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DESIGN, INSTALLATION AND OPERATION OF THE WAINWRIGHT REGIONAL WASTE-TO-ENERGY AUTHORITY COMBUSTOR

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ABSTRACT

A state-of-the art municipal Waste-to-Energy (WTE) combustor began operation in the town of Wainwright, Alberta, Canada in 1995. This 30 Tonne Per Day (TPD) system is the first small scale facility built to meet the Canadian Council of Ministers of the Environment (CCME) 1989 operation and air emission standards for Municipal Solid Waste combustors.

The combustor design utilizes a radiant waterwall, multi-chamber, multi-stage combustor design, followed by a convective boiler section, a flue gas economizer and an air to air heat exchanger. The air pollution control system consists of an all dry lime injection system followed by a fabric filter collector. The system has the capability for delivering activated carbon, if needed, for the control of various pollutants. The pulse-jet fabric filter collector utilizes GORE-TEX® membrane/ TEFLON® B fiberglass filter bags for highly efficient capture of the Particulate Matter (PM), which includes lime reaction and absorbent products, unreacted lime, and fly ash which is rich in trace metals and other fine particulates.

Compliance testing revealed that the system is providing low outlet emission levels and would meet the proposed U.S. EPA New Source Performance Specifications for Municipal Waste Combustor's in the United States for all categories. This includes acid gases, trace heavy metals including Pb, Cd, Hg, and PCDD/PCDF as measured by toxic equivalency factors. PM levels were measured at 9.8 mg/Rm^3. Lead, cadmium and mercury emission levels were measured at 0.37 μg/Rm^3, <0.001 μg/Rm^3, and 0.24 μg/Rm^3 respectively. PCDD/PCDF emissions were measured to be 0.044 μg/Rm^3 (TEQ). Finally, HCl and SO_2 emissions were measured to be 11 mg/Rm^3 and 13 mg/Rm^3 respectively. All levels are corrected to 11% O_2 with a reference temperature of 25°C. This paper presents the methodology for achieving cleaner combustion which takes full advantage of a completely dry acid gas scrubbing system.

INTRODUCTION

Municipal Solid Waste (MSW) is a worldwide problem. Various solutions have been attempted: landfills; gasification; combustion only for volume reduction; energy from waste. For example, in the 1980's, Tsukishima Kikai Co., Ltd. constructed a 200 TPD pyrolysis plant in Japan (Igarashi, 1984). After operating successfully for a number of years, it was concluded that producer gas and char by-products could be generated from the pyrolysis, but the economics could never compete with recovering energy from waste in solid waste fired boilers. Today the emphasis is on environmental standards and the perceived impact in the Biosphere. Wilson, D.J. et al (1995) postulated that a correctly designed and operated Municipal Waste Combustor would emit fewer PCDD/PCDF compounds than an equivalently sized hazardous waste combustor. The goal then is to design a combustion system that emits lower levels in every pollutant category.

HISTORY

Faced with substantial increases in the cost of landfill by the Town of Wainwright, and Alberta's recognition of this on a Provincial scale, funding for a capital project to assess the viability of a *Waste-To-Energy Plant* was made in 1984. Wainwright, located in the western Canadian province of Alberta, initially selected two modular starved air systems at a capital cost of approximately 4.0 million $CAN. Despite incurring numerous problems in combustion that subsequently resulted in the disposal of the two units, the Wainwright Regional Waste-to-Energy Authority and the Province believed that waste-to-energy would be a proper solution to complement its landfill, composting, and recycling programs. Stanley Industrial Consultants Ltd. of Edmonton, Canada were retained to assess small scale waste-to-energy technology to replace the previous units. Inherent in the analysis was the capability to burn other fuel mixes such as biomedical, industrial, and tires.

Additionally, the Authority elected to pursue a Build-Operate-Transfer (BOT) concept for the purchase, installation, and operation of the facility.

The Wainwright system was the first municipal solid waste combustor to be permitted under the new CCME operating and air emission standards for Municipal Solid Waste combustors. It needed to meet strict combustion, particulate, acid gas, metals, and trace organic limit requirements.

The chosen system was a 12,000,000 BTU/h (1.266E+10 J/h) BASIC® Model 1500 Solid Waste Boiler manufactured by Basic Envirotech Inc., an Illinois company, under license from Basic International, Inc. The BASIC® Model 1500, when processing Municipal Solid Waste, has a nominal firing rate of 30 tonnes per day.

