MULTI-FUEL BOILER TECHNOLOGY

RICK A. HAVERLAND
SYSTECH Corporation (SYSTECH)
Xenia, Ohio

ABSTRACT

The paper presents the concept of resource recovery as an energy management alternative for industries with little or no waste fuel of their own. Two typical projects and the multi-fuel boiler equipment used for each project are described. Also, the technical merits of the multi-fuel boiler and heat recovery incineration (HRI) technologies are compared.

NOMENCLATURE

Btu = British thermal unit
°C = degrees Celsius
°F = degrees Fahrenheit
ft^3 = cubic feet
G = giga
gal = gallon
hr = hour
HRI = heat recovery incinerator
ID = induced draft
J = Joule
kg = kilogram
kW = kilowatt
kW·h = kilowatt hour
L = liter
lb = pound
m^3 = cubic meter
Mcf = thousand cubic feet
MPa = megapascal
Nm^3 = normal cubic meter
psi = pound per square inch
RDF = refuse-derived fuel
t = metric ton
WDF = waste-derived fuel

INTRODUCTION

The energy available from wastes generated by an industrial facility rarely matches the energy demand of the facility. Most of the industrial HRI systems have been installed at facilities where the energy demand is greater than or equal to the energy available from combusting the wastes generated at the facility. This is probably because both waste disposal and fuel savings are available for recovering the cost of the HRI system. The industries with large amounts of waste and little energy demand may have considered an HRI system, but a system could not be justified without the energy savings. Large energy users with small amounts of combustible wastes would probably not consider an HRI system because they have no waste, but they may have considered the installation of coal- or wood-fired boilers to replace their oil or gas boilers. Therefore, a possible approach for developing industrial waste-to-

FIG. 1 MIXTURE OF WASTE DERIVED FUELS

energy is to install (at a facility with a large energy demand) a boiler system capable of using a variety of wastes from industries with little energy demand and other solid fuels.

There are a variety of boiler system technologies that can utilize a variety of wastes and solid fuels. Because this energy management approach may require the purchase of wastes and fuels, the boiler system must be energy efficient. Also, most industrial systems will probably be in the size range where factory-assembled (packaged) boiler systems are the most economical. The multi-fuel boiler technology is both energy efficient and available in packaged systems. Therefore, one possible approach for developing industrial waste-to-energy projects is to install (at a large energy user's site) a boiler system that is capable of using a variety of wastes from nearby industries or other low cost solid fuels.

Following are project descriptions for two multi-fuel boiler installations in Belgium that use a variety of wastes from nearby industries as their fuel source. All economics are given in U.S. dollars.

PROJECT DESCRIPTIONS

The first Belgium company produces packing materials and needed an average of 12,100 lb/hr (5500 kg/h) of 175 psi (1.2 MPa) saturated steam, 16 hr/day, 240 day/yr. Their existing fuel was natural gas, and they were using 53,226 Mcf/year (1,507,200 Nm^3/year) for a total annual fuel cost of $301,440 at $5.66/Mcf (U$ 0.20/Nm^3).

The gas-fired boiler was replaced with a N. V. Vyncke multi-fuel boiler with a rated capacity of 17,600 lb/hr (8000 kg/h). The cost of the complete multi-fuel boiler system including the storage system, boiler, multiclone, ID fan, stack, and boiler feed conveyor was $291,000 in early 1984. Because the company has no waste fuel, they must purchase fuel on the solid-fuel market. They are using variable mixtures of bark, refuse-derived fuel (RDF), wood waste, pelletized RDF, pelletized brewery waste, peat, lignite, waste plastics, and textiles (see Figs. 1–3). The total annual fuel consumption and cost is approximately 6316 tons (5742 t) and $86,130. Therefore, the average

