

Pioneer Plus™ - The Next Generation of Mass Burn Combustors

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ABSTRACT

Two of Energy Answers Corporation's (EnergyAnswers) waste-to-energy (WTE) facilities utilize mass burn stepped hearth refractory combustors. Three 120 ton per day (TPD) units are located at the Pittsfield (MA) Resource Recovery Facility and three 136 TPD units are at the Pioneer Valley Resource Recovery Facility in Agawam, MA. EnergyAnswers has over 20 years operating experience with these mass burn units which are known for their rugged construction and dependable operation. Over the past several years, EnergyAnswers operating personnel have developed and installed numerous improvements which have reduced residual carbon in the ash, lowered operating and maintenance (O&M) costs, and increased steam generation and throughput. The following highlights the numerous improvements that have resulted in a new generation of mass burn combustor called Pioneer Plus™:

- Improved tracking and alignment of the ash transfer ram carriages for reduced air infiltration and jamming,
- Utilization of poured and sprayed refractories for lower O&M costs,
- Improved control of under-fire air to improve burn out and steam rate while maintaining throughput,
- Better sealing to reduce air in-leakage and ash accumulation.

The above improvements have been implemented on several of the combustors at the EnergyAnswers facilities. Additional improvements have been identified and will be incorporated into the design of new Pioneer Plus™ plants in the coming years.

Introduction

EnergyAnswers owns and operates the Pittsfield Resource Recovery Facility (Pittsfield RRF) in Pittsfield, MA and the Pioneer Valley Facility (Pioneer Valley RRF) in Agawam MA. Both of these facilities utilize the Enercon mass burn combustion technology with each facility having a total of three combustors each. The combustors are refractory lined and contain fixed masonry hearths, resembling steps, over which movable ash transfer rams (ATRs) operate to provide forward motion to the burning waste piles. As the waste burns, it is pushed over a successive series of lower hearths, ultimately ending up in an ash quench trough. The combustors in Pittsfield utilize four hearths each while the Pioneer Valley RRF combustors have five hearths. The Pittsfield facility, which has been on line since 1981, is permitted to combust 84,000 tons of municipal solid waste (MSW) per year. The Pioneer Valley RRF has been operating since 1988 and is permitted to combust 131,400 tons per year. Each combustor train is capable of processing up to 120 TPD (Pittsfield) or 136 TPD (Agawam) of MSW. In future installations, trains can be combined into groups as large as 4 for a maximum facility size of nearly 550 TPD.

The refractory combustors have been continuously improved by EnergyAnswers' operating team over the years in order to reduce operating and maintenance costs and maximize throughput while maintaining satisfactory residue quality and quantity. The combustors have proven to be both rugged and reliable. This paper will explore the improvements that have been developed and implemented at the EnergyAnswers facilities, as well as present additional improvements that will be incorporated into the next

generation of refractory mass burn combustors, now known as "Pioneer Plus™", that will be built in the near future. Many of the upgrades developed in the Pioneer Plus™ program are significant enough to have been awarded patent protection (US patent number 7,146,916 for Starved Air Inclined Hearth Combustor).

Combustion Process

At intervals of 8 – 10 minutes, MSW is fed by a bucket loader into the combustor feed hopper. After two complete cycles of the ATRs, the nearly one ton load of MSW is pushed into the primary chamber by the loader ram. The first hearth is used primarily to evaporate water from the waste. On the lower hearths the waste is combusted and on the last hearth the waste completes combustion.

Combustion air enters the combustors through nozzles above the waste feed hopper. Recirculating flue gas, which contains less oxygen and is critical for combustor temperature control, enters the combustor through nozzles in the ceiling as well as through pipes that are imbedded in the hearth refractory. These latter nozzles are positioned so that the under fire air penetrates into the burning waste pile not only providing oxygen but also adding agitation to the burning waste. By-products of combustion exit the combustor through a large duct in the roof of the combustor, located near the end opposite the in-feed hopper. Any unburned gases exiting the combustor are burned off in the secondary chamber which is downstream of the combustor.

