



BOTTOM ASH CONVERSION OPTIONS AND ECONOMICS

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INTRODUCTION

Wet Bottom Ash material handling systems and surface impoundments are presently regarded as the industry standard and are certainly the most commonly used method in the coal fired power industry around the world today. However, with the recent event of an ash pond (surface impoundment) failure and the ensuing EPA investigation of all existing facilities employing this technology, environmentally suitable alternatives are being investigated by coal fired electric power producers.

This paper will address the available technologies and their comparison. The four primary Bottom Ash conversion approaches are as follows:

- **DRYCON™ SYSTEM:** (retrofit) The collection, crushing, air cooling and mechanical conveying of bottom ash without the need for water quenching.
- **SUBMERGED SCRAPER CONVEYOR:** (retrofit) The collection, water quenching and mechanical conveying of bottom ash; with a closed loop cooling water system.
- **CONVENTIONAL TANK FARM DEWATERING:** The continued collection of bottom ash in water impounded hoppers, and the future addition of dewatering bins, settling tank and surge tank; with a closed loop water system.
- **ASHCON™ REMOTE SUBMERGED SCRAPER CONVEYOR SYSTEM:** The continued collection of bottom ash in water impounded hoppers, and the future addition of a hybrid Submerged Scraper Conveyor; with a closed loop water system.

This paper will detail the following for each of the four conversion options:

- **Site Specific Limitations:** Facility Age, Physical Layout, and Boiler design type and configuration.
- **System Design Parameters:** Thermal and Mechanical.
- **Environmental Issues and Benefits:** Zero water discharge and Boiler Efficiency improvement.
- **Economic analysis,** of each approach.

Conversion projects will differ from plant to plant and variations on the systems will be discussed.

Clyde Bergemann is recognized as a technical leader in the field of Bottom Ash and Fly Ash Handling Systems and has many reference installations around the world.

Wet Bottom Ash (BA) material handling systems and surface impoundments are presently regarded as the industry standard and are certainly the most commonly used method in the coal fired power industry around the world today.

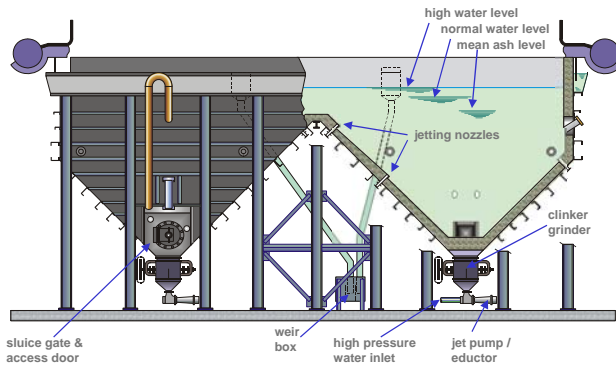


Figure 1: Typical Bottom Ash Hopper Arrangement

Water impounded bottom ash hoppers, located under the boiler throat are used to store the collected bottom ash and periodically (once or twice per 8 hour shift) the hoppers are discharged and Bottom Ash is hydraulically conveyed to surface impoundments (ash ponds). The ash is pumped utilizing either high pressure jet pumps or slurry pumps.

Surface Impoundment are large water filled basins, either man made or constructed using natural topography and the employment of a retainage dam, to store the coal combustion residuals (CCR) for extended periods of time.

At the time when many surface impoundments were constructed there was little state or federal regulation.



Figure 2: Typical Surface Impoundment (Ash Pond)




Figure 3: Typical Surface Impoundment after berm failure

However, with the recent event of an ash pond (surface impoundment) failure and the ensuing EPA investigation of all existing facilities employing this technology, environmentally suitable alternatives are being investigated by coal fired electric power producers.

As of the date of preparation of this paper, there were 162 Power Plants utilizing Surface Impoundments. Recently the US EPA is proposing to regulate CCR under one of two scenarios.

The Environmental Protection Agency (EPA) is proposing to regulate for the first time, Coal Combustion Residuals (CCRs) under the Resource Conservation and Recovery Act (RCRA) to address the risks from the disposal of CCRs generated from the combustion of coal at electric utilities and independent power producers. However, the Agency is considering two options in this proposal and, thus, is proposing two alternative regulations. Under the first proposal, EPA would reverse its August 1993 and May 2000 Bevill Regulatory Determinations regarding coal combustion residuals (CCRs) and list these residuals as special wastes subject to regulation under subtitle C of RCRA, when they are destined for disposal in landfills or surface impoundments. Under the second proposal, EPA would leave the Bevill determination in place and regulate disposal of such materials under subtitle D of RCRA by issuing national minimum criteria. Under both alternatives EPA is proposing to establish dam safety requirements to address the structural integrity of surface impoundments to prevent catastrophic releases. Following is a summary of the two proposals.



