TECHNICAL PUBLICATION

2,400 Tons Per Day Refuse Derived Fuel Facility with Advanced Boiler and Air Pollution Control Systems

by

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Presented at

The 18th Annual North American Waste-to-Energy Conference
Orlando, Florida

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ABSTRACT

A greenfield Refuse Derived Fuel (RDF) facility in Alliance Ohio will process 2,400 Tons Per Day (TPD) of Municipal Solid Waste (MSW) and Construction & Demolition Debris (C&D). The Ohio EPA has issued the final air permit for the facility. There will be two equipment trains to handle the material each consisting of Riley Power's Advanced Stoker boiler, Turbosorp dry scrubber, and Regenerative Selective Catalytic Reduction (RSCR) nitrogen oxides (NO_x) control system.

The key parts of the "chute to stack" equipment represent a significant advancement in technology when compared to past facilities, as demonstrated by the designation by the State of Ohio as an "Advanced Energy Project".

The Riley Advanced Stoker™ boiler has unique design features to ensure high efficiency, corrosion resistance, and fuel flexibility while at relatively low cost.

The use of the Turbosorp will result in lower emissions of lead, other volatile heavy metals, and mercury than for a typical spray dryer/baghouse (SDA) system. Acid gas removal is also superior to an SDA system while utilizing less lime reagent and power.

The RSCR follows the Turbosorp as a "low dust" SCR but with auxiliary energy consumption about 85% lower than a typical low dust, tail end SCR. The RSCR will reduce NO_x and Carbon Monoxide (CO) emissions to low values when compared to other facilities producing energy from waste.

This paper will describe the design basis for the system including fuels to be processed, steam flow and conditions, and emissions. A detailed description of the technologies will also be presented.

INTRODUCTION

In order to meet the growing demand for electrical power and to dispose of MSW and C&D in an environmentally friendly way, considering the constantly dwindling available landfill space, Mahoning Renewable Energy, LLC, (MRE) (owned by Caletta Renewable Energy) is developing a state of the art renewable energy facility in Mahoning County, Alliance, Ohio. There will be two separate equipment trains to process MSW into RDF and process the C&D. This material would otherwise be landfilled at the Central Landfill near Alliance, Ohio. The RDF will be combined with the processed C&D and then be sent to two boilers, which will produce a total of 66 MWgross which results in approximately 58 MW net of electric power.

THE PROJECT

The proposed facility will qualify as an Advanced Energy Resource as defined in the Ohio Alternative Energy Portfolio Standard. MRE offers numerous short-term and long-term benefits to Ohio. These benefits include, but are not limited to:

* Extending the useful life of the local landfill by processing approximately 2,400 tons of MSW and C&D per day that would otherwise be landfilled
* Improving on the rate of recycling by removing additional recyclable materials during the processing of MSW into RDF and during the processing of C&D
* Processing fuel from biomass waste to produce power thereby reducing Ohio's reliance on fossil fuels
* Providing increased fuel diversity for electric generation in Ohio, which will assist in the fulfillment of the requirements of the Ohio Alternative Energy Portfolio Standard
* Reducing greenhouse gas emissions associated with the disposition of this waste in the landfill and the resulting production of methane, a greenhouse gas 21 times more harmful to the environment than carbon dioxide

The RDF and C&D will be sent to two (2) Riley Power Inc. (a Babcock Power Company) Advanced Stoker boilers operating with high efficiency and incorporating the latest materials development technology to minimize corrosion. Each boiler will include a traveling grate stoker. The environmental equipment, provided by Babcock Power Environmental Inc., will feature a Turbosorp circulating dry scrubber and RSCR NO_x control system. This equipment will ensure that the emissions of certain key pollutants from the facility are low. The Ohio EPA has granted the final air permit for this facility, which is expected to open in 2013.

FUEL AND COMBUSTION SYSTEM

This facility will have the flexibility to process two types of waste; RDF and C&D. The boilers have been designed either for 50% of each fuel or 40% C&D and 60% of RDF. At 100% boiler Maximum Continuous Rating (MCR) conditions, 83,333 lbm/hr of RDF and C&D will be sent into each boiler. The higher heating values of the fuels will be 4,500 BTU/lbm, 6,788 BTU/lbm and 5,681 BTU/lbm for the RDF, C&D, and combined (50%) respectively.