Recirculating flue gas is also added to the secondary chamber to further regulate the gas temperature thereby inhibiting the generation of thermal oxides of nitrogen (NOx). The

secondary chamber of each combustor discharges into a tertiary chamber which combines the flows from multiple combustion trains. The hot gases then pass through heat recovery boilers and economizers. Upon exiting the boilers the gases are treated in the air quality control systems (AQCS) before discharge to the atmosphere. The AQCS trains at Pittsfield consist of activated carbon injection, electro-static precipitator (ESP), a quench venturi scrubber, and a packed tower scrubber. The AQCS at the Pioneer Valley RRF facility consists of activated carbon injection, dry lime reactor, and a bag house for each train.

Operating Experience

These refractory lined, stepped, combustors are known for being rugged and dependable by nature of their sheer mass and limited number of moving parts when compared to systems utilizing movable metal grates. In addition, the precise control of combustor temperature by utilizing recirculated flue gas, and in some cases, the introduction of liquid sludge via EnergyAnswers' patented liquid Sludge Injection System (SRS), ensures low NO_x levels without having to incorporate urea or ammonia injection systems. [1,2]

However, as with any combustion process, there is always room for improvement. While the combustor, ATRs and under fire air system have proven to be reliable, there were limitations in the original design in regards to tramp air in-leakage, ATR alignment and tracking, masonry maintenance, under fire air flow control, and under fire air piping. Over the years, these initial challenges have been addressed, with improved performance and operability as a result. Collectively, these changes have transformed the original design into the Pioneer Plus™ combustor of today.

For this review, the improvements will be combined into groups as follows: General Arrangement, Refractory, Ash Transfer Ram, and Under Fire Air.

General Arrangement Improvements

In profile, the refractory lined, stepped hearth combustor resembles a large rectangular box with flat sides, a level roof and a bottom with a series of steps leading downward from the in-feed waste hopper to the ash trough at the opposite end. For a typical five hearth unit, such as at the Pioneer Valley RRF, the box measures approximately 62 feet long, 12 feet wide and 23 feet tall. The height is about 13 feet at the in-feed end, and due to the descending steps, the height increases to 23 feet above the ash discharge. With an increasing number of hearths, this vertical distance will increase to a maximum of 25 feet for a six hearth unit. Likewise, the length will also increase for a sixth hearth unit by approximately 10 feet. It has been determined that six hearths is the practical limit for this technology, and this configuration will be the standard on future units. The operational advantages for having six hearths versus five include: greater grate surface area for drying wet MSW, longer retention time, larger furnace volume for improved combustion of gases (critical when adding waste sludge injection), reduced carbon-in-ash, as well as lower bottom ash quantities.

To minimize building height, most of the mass of the refractory stepped hearth unit is located below grade, with minimal clearance between the bottom of the last ATR and the basement floor. While this design aids in reducing building costs, the short distance between the floor and the bottom of the combustor makes servicing the lowest ATR carriage and hydraulic cylinder difficult. Therefore, a four foot minimum clearance

should be maintained between the floor and the bottom of the steel supporting the last hearth.

Combustion air is pre-heated in a two stage process. The first stage involves passing the air through a 4" annular plenum surrounding the combustor. The air is then ducted to a traditional steam-to-air heat exchanger prior to being blown into the combustor. The problem with this design lies with the annular chamber – some portions are vertical while others are horizontal. In the flat areas, it was common for air borne dust to accumulate to the point where it impeded air flow as well as created a corrosive environment leading to combustor skin deterioration. In most installations, the exterior layer of the annular chamber was removed after several frustrating years attempting to keep the space clean. However, removal of the outer layer, and the loss of the first stage of heat recovery, has an effect on overall unit thermal efficiency. In Pioneer Plus™, the horizontal portions of the annular space will be pitched in order to hinder the accumulation of dust. In addition, access points for cleaning with high powered equipment will also be provided.

Other locations where dust, in this case fly ash, accumulates are in two of the recirculating flue gas (RFG) supply points. One of these locations is in the secondary chamber where the RFG is added to the flue gas leaving the combustor. Fly ash, which is entrained in the RFG, becomes deposited in the low velocity sections of the secondary chamber. In Pioneer Plus™, the RFG will be introduced to the secondary chamber in one of the low velocity sections in order to add energy to the fly ash thereby propelling it to the boiler where it will drop out in the hoppers. A similar problem had existed in the ducting under the combustor that delivers RFG to the under fire air system at each

hearth. In this location, fly ash accumulated in plenums that were nearly inaccessible and did not have clean out ports. These systems have now been modified to include improved access for cleaning with strategically located access ports. The plenums themselves are also now constructed with heavier gauge carbon steel to increase their service life as well.