<http://www.epa.gov/epawaste/nonhaz/industrial/special/fossil/ccr-rule/ccr-table.htm>
 Last updated on Thursday, July 29, 2010

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Coal Combustion Residuals - Key Differences Between Subtitle C and Subtitle D Options

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Key Differences Between Subtitle C and Subtitle D Options

	SUBTITLE C	SUBTITLE D
Effective Date	Timing will vary from state to state, as each state must adopt the rule individually-can take 1 - 2 years or more	Six months after final rule is promulgated for most provision; certain provisions have a longer effective date
Enforcement	State and Federal enforcement	Enforcement through citizen suits; States can act as citizens.
Corrective Action	Monitored by authorized States and EPA	Self-implementing
Financial Assurance	Yes	Considering subsequent rule using CERCLA 108 (b) Authority
Permit Issuance	Federal requirement for permit issuance by States	No
Requirements for Storage, Including Containers, Tanks, and Containment Buildings	Yes	No
Surface Impoundments Built Before Rule is Finalized	Remove solids and meet land disposal restrictions; retrofit with a liner within five years of effective date. Would effectively phase out use of existing surface impoundments	Must remove solids and retrofit with a composite liner or cease receiving CCRs within 5 years of effective date and close the unit
Surface Impoundments Built After Rule is Finalized	Must meet Land Disposal Restrictions and liner requirements. Would effectively phase out use of new surface impoundments.	Must install composite liners. No Land Disposal Restrictions
Landfills Built Before Rule is Finalized	No liner requirements, but require groundwater monitoring	No liner requirements, but require groundwater monitoring
Landfills Built After Rule is Finalized	Liner requirements and groundwater monitoring	Liner requirements and groundwater monitoring
Requirements for Closure and Post-Closure Care	Yes; monitored by States and EPA	Yes; self-implementing

The requirements under subtitle D are those that EPA will be proposing based on statutory authority. States, under their own programs, can adopt requirements for which we do not have authority.

While the co-proposed RCRA subtitle D regulations do not include provisions for financial assurance, EPA has stated that classes of facilities within the Electric Power Generation, Transmission, and Distribution industry are among those for which EPA plans to develop, as necessary, a proposed regulation under the authority of CERCLA 108(b).

Figure 4: Proposed CCR Regulatory Differences

In most cases, under the current proposed regulatory scenarios, surface impoundments will no longer be a viable disposal option. This paper will address the available technologies and their comparison for eliminating the need for surface impoundments. The four Primary Bottom Ash Conversion approaches are as follows:

- **CONVENTIONAL TANK FARM DEWATERING:** The continued collection of bottom ash in water impounded hoppers, and the new addition of dewatering bins, settling tank and surge tank; with a closed loop water system.
- **SUBMERGED SCRAPER CONVEYOR:** (retrofit) The collection, water quenching and mechanical conveying of bottom ash; with a closed loop cooling water system.
- **REMOTE DEWATERING CONVEYOR SYSTEM ASHCON™:** The continued collection of bottom ash in water impounded hoppers, and the added integration of a hybrid Remote Dewatering Conveyor; with a closed loop water system.
- **DRYCON™ SYSTEM:** (retrofit) The collection, crushing, air cooling and mechanical conveying of bottom ash without the need for water quenching.

This paper will detail the following for each of the BA conversion options:

- **Site Specific Limitations:** Facility age, physical layout, and boiler design type and configuration.
- **System Design Parameters:** Thermal and mechanical.
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- **Economic analysis, of each approach.**

Conversion projects will differ from plant to plant and variations on the systems will be discussed.

- **Conventional Dewatering Systems:**

When new power plants were being designed in the 1970's, the state of the art ash handling systems at the time were closed loop water recirculation systems that involved a "tank farm" thousands of feet away from the boiler.