A distributor fan will blow the combined fuel into the boiler. The fuel feed system will be controlled for optimal distribution across the grate depth and width. For example, the air pressure can be adjusted to ensure the fuel is evenly distributed across the grate. The air swept distributors conveying the RDF and C&D fuel into the furnace can also be adjusted vertically and horizontally.

The fuel will be burned on a catenary traveling grate stoker. The stoker system requires little maintenance and automatically discharges ash. This stoker has a tray system, located under the first grate level, that collects melted metals and other solids that fall through the grate. Air is directed below the grate in separate controllable air zones to ensure there is a balanced air distribution across the grate's width resulting in complete combustion across the grate. The stoker will also have special seal designs that will reduce air infiltration into the boiler. An ash handling system will be installed.

Normally the ambient air will be heated to approximately 450ºF when it passes through a tubular air heater. During startup and on cold operating days a steam coil will heat the ambient air before it enters the tubular air heater. A portion of the combustion air is used as Overfire Air (OFA). A booster fan increases the pressure of the OFA and directs it into the furnace above the grate. The furnace employs a multi-level OFA system designed to provide complete penetration and mixing of the OFA with the suspended fuel and products of combustion on the grate. The OFA system maximizes the turbulence above the grate to allow complete mixing of the air and fuel.

All of this equipment will ensure that the combustion is efficient. This combustion system will feature low excess air and low unburned carbon as well as low NO_x, and low CO emissions. A low grate heat release rate will improve combustion, reduce CO emissions, and extend the operating life of the grate. A stable heat input will result in stable final steam pressures and temperatures.

RILEY ADVANCED STOKER BOILERS

These two natural circulation boilers are fully integrated with the fuel feed and combustion system and incorporate state of the art design features. The furnace height has been designed for optimal furnace retention time to ensure that CO and char in the flue gas are completely burned out prior to leaving the furnace and entering the convective pass.

A nose arch has been located at the furnace outlet serving to distribute the flue gas over the entire height of the superheater and minimize areas of high velocity, which could lead to erosion and fouling.

Processing the MSW reduces the amount of metal and plastics in the fuel, but the resulting RDF fuel will still contain some chlorine and low melting point metals such as lead, zinc and tin. The molten chloride salts that form (Na, K, Zn, Pb, and Sn), are highly corrosive and will readily attack the waterwall tubes leading to unacceptably high metal wastage rates. High nickel alloys have been proven to be the most resistant to molten chloride attack with 625 Alloy being the most widely used. To minimize waterwall tube corrosion, all of the waterwall tubes have an alloy 625 weld overlay.

Experience has shown that the rate of corrosion by chloride gas (HCl) in convective superheaters is a strong function of gas temperature. To this end, the furnace has been sized to limit the maximum value of the furnace exit gas temperature. Designing the furnace for low exit gas temperatures will increase the service life of the superheaters.

Due to the high fouling nature of the fuel, the sootblower spacing (side to side) coverage for the superheater is increased compared to other lower fouling fuels. For the same reason, superheater, boiler bank, and economizer tube spacing has also been increased. Figure 1 highlights the boiler's features.