A combustor only version of the BASIC® Model 1500 has been burning the combined waste stream from two towns in New Hampshire for a number of years. A second combustor only unit has been in operation burning pathological waste for over twelve years for the City of Chicago. A third version with heat recovery and wet venturi scrubber has been burning medical waste for the University of Michigan Hospitals. This BASIC® Model 1500 was utilized in the 1989 U.S. EPA test program for medical waste (Durkee & Eddinger, 1993). During this study, simultaneous emission testing was conducted at the outlet of the last combustion chamber, the outlet of the wet scrubbing system, as well as at numerous additional locations. The testing included all pollutants, bottom ashes, and PCDD/PCDF emissions. Consequently, an emission and operating data base exists for uncontrolled MSW, uncontrolled pathological waste, controlled medical waste, and now extremely controlled municipal solid waste combustion all in the same model.

PROCESS AND DESIGN

Material Handling

Figure 1 represents a schematic diagram of a typical BASIC® Solid Waste Boiler system configured with the dry acid gas scrubber. Material handling is performed by three sub-components and systems. Bulk refuse is fed into the furnace by an electro-mechanical rack and pinion style boom with a refractory coated pusher platen. A refractory covered air cooled rotary charge door isolates the hopper from the hot furnace environment. Waste is loaded into the hopper and the batches charged into the furnace typically at eight to ten minute intervals.

All BASIC® systems incorporate the patented Pulse Hearth® stoker system for fuel/air distribution, ash agitation, and bed turbulence. This patented design is a refractory covered hearth that intermittently tosses the burning waste upwards and forward away from the entry point of the furnace. Compressed air provides the external "pulses" to the externally supported hearth. No internal metal parts in the furnace are utilized to move the waste. Consequently, one of the inherent characteristics of the hearth is a wide heat release bandwidth of 0 - 20,000 BTU/lb HHV (0-46,500 kJ/kg), ideal for variable waste mixtures such as MSW, medical waste, industrial waste, and tires.

Ash is discharged from the Pulse Hearth® into a submerged ash pit at the end of the hearth. A steel ash remover incorporating the back hoe principle rides up and down in a steel trough to extract the ashes. The remover enters the water pit for small intervals of time. Excess water is drained before the ash is dumped into the waste container. Testing of the ash has shown the ash not toxic nor rich in metals. Bottom ash is placed with other general wastes in the town-owned landfill located near the facility and fly ash is placed into an isolated cell of the landfill.

Combustion Technology

The combustion of solid waste occurs within the boundary of the Stage 1 chamber and on the surface of the Pulse Hearth®. Underfire air is progressively introduced and distributed uniformly from the front to the back of the chamber. The geometric shape of the rectangular chamber forms a constant section for uniform laminar gas to flow vertically and horizontally across the furnace. Different realms of stoichiometry exist based on the measurement location within the furnace. Beginning at loader entry the ratio is substoichiometric; farther down the chamber the ratio approaches stoichiometry. Near the ash discharge end, excess air is used to burn out the carbon. The net air/fuel ratio existing in the first chamber is near theoretical but is not fully mixed. The gas composition and particle size is quite predictable; under 100 microns. The second stage adds a limited amount of excess air and is coupled to an independently controlled third stage, also operated at excess air levels. Operated in an endothermic mode, the second stage builds up the required heat to initiate hydrocarbon destruction. Operated in an exothermic mode, the third stage adds excess air to complete combustion. High Reynolds number air jets create turbulent mixing and shearing of halogens when present.

Heat Transfer

Like large mass burn systems, the first stage of the BASIC® unit is constructed with a waterwall membrane surrounding the fireball at the point of highest heat release. Radiant energy is transferred in this chamber. The flue gas temperature is lower than equivalent refractory lined chambers. The initial mechanism for nitrogen oxide formation and for metal emission are reduced here. The combustion gases of the third stage are introduced into a second boiler, in this case, a three-pass firetube boiler which extracts the convective energy of the flue gas. The waterwall and convection section are piped as a naturally circulating tandem, or hyphenated boiler arrangement.

An economizer is employed to boost steam conversion efficiency and to reduce flue gas temperature. Recirculated flue gas from the exit of the economizer is mixed ahead of the convection boiler to control inlet temperatures. This minimizes the fouling of the convective boiler tubes. Based on the type of waste being burned, the initial controlling point is adjusted to the temperature window where particulate vapors are transformed to soft powders.