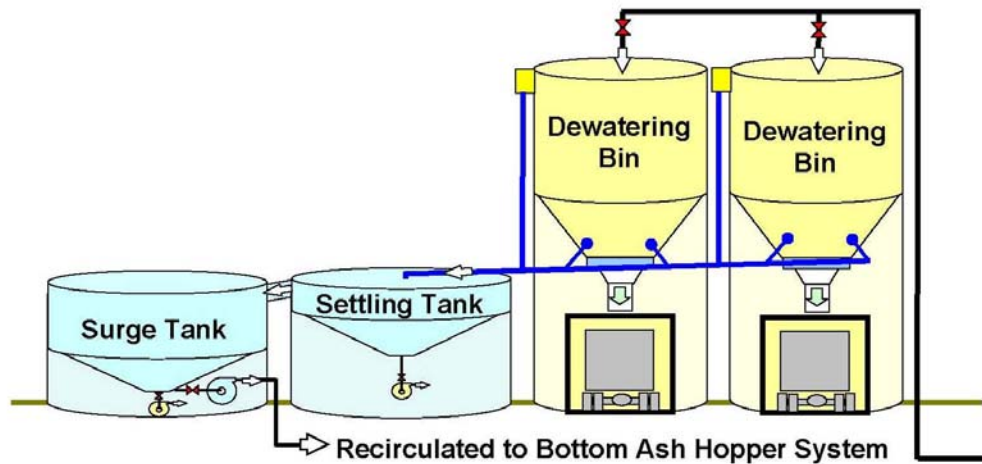


Figure 5: Conventional Bottom Ash Dewatering System

In these systems the bottom ash was pumped from the ash hoppers to the top of tall dewatering bins using either jet pumps or centrifugal slurry pumps. In either case, the Total Dynamic Head, TDH, that these pumps were designed to overcome included the height of the dewatering bins as well as the horizontal distance to the location of the bins. This vertical lift was a significant number and led to the phase out of jet pumps for these closed loop systems in favor of high-head single stage mining pumps to handle the high TDH as well as the larger slurry flows associated with greater ash generation rates.

When the bottom ash slurry is pumped to the top of the dewatering bins, it is discharged into one of two bins: one bin is always ready to receive slurry while the other may be off-line and in the midst of a 4-8 hour decanting cycle. All of the water entering or decanting from any dewatering bin overflows by gravity to a settling tank that reduces the Total Suspended Solids, TSS, and returns collected sludge back to an available dewatering bin. The clearer water overflowing the settling tank is stored in a surge tank for eventual return to the ash hopper to form the closed loop. There is still some ongoing particulate settling in the bottom of the surge tank which is also returned to an available dewatering bin. The actual discharge point from the surge tank for the closed loop recirculation path is above the lower settling zone.

The dewatering bins themselves have an upper portion with an inlet baffle, underflow baffle and overflow weir to force the ash itself down into the lower collection cone while providing a tortuous path for the water that reduces the ash carryover to the settling tank as much as possible, given the high flow rates.

Once the incoming slurry flow to the dewatering bin ceases and the ash level is above the conical section, lower decanting valves are opened which allow water trapped in the ash volume to work its way by gravity out of the interstitial voids in the ash to decanting screens along the walls and possibly center of the bins. These screens have small openings to hold the ash in the bin while the water passes through them and down to a collecting ring header and out through the decanting valves to the settling tank.

The settling tanks have to be quite large, on the order of 50 to 75 feet diameter, to slow the water flow velocity rates down and allow the ash fines to settle to the bottom. Underflow baffles and weirs are used here also to reduce the ash carryover to the surge tanks.

• **CONVENTIONAL TANK FARM DEWATERING:**

Where the boiler house configuration or type of boiler technology employed (cyclone boilers), prohibits the use of under the boiler retrofit technologies, the use of Conventional Tank Farm Dewatering can be utilized.