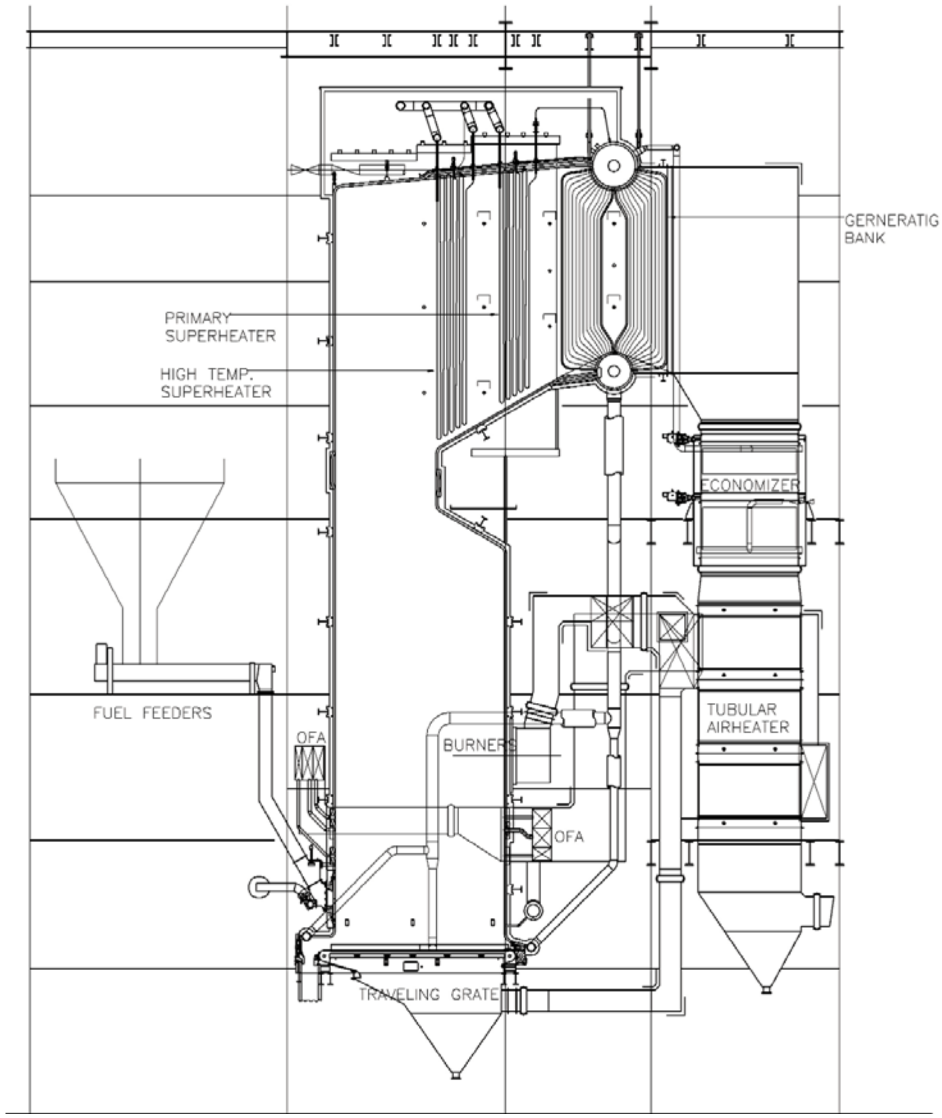

Figure 1: Riley Power Inc. Advanced Stoker Boiler

Figure 2 shown on the next page shows the same boilers, but with a module evaporator replacing the boiler bank modules. This design allows the evaporators to be shop assembled resulting in less field execution manhours.

A bare tube design is used for the economizer to reduce fouling. Rotary sootblowers will be located above the economizer tube bundles.