Air Pollution Controls

The first three stages burn organic compounds to a high level of completion, minimizing metal emissions and the formation of oxides of nitrogen. Previous U.S. EPA testing at other plants

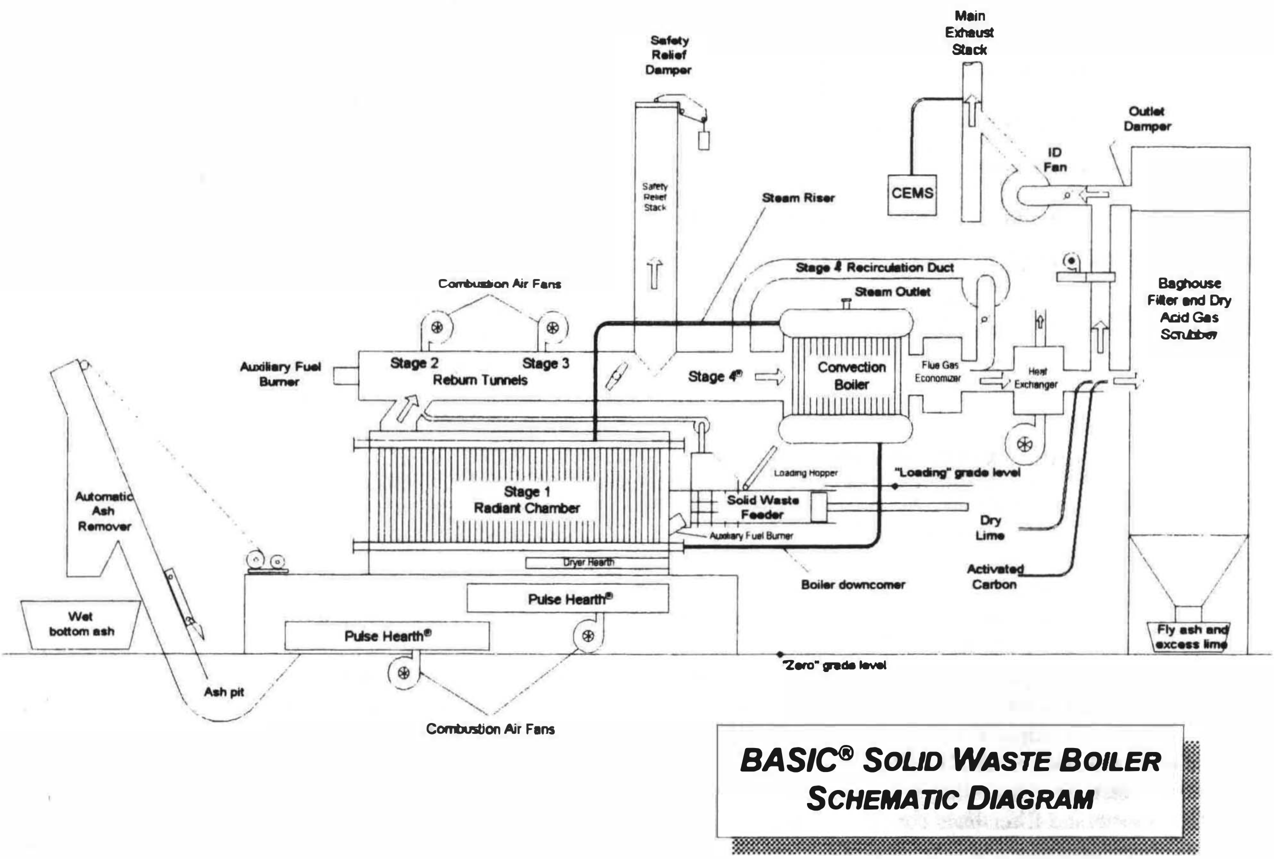

FIGURE 1

with chlorinated medical waste demonstrated PCDD levels of 1.6 mg/Rm^3 at the exit of the third stage with low CO, but particulate emissions still require additional control. The use of the convective boiler and economizer creates a potential zone for organic vapors to condense onto particulate and reform trace PCDD/PCDF emissions.

A forced air glass tube heat exchanger at the discharge of the economizer section is employed to cool the flue gas to less than 150°C. Acid condensation and metal vapor agglomeration occurs in this temperature zone so the materials in the exchanger must be carefully chosen. Hydrated agricultural lime is injected downstream of the exchanger directly into the ductwork. The combustion byproducts and lime fly ash mixture flows into the fabric filter assembly.