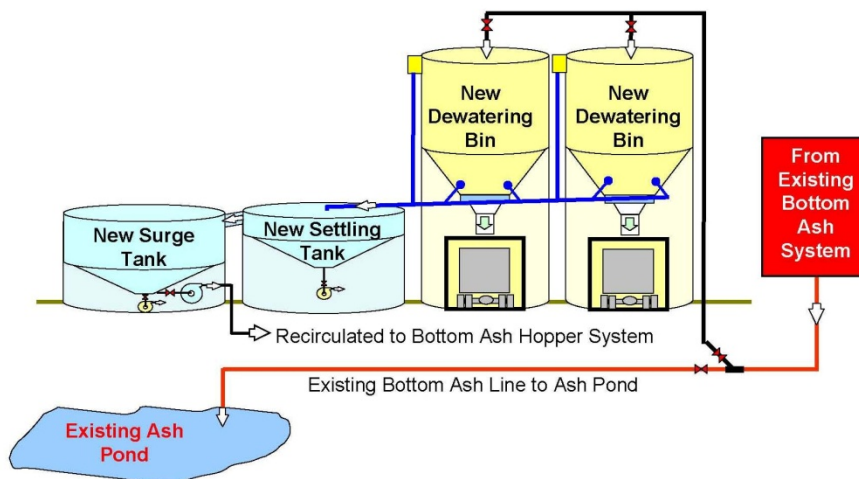


Figure 6: Conventional Bottom Ash Dewatering System as Retrofit

If the bottom ash currently is pumped to an ash pond, a complete closed loop water recirculation system can be erected in a field along the path of the existing ash lines and two diverter valves installed during a very short outage to divert the ash away from the pond and into the new closed loop system.

From a design standpoint, however, the biggest issue is replacing the low TDH capability of any existing jet pumps or even slurry pumps to handle the new vertical height and increased TDH of a closed loop system. This involves changing the water supply pumps and increasing the horsepower of their motors.

- **SUBMERGED SCRAPER CONVEYOR (Retrofit)**

Another viable option for Bottom Ash Handling is to utilize Submerged Scraper Conveyor (SSC) technology. For most Pulverized Coal (PC) fired boilers and some cyclone fired units it is possible to retrofit the bottom of the boiler with a Submerged Scraper Conveyor. However, for stations with multiple adjacent units, the physical arrangement of existing equipment may prohibit use of this technology, as the inclined dewatering section has no place to exit the boiler house.

The SSC is a heavy duty dual drag flight chain conveyor. The conveyor is submerged in a water trough below the furnace which quenches hot bottom ash as it falls from the combustion chamber. The bottom ash is then dewatered as it travels up the inclined section before it discharges. Double roll crushers can be used for final particle reduction at the discharge of the SSC. The discharge of the SSC can be fed into removable containers or onto a transfer conveyor, which transports the Bottom Ash to storage, for by-product reuse or landfill. The SSC can be driven via single or twin hydraulic or electro-mechanical drives to suit the application requirements. Optional discharge Slide Gates can be provided depending on the application requirements, and removable or static conveyors can be engineered to suit boiler geometry or operational requirements.



Figure 7: SSC Factory Assembled for Testing



Figure 8: SSC Discharging to Dewatering Bins

The final Bottom Ash moisture content is generally between 15 to 20 percent. If new regulations require further dewatering, the SSC can be discharged to a dual dewatering bin arrangement to further reduce the BA moisture content.

To achieve “zero discharge” (water) for an SSC system, a “closed loop” water system can be installed. In order to minimize corrosion, water treatment for pH control and heat exchangers may need to be included as part of the total system. This adds additional capital cost and operating cost.

- **REMOTE DEWATERING CONVEYOR SYSTEM**

ASHCON™ Remote Submerged Scraper Conveyors:

Clyde Bergemann Delta Ducon, CBDD, now offers a unique way to allow plants to retain all of their existing traditional wet bottom ash hoppers and slurry systems and still eliminate their ash ponds. By intercepting the pipelines leading to the ash ponds, the slurry flow is diverted to an ASHCON™ Remote Submerged Scraper Conveyor that has all of the bottom ash dewatering characteristics of a regular Submerged Scraper Conveyor plus the water flow control aspects of a dewatering bin without requiring the height of traditional dewatering bins.