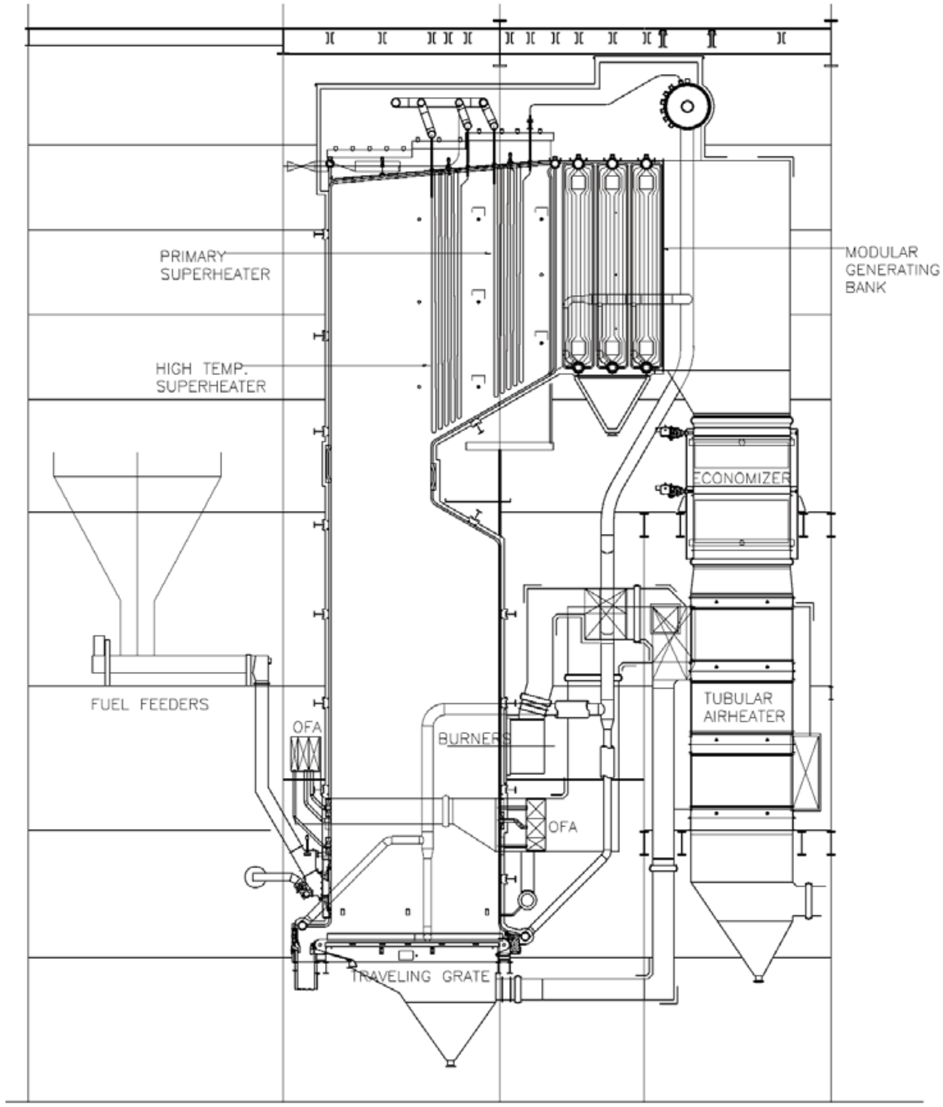

Figure 2: Riley Power Inc. Advanced Stoker Boiler with Modular Boiler Bank

The air heater is a cross-flow tubular design with flue gas flowing vertically down over the tubes and air flowing horizontally through the tubes. This allows sootblowing capability between the air heater sections.

Retractable steam sootblowers will be used for the superheater and boiler bank. There will be two (2) upstream of the superheater, two (2) between the superheater and boiler bank, and two (2) retractable sootblowers between the boiler bank tubes. Additional sootblowers can be added in the future between the superheater and boiler bank and between the boiler bank tubes.

Figure 3, on page 8, shows a side view of one boiler and the environmental equipment attached to it.

The performance of one boiler is shown in Table 1 on page 8 and 9. Note that of the 2,400 TPD entering this facility, approximately 2,000 TPD is sent to the boilers. The difference, approximately 400 TPD, is recycled or landfilled.

AIR QUALITY CONTROL SYSTEM

The Ohio EPA issued the final Air Pollution permit for the MRE facility on April 3, 2009. The permit was based on the use of independent Air Quality Control Systems (AQCS) for each boiler, consisting of:

* A Turbosorp Dry Circulating Fluid Bed Scrubber system to remove acid gases from the boiler flue gas with lime injection
* A fabric filter (baghouse) to control particulate emissions
* A RSCR system to reduce emissions of NO_x
* An activated carbon injection system used to remove heavy metals, including mercury, as well as dioxins/furans

The AQCS will control pollutant emissions to levels equal to or less than other facilities of its kind in the US. The permitted NO_x emissions are significantly more stringent than the 40 CFR Part 60, Subpart Eb. Table 2 below provides information of the key air permit emissions[1].