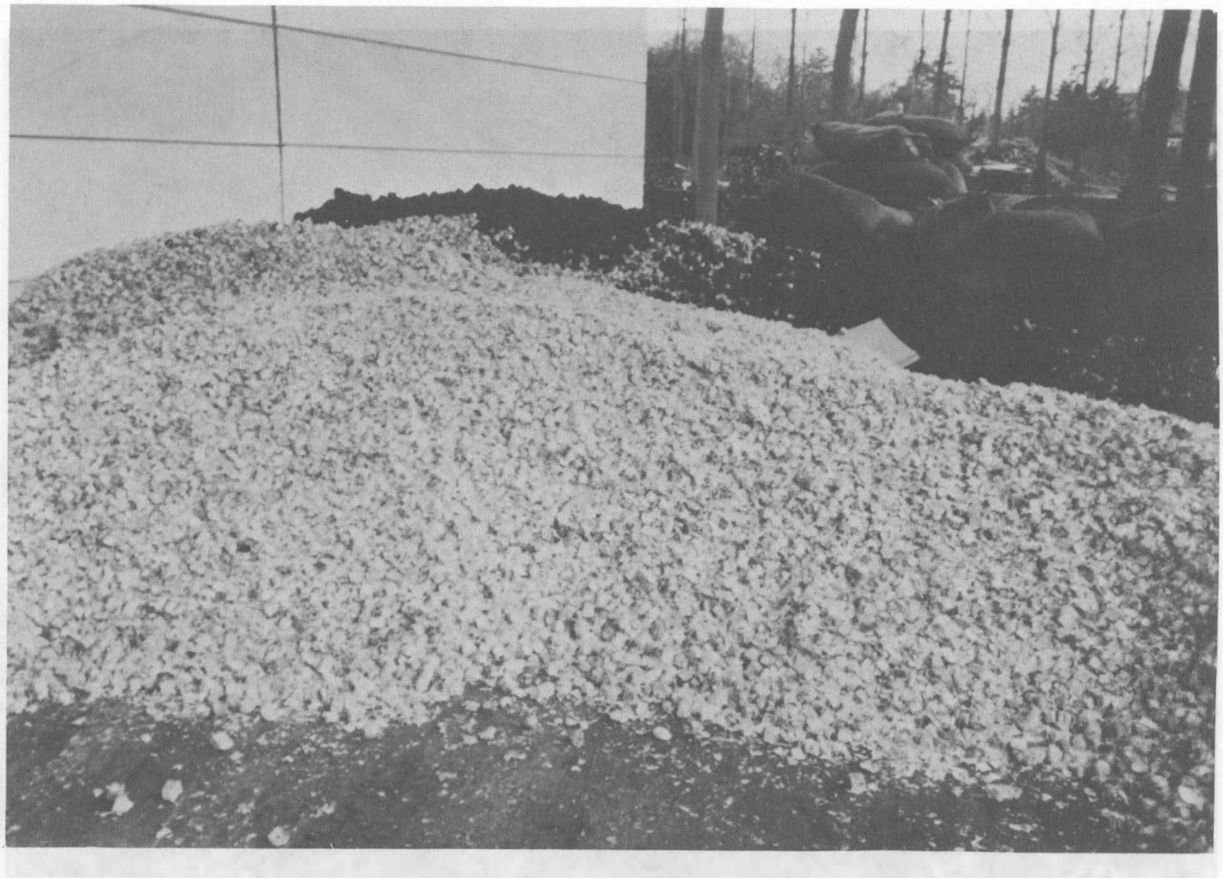

FIG. 2 PELLETIZED PAPER WASTES

cost for solid fuels is \$13.64/ton (\$15.00/t). Assuming a very conservative heating value of 4500 Btu/lb (10.5 J/kg), the average fuel cost is \$1.52/10^6 Btu (\$1.44/GJ).

The efficiency of the boiler varies significantly depending upon the fuel being used. Using green wood waste with a higher heating value of 4460 Btu/lb and a moisture content of 50%, the efficiency of the multi-fuel boiler using the ASME Power Test Code is approximately 63%. Using select industrial waste with a higher heating value of 7582 Btu/lb and a moisture content of 15%, the multi-fuel boiler efficiency is 77%.

Compared to the natural gas boiler system, the multi-fuel boiler system requires an additional 1 man-hour/day of operation and maintenance labor. At \$12/manhour the additional annual labor cost is \$2880. The multi-fuel boiler system also uses 50 kW more of electricity than the gas boiler system for an annual cost of \$10,560 when electricity rates are \$0.055/kWh.

Based on these values, the annual savings using the multi-fuel boiler are \$201,870 neglecting capital costs. The payback period (investment/annual savings excluding capital costs) is 1.4 years.

The second company also produces packing material and needed an average of 8000 lb/hr (3600 kg/h) of 58 psi (0.4 MPa) saturated steam 16 hr/day, 240 days/year. The existing boiler used No. 6 fuel oil as the fuel, with an annual consumption of 290,400 gal (1,099,164 L) and an annual cost of \$228,096. This corresponds to a unit price of \$0.785/gal (\$0.208/L).

The oil-fired boiler was replaced with a N. V. Vyncke multi-fuel boiler with a rated capacity of 10,500 lb/hr (4775 kg/h) of 320 psi (2.2 MPa), 536°F (280°C) superheated steam which is expanded through a single-stage backpressure turbine to produce 160 kW of electric power. The cost of the system including storage system, boiler, multiclone, ID fan, stack, boiler feed conveyor, turbine generator, and water treatment system was approximately \$400,000 in late 1983. They also purchase similar fuels as the other company on the solid-fuels market. The total annual fuel consumption is 4170 tons (4700 t), and the annual fuel cost is \$70,500. The average cost of the fuel is the same

FIG. 3 PELLETIZED BREWERY WASTES

as the other company. The multi-fuel boiler and electrical generation system has a maintenance budget which is $8,800 more than for the oil-fired boiler. The electrical usage by the multi-fuel boiler system is 40 kW more than the oil-fired boiler for an additional annual cost of $8,448. However, the multi-fuel system produces 160 kW with an annual value of $33,792.