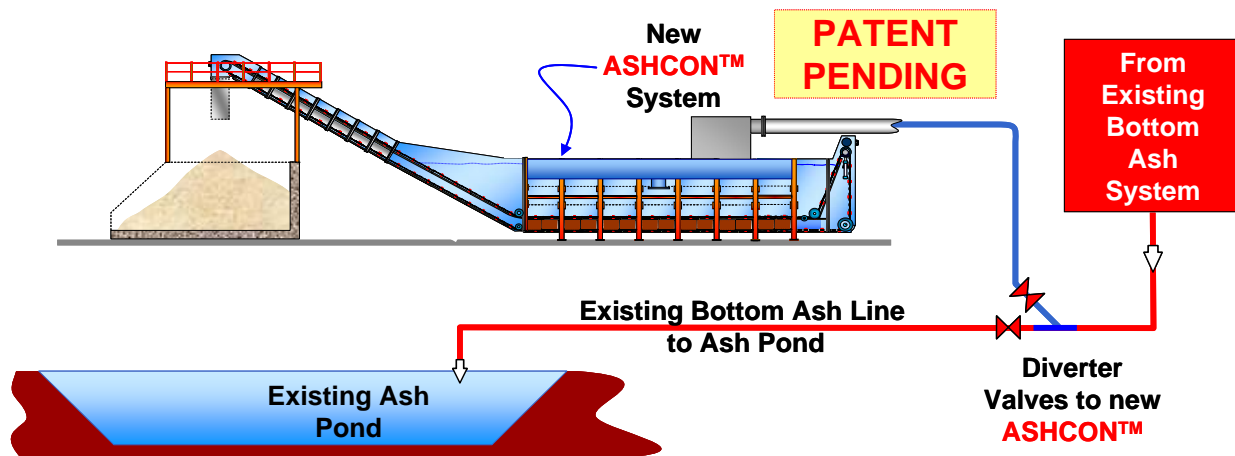


Figure 9: ASHCON™ Remote Submerged Scraper Conveyor as Retrofit

By staying close to the ground, there is little, if any, increase in Total Dynamic Head, TDH, requirements on the existing jet pumps and water supply pumps associated with the existing pond disposal system. Rather than retrofitting jet pumps and water supply pumps to lift the slurry high in the air to reach new dewatering bins, the ASHCON™ Remote Submerged Scraper Conveyor easily accepts what exists and continuously dewateres the ash to the commercially required level of dryness. The resultant bottom ash product can immediately be loaded on to trucks for off site disposal or stored in temporary piles on the ground. The overflow water is handled by traditional or more state-of-the art water clarifiers.

The ASHCON™ RSSC Advantage

The continued use of the entire ash hopper system with seal troughs, gates, grinders, jet pumps and water supply pumps means many of the advantages of a true SSC retrofit cannot be realized but adding a Remote SSC as opposed to traditional water recirculation tanks with dewatering bins, settling and surge tanks, allows the plant to eliminate the pond and save costs. These benefits include;

- The ability to retrofit to multiple existing Units and remove the ash pond disposal without interfering with the boiler islands. Multiple Units can use one **ASHCON™**.
- Lower power consumption than with a traditional water recirculation system with tall dewatering bins starting with savings with the initial water supply pumps.
- Simplified process complexity: only one continuous conveyor is used instead of two batch-type dewatering bins to reach the same level of dryness.
- Lower operational and maintenance costs than traditional water recirculation systems.

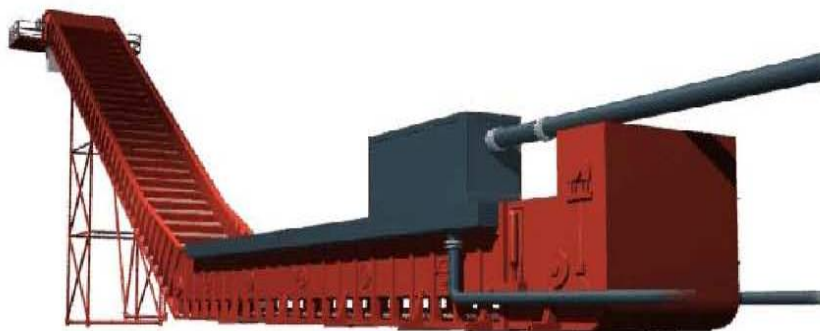


Figure 10: ASHCON™ Remote Submerged Scraper Conveyor

The ASHCON™ compared to an SSC

Both a traditional SSC and an **ASHCON™** Remote SSC is used for the continuous removal of bottom ash from conventional Pulverized Coal fired boilers and are particularly well suited when high ash generation rates are expected. Both conveyors are capable of quenching, dewatering and transporting high rates of ash and offer greater energy efficiency than hydraulic systems of comparable capacity. Factory assembly and a trial prior to shipment ensures an accelerated installation and start-up program, avoiding timely delays.

The differences start with the location of the conveyor relative to the boiler. An SSC located under a large Pulverized Coal fired boiler has to be designed for the potential of large slag falls associated with some coals and certain events such as boiler cleaning with soot blowers. This leads to additional structural steel beyond what is needed for the conveyor function itself. The ASHCON™ Remote SSC, by contrast, receives bottom ash that has already passed through a grinder and there is very little vertical drop down into the conveyor water trough. This leads to much longer conveyor life and reliability.