Table 2

POLLUTANT QUANTITY

Pollutant	Permit Limits
SO_2	24 ppmvd
H_2SO_4	2 ppmvd
HCl	25 ppmvd
HF	0.5 ppmvd
PM	20 mg/dscm
Mercury	30 ug/dscm
D/F	13 ng/dscm
Lead	140 ug/dscm
Cd	10 ug/dscm
NO_x	75 ppmvd
@ 7% O_2 basis	

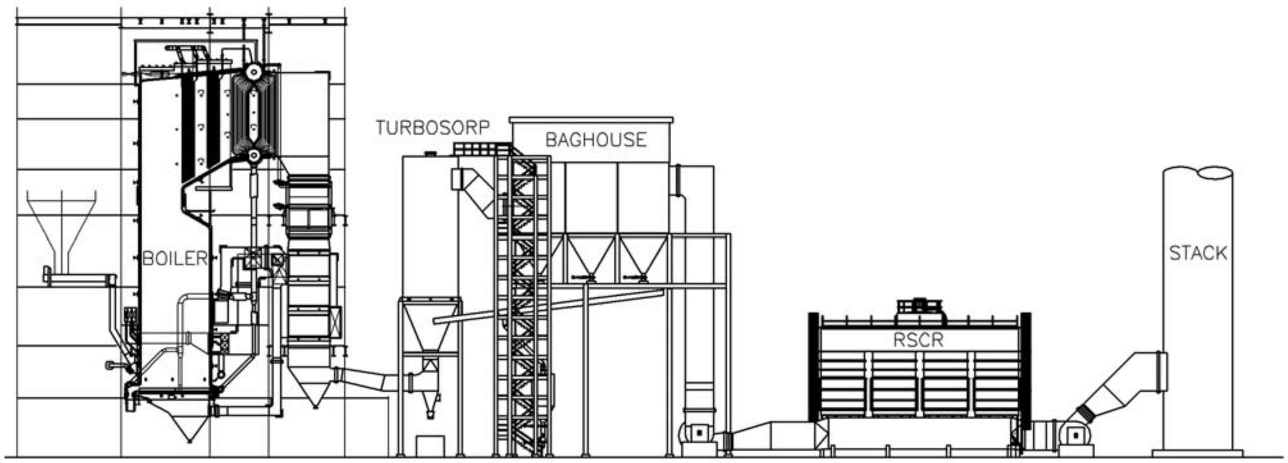

Figure 3: Boiler and Air Quality Control Equipment

Table 1

BOILER DESIGN PERFORMANCE SUMMARY

Parameter	Units	50% C&D / 50% RDF 100% MCR	50% C&D / 50% RDF 75% MCR	40% C&D / 60% RDF 100% MCR	40% C&D / 60% RDF 75% MCR
1.0 General					
1.1 Fuel Flow	TPD	1,000	765	1,000	765
1.2 Fuel HHV (As Fired)	Btu/lb	5,681	5,681	5,377	5,377
2.0 Steam Flow					
2.1 Main Steam Flow	lb/hr	396,188	296,859	371,900	279,000
3.0 Water & Steam Temperatures					
3.1 Feedwater Temperature	°F	450	430	450	430
3.2 Superheater Outlet Temperature	°F	750	750	750	750
4.0 Steam Pressure					
4.1 Steam Drum Pressure	psig	975	955	975	955
4.2 Main Steam Pressure	psig	830	830	830	830
5.0 Fuel, Air & Gas Flow Rates					
5.1 Fuel Flow	lb/hr	83,333	63,666	83,333	63,738
5.2 Total Combustion Air Flow	lb/hr	442,167	337,814	419,534	320,880
5.3 Flue Gas Flow	lb/hr	516,275	394,432	491,518	375,935
5.4 Excess Air	%	30	30	30	30
6.0 Flue Gas Temperatures					
6.1 Air Heater Exit Gas Temperature	°F	320	305	320	305
7.0 Air Temperatures					
7.1 Ambient Air Temperature	°F	80	80	80	80
7.2 Air Heater Outlet Air Temperature	°F	450	430	450	430