In another general materials upgrade, the over fire air inlet nozzles, which had been carbon steel have been replaced with stainless steel.

Refractory Improvements

When they were constructed, the combustors at the Pittsfield and Pioneer Valley Facilities featured shop fabricated masonry which was suspended from "T" hangers on the ceiling and hand laid block walls. At the time of their installation (in 1981 and 1988, respectively), this was the state of the art. However, since the 1980's there has been a tremendous leap forward in refractory technology including the introduction of materials that can be sprayed and poured. To reduce O&M costs at these plants, the refractory has been replaced with the newest materials. The side walls of the combustors now utilize poured refractory for the lowest four feet of the wall. Above that height, up to and including the ceiling, a sprayed refractory is used. It is estimated that the use of modern refractory materials has saved the facility over \$100,000 in repair costs from 2002 to 2006.

Poured refractory is also used for the horizontal portions of the hearths. However, to ensure that the RFG tubes that are embedded in the refractory are never exposed to severe temperatures, they are wrapped in 1" ceramic blanket material as well. This insulation upgrade eliminates a past problem when the embedded steel tubes would often

bend from heat exposure over time. Once bent, the tubes were unable to be cleaned by the ATR push rod assembly, thereby reducing RFG flow. This combination of materials performs as well as, or better than, the original material, and are much easier, and less expensive to maintain. These will be the refractories of choice for new Pioneer Plus™ combustors.

ATR Improvements

The ash transfer rams serve several functions. The primary purpose is to extend from the hearth refractory step and push the bottom of the waste pile, moving it towards the opposite end of the hearth. The ATRs do not extend so far as to push all the waste off of the succeeding step in a single stroke, but rather provide about 60 inches of travel to the pile. Therefore, multiple strokes of the ATR are required to push a given amount of burning waste onto the next step. This action ensures that the waste pile has sufficient residence time on the hearth before being ejected. Another equally important function of the ATR is to clean the RFG feed tubes that are imbedded in the hearth. This is accomplished by an arrangement of round bars that travel inside the RFG tubes, pushing any accumulated ash or slag out of the tube. The round bars are assembled onto a second level of the ATR carriage and travel in unison with the ATR as it is stroked by the attached hydraulic cylinder.

As originally designed and built, the body of the ATR was constructed of steel sheet metal over a steel frame. Since the ATR was only exposed to the under side of the waste pile for a short period of time this construction was deemed sufficient. However, in actual use, the frame and sheet metal actually became disfigured over time resulting in excessive clearances between the ATR body, the hearth

opening and the combustor side walls. The clearances would permit tramp air to gain entry into the combustor. To remedy this unacceptable situation the ATRs were reconstructed by removing the forward four feet of the upper steel deck and replacing it with a 3” thick layer of refractory. Not only does this improve the operation of the ATR but it also allows for the tightening of the clearance between the ATR opening and the upper surface of the ATR, eliminating much of the tramp air access.

As previously mentioned, round bars travel through the RFG tubes to keep them clear of foreign material. As originally designed, these bars have a clearance fit to allow them to slide easily inside the tubes, without binding. This clearance can provide a path for the RFG to flow out of the system by escaping through the clearance around the bar. To eliminate this path, the clean out bar assemblies have been retro-fit with packing glands to seal the RFG system. Special carbon fiber packing is used that can withstand the high heat and harsh environment.

Other significant ATR improvements incorporated into the Pioneer Plus™ design include changing the carriage wheels from a flat surface to a “V” groove, with a matching track. This change permits the carriage to travel in a fixed, straight line that is repeatable stroke after stroke. The original design did not incorporate any tracking device which allowed excessive side to side movement. With the ATR tracking in a much narrower range, the clearance on the side of the ATR have been closed, with the addition of wear plates further reducing the introduction of tramp air. Other improvements include: PLC upgrades that permit adjustments to the ATR stroke sequence and timing, larger wheel axle diameters, strategically placed gussets in the

ATR frame and the addition of a wiper blade to reduce ash drag-back when the ATR is being retracted.