A typical SSC only requires 35-50 GPM continuous water input to maintain water level and temperature in the water trough. Often this water supply service is intermittent and assisted by cooling water from the associated mill rejects/pyrites system. An ASHCON™ Remote SSC, by contrast, needs to receive and handle all of the dilute water slurry in the existing pipeline system. This flow can be several thousand gallons per minute, GPM. But this flow is the same flow that has been addressed and handled by dewatering bins for many years. By placing the same amount, or more, of overflow weir length used by circular dewatering bins all along both sides of the ASHCON™ Remote SSC, the incoming water is easily drained off while the bottom ash continues up the conveyor incline.

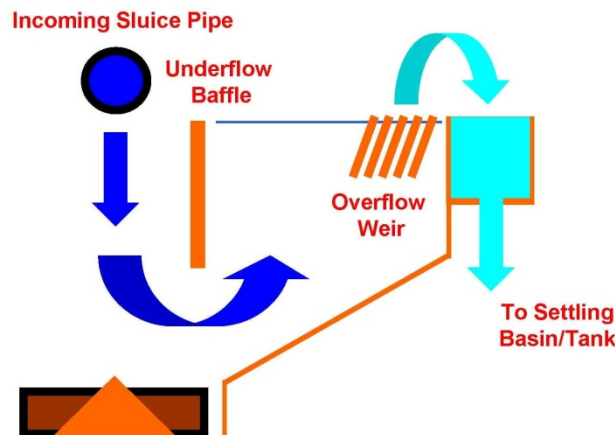


Figure 11: ASHCON™ RSSC Design Concept

When contemplating the removal of an ash pond serving several boilers, the cost of individual SSC's and boiler outages, including demolition of existing traditional equipment can be financially prohibitive especially for older Units. A single ASHCON™ Remote SSC merely has to be erected on open land and can serve many Units, usually receiving ash from one Unit at a time or as they are already grouped together in common pipelines.



Figure 12: ASHCON™ Remote Submerged Scraper Conveyor Retrofit

- **DRYCON™ SYSTEM (retrofit):**

DRY vs. WET

Traditionally bottom ash has been handled in a wet condition utilizing established technologies such as water impounded hoppers or submerged scraper conveyors. The use of water as opposed to air as a cooling agent incurs additional costs. Factors such as water treatment, corrosion damage, higher disposal costs and environmental problems as well as the higher cost of operation and maintenance must all be considered. Using a dry system means that no water is required in the process, therefore no water treatment is necessary. Reduced emissions and returning thermal energy to the boiler results in lower coal usage, which means fewer emissions to produce the same electric power. The table below shows the main factors which compare between the two methods of conveying:

WET ASH HANDLING	DRY ASH HANDLING
<ul style="list-style-type: none">• Cooling water requirements	<ul style="list-style-type: none">• No water requirement
<ul style="list-style-type: none">• Water treatment & environmental issues	<ul style="list-style-type: none">• No water treatment
<ul style="list-style-type: none">• Significant energy loss	<ul style="list-style-type: none">• Reduced thermal energy losses
<ul style="list-style-type: none">• Corrosion damage	<ul style="list-style-type: none">• Reduction of unburned carbon (LOI) and contribution to energy recovery
<ul style="list-style-type: none">• Steam is produced escaping into the boiler house area	<ul style="list-style-type: none">• Improvement in boiler efficiency
<ul style="list-style-type: none">• Higher disposal costs	<ul style="list-style-type: none">• Easier compliance with the environmental protection regulations
<ul style="list-style-type: none">• Maintenance intensive	<ul style="list-style-type: none">• Marketable ash quality → better ash sales
<ul style="list-style-type: none">• Significant energy consumption	

The **DRYCON™** system is installed below the boiler fully sealed to the combustion chamber. The negative pressure inside the boiler sucks air, in a controlled manner, (predominately at the top end of the **DRYCON™**) into the bottom ash conveyor system. The air moves counter flow direction along the surface of the ash which rests on the conveyor pans. This activates a reburning process of the glowing ash, which reduces the unburned carbon level and frees up additional thermal energy. The air is heated up before it enters the combustion chamber and adds additional thermal energy to the steam generating process inside the boiler. Approximately 1% of the total combustion air is required for the dry cooling system and can be considered as a constant value in the boiler design. This ensures that the combustion process and the exhaust gas composition are not affected.