GORE-TEX® membrane filter bags and lime injection have been used successfully with the BASIC® system and technology for a number of years in various applications. The preferred filter system is a pulse jet backwash for bag cleaning. Air to cloth ratios are not particularly critical to the successful operation of the system. In medical waste applications, filter life of nearly five years has been demonstrated so it is projected that replacements for municipal waste combustors will be similar. Reduced HCl, metal, and mercury emissions have been demonstrated at BASIC® facilities worldwide without the usual injection of activated carbon.

Fabric Filter Technology

Presently, two filtration technologies are used in fabric filtration: GORE-TEX® membrane surface filtration; and depth filtration. Depth filtration depends upon a two-stage dust cake development. The primary dust cake is located within the filter media and is the first to develop. The secondary dust cake builds upon the primary dust cake. Primary dust cake maintenance is extremely important because the primary dust cake is responsible for PM capture; that is, maintaining low PM emissions. However, the secondary dust cake is responsible for increased static pressure loss, and must be removed by the action of the cleaning cycle. Excessive cleaning disturbs the primary dust cake and can lead to excessive emissions.

GORE-TEX membrane surface filtration, by comparison, uses the GORE-TEX membrane to collect the PM which impinges upon the surface. Consequently, even fine, non-agglomerative

	Wainwright Test Value	CCME Limits	U.S. EPA MWC Limits (proposed)
Particulate Dust	9.8 mg/Rm^3	30 mg/Rm^3	15 mg/sm^3
Carbon Monoxide	1.8 ppmdv	50 ppmdv	50 ppmdv
Nitrogen Oxides	63.8 ppmdv	210 ppmdv	180 ppmdv
Hydrogen Chloride	6.7 ppmdv	50 ppmdv	25 ppmdv
Sulfur Dioxide	4.6 ppmdv	100 ppmdv	30 ppmdv
PCDD (TEQ)	0.044 $\mu g/Rm^3$	0.50 $\mu g/Rm^3$	0.20 $\mu g/dsm^3$
Pb	3.7×10^{-5} mg/Rm^3	0.05 mg/Rm^3	0.10 mg/dsm^3
Cd	1.0×10^{-6} mg/Rm^3	0.10 mg/Rm^3	0.01 mg/dsm^3
Hg	2.4×10^{-4} mg/Rm^3	0.20 mg/Rm^3	0.10 mg/dsm^3

NOTE: CCME limits expressed in values corrected to 11% O_2 and 25°C (Reference conditions).
U.S. EPA limits are expressed in values corrected to 7% O_2 and 20°C (Standard conditions).

TABLE 1

PM does not penetrate or pass through the filter media. The GORE-TEX membrane laminate construction allows the filter bags to operate on the principle of surface filtration. That is, PM is collected on the surface of the GORE-TEX membrane, and not within the interstices of the felted or woven fabric.

GORE-TEX membrane filter bags consist of a microporous expanded polytetrafluoroethylene (expanded PTFE) membrane laminated to a felted or fabric backing material. The substrate is chosen based on the temperature and chemical composition of the gas stream entering the baghouse. The expanded PTFE membrane is inert to most chemicals and can withstand continuous operating temperatures of 260°C.

INSTALLATION

The two original starved air incinerator systems were removed from the Wainwright Regional Waste-to-Energy Authority site. A portion of the roof was uncovered and a penthouse was created to accommodate the taller height of the fabric filter assembly with walk-in plenum so all of it could be contained within the plant. The foundation was altered to accept the footprint requirements of the equipment. The orientation of the boiler was such that two distinct elevations were created for access and proper maintenance. An "L" configuration of the second and third stages worked well to fold the 2-second retention design requirement into the building space.

The microprocessor based control panel is located adjacent to the loading hopper next to the tipping floor. All control functions for the proper operation of the plant, including the fabric filter system and steam condenser, are incorporated into this system. A Man/Machine Interface (MMI) with a color graphic provide the direct operator interface. A high performance industrial Programmable Logic Controller is the backbone of the control system. Direct communications is provided via modem back to Basic Envirotech Inc.'s home office for enhanced troubleshooting and quicker response.

At 12,000,000 BTU/h input (1.266 E+10 J/h) approximately 8,000 lb/h (3,630 kg/h) of 200 psig (1.48 E+6) steam is available for the process needs of a food processing plant located within a short distance from the Wainwright facility. The steam is metered at the food processing plant and the condensate is returned to the WTE facility. A glycol/air cooled steam condenser is used to automatically condense the steam at the WTE facility in the event of low steam demand from the food processing plant.