Table 1 Continued on page 9

Table 1 Continued from page 8

Parameter	Units	50% C&D / 50% RDF 100% MCR	50% C&D / 50% RDF 75% MCR	40% C&D / 60% RDF 100% MCR	40% C&D / 60% RDF 75% MCR
8.0 Efficiency (per ASME PTC 4.1)					
8.1 Efficiency w/ Margin	%	77.49	77.81	76.83	77.16
9.0 Fuel Analysis & Fuel Flow					
9.1 RDF					
HHV	Btu/lb	4,500	4,500	4,500	4,500
Carbon	% by wt	24.91	24.91	24.91	24.91
Hydrogen	% by wt	3.52	3.52	3.52	3.52
Oxygen	% by wt	18.05	18.05	18.05	18.05
Nitrogen	% by wt	0.45	0.45	0.45	0.45
Chlorine	% by wt	1.00	1.00	1.00	1.00
Sulfur	% by wt	0.27	0.27	0.27	0.27
Water	% by wt	31.40	31.40	31.40	31.40
Ash	% by wt	20.40	20.40	20.40	20.40
Total	% by wt	100.0	100.0	100.0	100.0
Fuel Flow	lbs/hr	40,333	30,814	51,387	39,291
9.2 C&D					
HHV	Btu/lb	6,788	6,788	6,788	6,788
Carbon	% by wt	40.00	40.00	40.00	40.00
Hydrogen	% by wt	5.30	5.30	5.30	5.30
Oxygen	% by wt	35.49	35.49	35.49	35.49
Nitrogen	% by wt	0.16	0.16	0.16	0.16
Chlorine	% by wt	0.16	0.16	0.16	0.16
Sulfur	% by wt	0.09	0.09	0.09	0.09
Water	% by wt	18.00	18.00	18.00	18.00
Ash	% by wt	0.80	0.80	0.80	0.80
Total	% by wt	100.0	100.0	100.0	100.0
Fuel Flow	lbs/hr	43,000	32,852	31,953	24,448

Turbosorp and Fabric Filtration AQCS

The function of the Turbosorp system is to reduce the acid gas content of the flue gas, adsorb heavy metals, and collect the solids in the flue gas resulting from these reactions. In combination, this system can achieve sulfur dioxide (SO_2) removal efficiencies of 95% or greater, plus removal of sulfur trioxide (SO_3), sulfuric acid (H_2SO_4), hydrochloric acid (HCl), hydrofluoric acid (HF), mercury, particulates and dioxin/furans.

The principle of the Turbosorp dry scrubbing technology is to bring together high levels of solid circulation, finely atomized water, hydrated lime and flue gas within a circulating bed reactor. Lime and finely atomized water are injected independently into the Turboreactor to lower flue gas temperatures and enhance absorption capacity. The fluid bed material is comprised of solids, including calcium hydroxide, recirculated fly ash from the combustion process, and solid reaction products from the fabric filter. Upon leaving the Turboreactor, the solid particles are separated from the flue gas in a baghouse and recycled back to the reactor.

The Turbosorp has the ability to handle RDF fuels with high sulfur and chlorine contents at high efficiencies and is designed for continuous operation to treat 100% of the flue gas generated during the combustion process. Figure 4 below is an illustration of the Turbosorp and the fabric filtration AQCS.