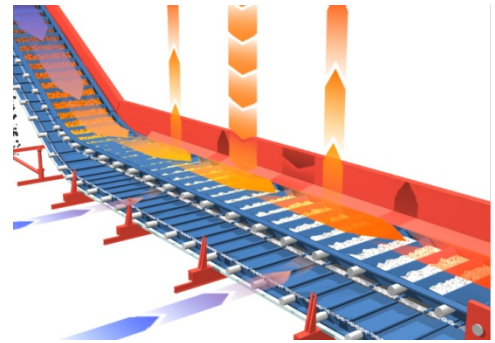


Figure 13: DRYCON Cooling Air Flow

THE ARRANGEMENT

Underneath the combustion chamber a transition chute or hopper is installed and supported from the floor by means of a steel structure. The transition chute or hopper is lined with special refractory and insulation at the inside to withstand the radiation from the combustion chamber of the boiler. As a standard a heat resistant fabric or HT metal compensator (expansion joint) is installed between the boiler/hopper outlet and the **DRYCON™** intake, to compensate the movement between cold and hot condition of the boiler. The compensator is fabricated from elastic metal, resistant to high temperatures. To avoid damage due to high temperatures by the radiant heat from the combustion chamber, a special protective skirt with lining is provided at the inner side of the compensator. The compensator will be delivered and mounted in one piece only, to assure tightness and the required flexibility.



Figure 14: DRYCON Installed Under the Boiler Discharge

KEY DESIGN FEATURES

DRYCON™ utilizes many key features which contribute to the technology's success in the market. The conveying design is similar to proven SSC systems, employing many of the SSC components:

Chain And Sprocket Wheel – the sprockets are manufactured from wear resistant materials and have exchangeable pockets for easy replacement.

Tension And Drive Stations –The tension roller is mounted with lubricated long life heavy duty roller bearings. Tension is applied via manually or automatically operated hydraulic cylinders.

Supporting Idler – mounted on close centers and lubricated, manually or automatically, with hear resistant grease, the rollers can be replaced from the outside whilst the boiler is still on-line.

Fines Recirculation – the system is self cleaning with the integration of a fines re-circulation plates.

Impact Beams – impact beams have been designed into the conveyor casing to withstand any loads imposed from large slag falls ensuring that the drive elements are not damaged

Jaw Crushers – large slag material can be broken down by jaw crushers in order to ensure they are an appropriate size to be cooled and conveyed.

Safe Monitoring – should a blockage occur, the drive motor stops immediately then enters a removal procedure before giving an alarm to the control room.



Figure 15: DRYCON Assembled for Factory Testing

• **BOTTOM ASH CONVERSION TECHNOLOGY SELECTION**

To determine which of the Bottom Ash conversion technologies presented herein may be a consideration for your power plant, a detailed investigation of your facility will be necessary. The following summarizes the key impacts of the technologies.

BA CONVERSION SELECTION COMPARISON	CONVENTIONAL TANK FARM DEWATERING	REMOTE DEWATERING CONVEYOR SYSTEM - ASHCON™	SUBMERGED SCRAPER CONVEYOR (SSC)	DRYCON™ SYSTEM
Site Specific Limitations:				
Physical Layout	No Major Change Required within the boiler house	No Major Change Required within the boiler house	Removal of existing BA Hopper and conveying system with retrofit under the boiler.	Removal of existing BA Hopper and conveying system with retrofit under the boiler.
Boiler design type				
PC	Applicable for most units	Applicable for most units	Applicable for most units	Applicable for most units
CYCLONE	Applicable for most units	Applicable for most units	Not Applicable (generally due to space limitations)	Not Applicable (Boiler is Wet Bottom)
Environmental Considerations:				
Surface Impoundment Elimination	Yes	Yes	Yes	Yes
"Zero Discharge" (Water)	Closed Loop System - pH Conditioning required	Closed Loop System - pH Conditioning required	Closed Loop System - pH Conditioning and Heat Exchangers may be required	Not required - No water is used in the System
Maintenance Budget Considerations:				
O&M Cost Impact	~25 to 30 % Increase with the addition of the Tank Farm Dewatering	~5 to 10 % Increase with the addition of the ASHCON	~30-35% Decrease with SSC	~40-50% Decrease with DRYCON
Energy Efficiency Considerations:				
Energy Consumption	~80 to 90 % Increase with the addition of the Tank Farm Dewatering	~15 to 20 % Increase with the addition of the ASHCON	~45-55% Decrease with SSC	~60-70% Decrease with DRYCON
Boiler Efficiency	No Change	No Change	No Change	0.02% TO 0.07% Boiler Efficiency Increase

Figure 16: Bottom Ash Technologies Comparison

• **ECONOMIC COMPARISON:**

Following is an estimated financial comparison of the technologies over a ten year period of operation. A typical 500 MW Unit, with a current Surface Impoundment operation was considered for this analysis.

