also recovered. As a result, cooling air enters the furnace through the boiler throat at quite a high temperature, recovering a significant amount of

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