Under Fire Air Improvements

The flue gas recirculation system is supplied by a fan that draws 400⁰ F gas from the main duct downstream of the boiler economizer. The gas is directed through a cyclone separator to remove particulate matter prior to passing through the RFG fan. The RFG fan propels the gas to the secondary chamber, to the over fire air ports on the combustor roof and also to the under fire air fan which raises the gas pressure prior to delivery to the under fire air tubes in each hearth.

The original design of the under fire air system utilized hand valves in the distribution system to balance the RFG pressure among the hearths. Depending on the depth of the MSW piles on the hearths, different RFG flows and pressures were desired. This manual balancing proved to be a tedious and frustrating task – always walking the fine line between too little, and too much RFG. In addition, in only a couple of years, the hand valves deteriorated beyond use due to the harsh environment, and were replaced with orifice plates.

In order to optimize the under fire gas flow with combustion conditions, a number of improvements have recently been made to the combustors at both the Pittsfield and Pioneer Valley facilities. The improvement with the greatest impact on combustion performance, as well as ash quality, has been the installation of a variable speed drive (VSD) on the under fire air fan motor. The drive is programmed to maintain a constant current (amperage flow) to the fan motor. This is referred to as a constant current control mode. As such, when the bed depth of MSW and/or ash on the

hearth is heavy, motor current will not be reduced, as would otherwise happen without the VSD on the fan motor. Therefore, RFG flow and pressure is maintained to help assure sufficient penetration of the bed by the RFG. This action is critical to ensuring complete combustion of the waste and minimizing the amount of un-burned carbon in the ash. Likewise, when the bed depth of MSW and/or ash is light, motor current will not be increased, as would otherwise happen without the VSD, but will be maintained to help assure sufficient penetration of the bed without adding excess RFG. Too much RFG over agitates the waste bed resulting in a higher particulate load. The drive is also programmed to ramp down in speed when the waste feed hopper door opens in order to avoid momentary oxygen spikes. These spikes were a characteristic of the original design, with every opening of the feed hopper, there would be an in-rush of air, up setting the oxygen balance as well as the combustor pressure. These spikes have been dramatically reduced with the addition of the VSD. The drive also ramps down during ATR cycles in order to avoid over-agitating the waste piles which can often lead to a momentary high particulate load.

To further optimize the RFG flow to the hearths, small blowers with individual VSDs will be installed in the ducting to the hearth plenums in the near future. Much like the main under fire gas fan, these individual fans will be programmed to operate in constant current mode, providing a gas flow that is constant and better matched to the combustion conditions. The new system will also include an oxygen enrichment system to further tune the combustion conditions. To avoid high local temperatures, and creating slag, feedback control via temperature sensors or infrared cameras will be included.

A final improvement that will be incorporated into the next installation will be a small “polishing” bag house that will replace the cyclone separator used for cleaning the RFG. This device will remove considerably more particulate matter than the mechanical separator, thereby reducing wear on down stream components such as the RFG fan, duct work, hearth blowers and reduce the frequency of RFG plenum cleaning.

Pioneer Plus – the Future

Pioneer Plus™ is the result of over 25 years of continuous improvement by EnergyAnswers operations personnel to the original refractory combustors. Most of these improvements, such as the ATR and under fire air systems, have been completed on the combustors at the Pittsfield facility. Many of these same improvements have been incorporated at the Pioneer Valley Facility as well, the balance being installed in 2007. The upgrades have resulted in better loss-on-ignition (burn out), improved steam generation and reduced refractory and ATR maintenance costs, over the period from 2004 to 2006. These modifications have resulted in a technology, once considered antiquated, that when properly updated, can successfully compete with any small scale mass burn technology available today.

As the potential market for small mass burn combustors continues to show potential for growth, both in the U.S. as well as internationally, EnergyAnswers will be ready to respond with a dependable, proven, and financeable technology – the Pioneer Plus™ combustor.

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