Items included in this analysis are:

- Ten Year Capital Cost Amortization (“Turnkey Project”)
- Operation and Maintenance Costs
- Electric Power Costs
- Boiler Efficiency Improvement (Fuel Savings)
- Costs are based upon single unit conversion

(For multiple unit conversions, ASHCON™ may exhibit some Capital cost benefits if multiple units can be discharged to single ASHCON™ system.)

TYPICAL 500 MW BOTTOM ASH CONVERSION COMPARISON

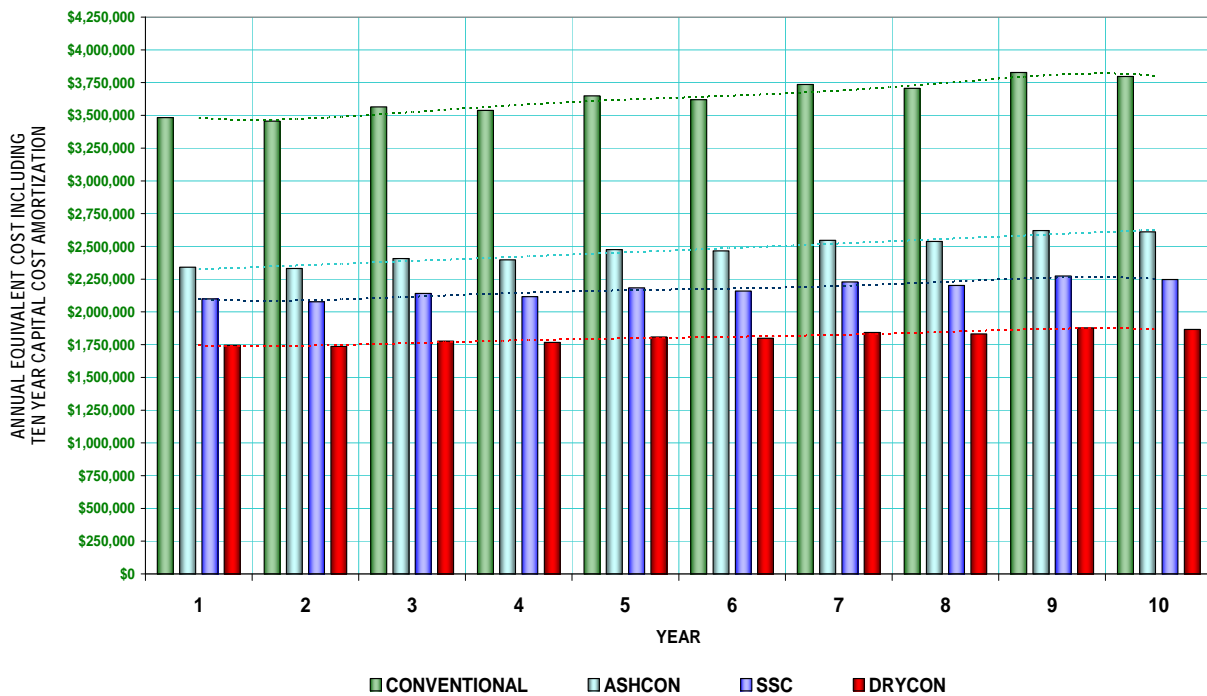


Figure 17: Bottom Ash Technologies Economic Comparison

CONCLUSION

This paper has presented four viable alternatives to the disposal of bottom ash in ash ponds. No one technology will apply to all plant sites and each of the four will be chosen by some plants facing the daunting task of closing their ash pond.

Two of the choices offered involve replacing the existing water impounded ash hoppers under the existing boilers. While both of these continuous removal options would be the primary choices under new boilers, they may not fit or apply to all retrofit situations. Hence the other two choices offered provide methods for diverting ash slurry away from ash pond disposal with little or no impact on the operating plant's boiler island.

REFERENCES

1. Fleming, C.H. and Mooney, G.D., "Bottom Ash Conversion Options and Economics" Power-Gen International Conference, Orlando, FL, December 14-16, 2010
2. Fleming, C.H. and Mooney, G.D., "Bottom Ash Conversion Options and Economics" Electric Power Conference, Chicago, IL, May 10-12, 2011