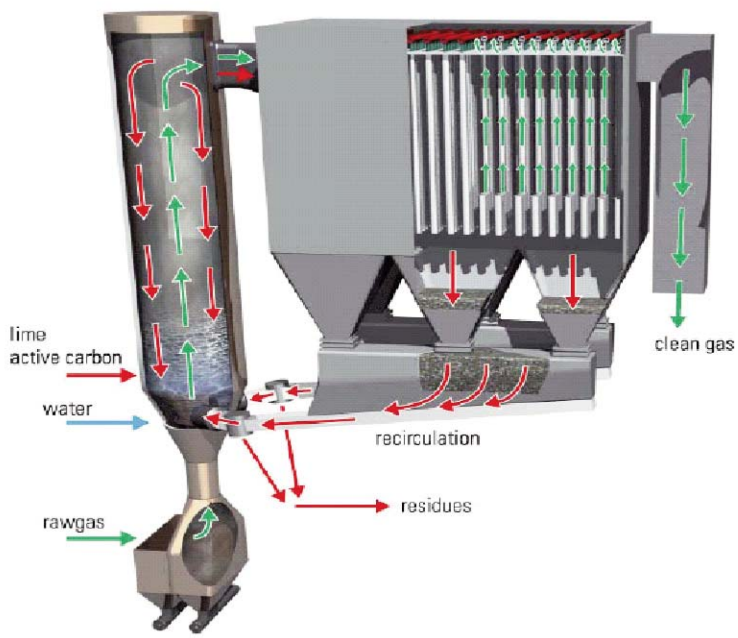

Figure 4: Turbosorp and Fabric Filtration AQCS

Untreated flue gas is directly ducted to enter the lower portion of the Turbosorp scrubber vessel. The gas is accelerated to a high velocity by passage through an internal venturi nozzle. Water and lime are injected into the gas stream downstream of the venturi, along with recirculated solids captured by the baghouse. This mixture of materials forms a fluidized bed in the Turboreactor. Turbulent flow within the reactor permits intimate contact between the gas and reagents promoting the chemical reaction between the gas and the active portions of the reagent.

The gas-solid mixture is cooled to about 280°F by the addition of water. Both gas and solids exit the Turboreactor and enter the baghouse. The baghouse separates the gas from the solids. The cleaned gas then exits the baghouse. The collected solids contain unreacted reagent, inert dust and products of chemical reactions from both the steam generator and the Turbosorp fluid bed. These solids are recirculated back to the Turboreactor to use the available reagent and promote the formation of the fluid bed. A portion of the recirculated solids is drawn out of the system to maintain mass equilibrium. The fly ash material drawn off is conveyed to an ash silo.

In order to control emissions of heavy metals and dioxins/furans, activated carbon will be injected, if needed, into the flue gas stream immediately upstream of the Turbosorp reactor. The reaction of lime with acid gas in the Turboreactor and contact of heavy elements with activated carbon provides the desired reaction to control emissions of these pollutants. Provisions to inject activated carbon into the gas stream will be provided, but not implemented in the initial operation. The efficiency of the Turbosorp process is expected to achieve the required emissions without the addition of activated carbon.

The benefits of the Turbosorp technology over the spray dryer absorber (SDA)/ baghouse system typically used in a waste to energy facility include:

- Lower lime stoichiometry for the Turbosorp when compared at a fixed set of conditions of removal efficiency and approach temperature

- The Turbosorp is able to achieve higher removal efficiencies than an SDA for acid gases

- Reduced parasitic power consumption for the Turbosorp since slurry atomization is not utilized

- Simpler system with less maintenance because it's a dry system without the need for slurry handling

RSCR System

The RSCR system[2], is an advanced, high-efficiency NO_x reduction system. The RSCR system is targeted at tail-end/low temperature applications were the flue gas is relatively cool and clean of particulates and acid gases.

For this project, the RSCR will be installed after the Turbosorp / baghouse and between the outlet of the ID fan and the booster fan, upstream of the chimney. The purpose of this equipment is to convert NO_x in the cleaned flue gas into nitrogen and water. This gas phase reaction occurs on the clean side, or outlet, of the baghouse. Since the flue gas temperature at this point is too low for SCR catalyst to function, the RSCR temporarily elevates the flue gas temperature to the proper level while using minimal auxiliary fuel. Operating in this manner allows NO_x reduction efficiencies of greater than 70% to be achieved in a RSCR system.

The RSCR device is a multi-chamber reaction vessel, with each chamber containing catalyst and ceramic beds. Each chamber is arranged for vertical flow of gas in both the upward and downward direction. Dampers built into the gas ductwork control the directional flow of gas. Figure 5 below is an illustration of the RSCR process.