OPERATIONS

The Wainwright Regional Waste-to-Energy Authority serves the needs of approximately 10,000 people. The wide variability of the waste stream has been a surprise with its own problems to the operations. The intended composting program has not been fully implemented, therefore considerably more organic matter has ended up in the plant. During the fall and spring seasons greater than 60% of the materials brought to the facility could have been composted. Higher utility costs are incurred from combustion of the high moisture wastes, specifically from the natural gas needed to maintain combustion levels, which raises the disposal costs to above 70 $CAN/Tonne.

Wainwright is located in a rural area and a number of farmers in the area raise animals. In addition to usual farm livestock, ostriches have been brought to the facility for disposal. A nearby military base utilizes the facility for processing of its MSW and commercial waste. This waste stream contains a significant amount of metals and glass which poses problems similar to the compostable materials received from the town.

Already, sufficient MSW material is not available for the unit to run at full capacity. The MSW generated is enough to run the system continuously for approximately 4 to 5 days out of a 14 day period. The Authority is beginning to implement programs and fines for disposing of wastes which could have been composted or recycled and the community has begun to positively respond. As future MSW waste streams are expected to be dramatically reduced, the excess capacity will be used to process materials with higher tipping fee values.

At the time this paper is written, Alberta Environment has given permission to the Wainwright facility to burn whole tires and medical waste in the unit on a trial basis. As in the USA, proper disposal of these items is a major problem in Canada. Current tip fee for whole tires is 150 $CAN/Tonne and medical waste is 800 $CAN/Tonne. Adding these materials to the Wainwright fuel mix will contribute to the Authorities objective of maintaining an acceptable tipping fee for MSW to the community. Emission testing for tires and medical wastes is planned for the end of March and May this year, respectively.

The BASIC® technology has been burning tires with industrial rubbish at a Bridgestone/Firestone Inc. plant in Illinois for over 10 years. The technology is also incorporated at a 25 megawatt tire-to-energy plant in the U.K. Essentially a unique multi-fueled, multiple waste disposal facility will exist.

EMISSIONS

With the introduction of amendments to the United States Clean Air Act and New Source Performance Standards (NSPS), emissions and permitting have been the focus of many professional activities. Basic, J.N., Sr. (1988) presents the argument that the regulatory authorities should be promoting rigid performance standards for emissions rather than design criteria such as extreme operating temperatures and long residence times. **Table 1** illustrates the pollutant concentrations measured at the Wainwright Regional Waste-to-Energy Authority facility source testing vs. permit requirements. Of particular note is the extremely low value for Carbon Monoxide (CO), a key combustion parameter of hydrocarbon destruction.

Basic, J.N.,Sr., realizing that CO and unburned hydrocarbons are important key surrogates for the PCDD formation, promoted an assertion that as the flue gas was burned to completion and less particulate was traveling in the stream, then less nuclei would be present for trace organics to re-form during the condensation phase. Current thinking and measurements support the facts that in a properly designed unit, dioxins will be found at the combustion outlet in nanogram to picogram concentrations. A substantial body of work exists that proves that trace organics do re-form during the temperature regions normally encountered in waste heat boilers and economizers. It should be noted that the low dioxin emission numbers at the Wainwright Regional Waste-to-Energy Authority facility were achieved without activated carbon being added to the lime.

Particulate numbers are combined front half and back half measurements which include condensable. All pollutants were measured at the outlet of the dry gas scrubber and corrected to 11% O_2, with a reference temperature of 25°C per cubic meter of flue gas.

At the facility, an extracting Continuous Emission Monitoring System (CEMS) measures and records Opacity, Oxygen, Carbon Monoxide, and HCl in the gas steam. Total mass of the MSW is recorded as well as operational records.

CONCLUSION

A 30 TPD small scale solid waste combustor has demonstrated low emission levels in every pollutant category without injection of activated carbon or ammonia injection. This system is also in the process of stack testing for whole tire combustion as well as future applications for medical waste.

The local community is comfortable to a high level with the technology and the facility performance. What faces the Authority now is to educate the public to better understand the costs and consequences of waste disposal so they can manage their waste streams more effectively. By doing this they open the door to increase the processing of higher valued feedstocks and further lower the costs of processing their own MSW.

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