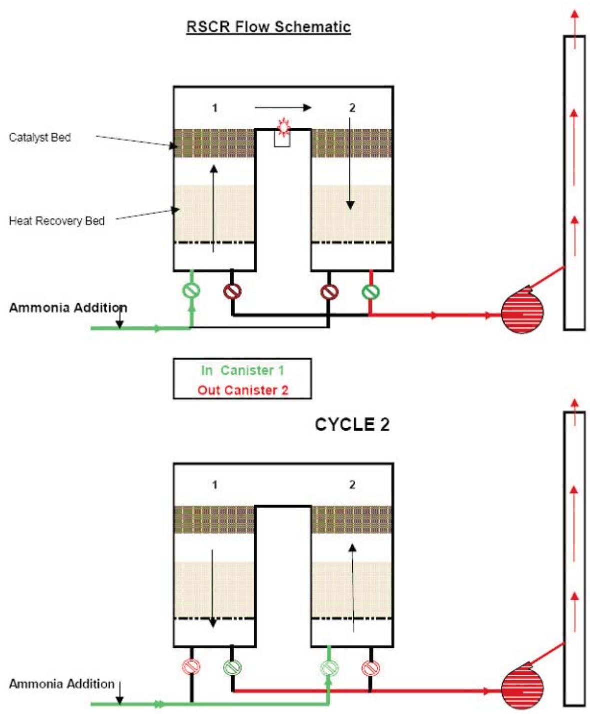

Figure 5: RSCR Process

The catalyst is mounted directly above the ceramic beds and promotes the reduction of NO_x to nitrogen and water while the ceramic bed is used to recover heat from the processed flue gas. The active reagent used in this process is 19% aqueous ammonia.

Flue gas enters an inlet header that connects to the four reaction canisters. An outlet duct on each canister is connected to the outlet header that leads to the stack. At any time, one inlet duct and one outlet duct on each pair of canisters is open, and one of each is closed. Flue gas enters one canister and rises through a heat recovery medium, picking up heat to attain the proper temperature for the NO_x removal reaction to occur (about 600°F). It then enters the catalyst, causing NO_x to be converted to nitrogen and water. After passing through the first catalyst, a small quantity of natural gas is combusted to raise the temperature of the flue gas by about 10ºF. The flue gas then turns and goes down through the second canister, first passing through the catalyst, causing additional NO_x to be removed, then through the heat recovery medium, where the heat in the flue gas is transferred back to the medium. The flue gas then exits through the outlet header to the stack.

The movement of the flue gas through the RSCR causes the heat recovery medium in the inlet side to be cooled from the flue gas, and the medium on the outlet side to be heated by the gas. About every three minutes, the inlet and outlet dampers switch positions. This causes the flue gas flow to be reversed, and the flue gas picks up heat from the now heated side and gives up the heat to the cooler side, while the reaction temperature remains constant. The regenerative nature of the unit results in low natural gas consumption. This process cools the gas to approximately 280°F before it exits the RSCR.

Upon leaving the RSCR equipment, the cleaned flue gas enters the chimney. The 12 foot diameter stack is a single flue design, approximately 241 feet high with an 8.5 foot diameter outlet. The stack outlet velocity is ~91ft/sec with a gas flow of approximately 1,033,000 lb/hr for both steam generators.

Each air quality control system will include a complete system for the storage and preparation of the Turbosorp and RSCR reagents. Turbosorp reagent will be stored as hydrated lime (calcium hydroxide) in the Lime Silo designed to receive lime from self-unloading trucks. The silo will be sized to contain approximately 75 tons of hydrated lime and will be equipped with a bin vent filter to control particulate emissions. The RSCR reagent is aqueous ammonia (19%) to be stored in two (2) 12,000 gallon storage tanks, shipped in by truck.

SUMMARY

The MRE facility represents an Advanced Energy Resource that offers numerous short-term and long-term benefits to Ohio. The permitted facility utilizes state-of-the-art technologies to achieve high efficiency and low emissions:

- Riley Advanced Stoker Boilers
- A Turbosorp Dry Circulating Fluid Bed Scrubber and associated equipment (hydrated lime storage silo, activated carbon storage silo, and baghouse)
- RSCR NO_x control system

The Advanced Stoker Boiler and air pollution control technologies to be employed at the MRE are reliable, generate low emissions, and are a proven means to convert fuel derived from solid wastes (MSW processed into RDF and processed C&D) to electricity.

REFERENCES

1. State of Ohio Environmental Protection Agency Permit Number 02-23003 for Mahoning Renewable Energy, Facility ID 0250001120.

2. R. F. Abrams and R. Faia, 2009, “RSCR® System to Reduce NO_x Emissions from Boilers”, Proceeding of North American Waste-To-Energy Conference 17, Chantilly, Virginia.