Based upon these values, the annual savings using the multi-fuel boiler cogeneration system is $174,140, neglecting capital costs. Therefore, the payback period is 2.3 years.

EQUIPMENT DESCRIPTION

Both of the multi-fuel projects described in this paper utilize the same boiler system. The equipment generally consists of a storage conveyor, a feed conveyor, a multi-fuel boiler, automatic ash removal system, air pollution control equipment, ID fan, and stack. One facility also has a superheater section on the boiler and a turbine generator. The equipment unique for use of multi-solid fuels are the storage conveyor, the feed conveyor, and the boiler. A more detailed description of those items follows.

Storage Conveyor

All the fuels for both facilities are delivered by truck, stored on a covered concrete pad, and loaded, as needed, onto the storage conveyor by a front-end loader. One of the facilities has a live bottom storage conveyor (Fig. 4) that can receive direct discharge of the fuel from the delivery truck. The live bottom floor consists of hydraulically-actuated reciprocating steel frames. The second facility has two elevated belt storage conveyors feeding one conveyor to allow blending of different fuels. Although both types of storage conveyors have worked well, the belt conveyor causes more housekeeping problems and requires more operating labor.

FIG. 4 LIVE BOTTOM STORAGE CONVEYOR

Feed Conveyor

At both facilities the fuels are fed to the boiler using an inclined belt conveyor and an inclined feed chute with pneumatic doors to prevent tramp air from entering the boiler. The feed conveyor has a surge hopper with a level indicator to control the storage conveyor. The feed conveyor (Fig. 5) meters the fuel fed to the boiler by the height of the push plates on the belt. If too much fuel is on the belt, the fuel will tumble back down the steeply-inclined (45 deg.) belt.

The feeding system allows automatic feeding of the fuels on a relatively continuous basis rather than feeding large batches. The maximum dimension of the fuel that can be fed is dependent on the size of the boiler and moisture content of the waste. For these boilers, the maximum fuel dimension is 43 in. Therefore, the automatic and relatively continuous feeding can be achieved with minimal or no shredding.

The automatic feeding reduces labor costs, and the relatively continuous feeding allows combustion at near steady state conditions on a uniform depth fuel bed. To date, the only operation problem with the feed conveyors at either facility has been when the fuel density was less than 10 lb/ft^3 (160 kg/m^3). When this occurred, the low density fuels rolled back down the conveyor, and the proper mass feed rate to the boiler could not be attained. To solve the problem, denser fuels were used, and roller weights were placed on the conveyor.

Multi-Fuel Boiler

Both boilers are the JUMBO (JH) series boiler manufactured by N. V. Vyncke of Harelbeke, Belgium. The boiler is a packaged (factory-assembled) unit consisting of a separate furnance and convective section (Figs. 6 and 7). The furnace section is formed of water tubes in a modified arch configuration to allow considerable radiant heat transfer without flame impingement on "cold" heat transfer surfaces. The convective

FIG. 5 DOSING BELT FEED CONVEYOR

section of the boiler consists of two passes of horizontal fire-tube bundles. The superheater section at the one facility is an external module added at the end (opposite from the furnace section) of the convective section. With regard to the flue gas flow, the superheater is between the two passes of the convective section. A slight negative pressure is maintained in the boiler furnace by the ID fan and a flue gas modulation valve. Underfire combustion air is supplied by a forced-draft fan. The total underfire air is divided into three zones under the grate. The air flow to each zone can be controlled for better combustion when the fuel change is made. The overfire combustion air is induced by the negative pressure in the furnace.

The unique feature of this multi-fuel boiler is the inclined water-cooled, step-grate stoking system. The grate begins at the base of the inclined feed chute. Each water-cooled step is an integral portion of the boiler heat transfer surface and is connected to both the steam and mud drums. The fuel is moved down the grate by a series of push plates between each step. The plates are normally retracted, but are pneumatically extended to push the fuel off one step and down to the next step. This action and the slope of the grate produces a relatively uniform fuel bed depth. The uniform bed depth allows good combustion control and fuel burn-out. The boilers at both companies are designed for a maximum fuel moisture content of 35%, but the boiler manufacturer reported having other multi-fuel boiler installations that are designed for a maximum fuel moisture content of 60%.

Each of the boilers is equipped with a flat postcombustion grate which retains the fuel until combustion is complete. The fine ash falls into the ash hopper when the grate is pneumatically opened. Any larger ash particles are manually pushed off the end of the post-combustion grate into the ash hopper. A pneumatically-acutated ram pushes the ash in the hopper through a flap door to the ash conveyor. The ash conveyor transports the dry ash to a container. One facility has a bucket ash conveyor while the other has a drag-chain ash conveyor.

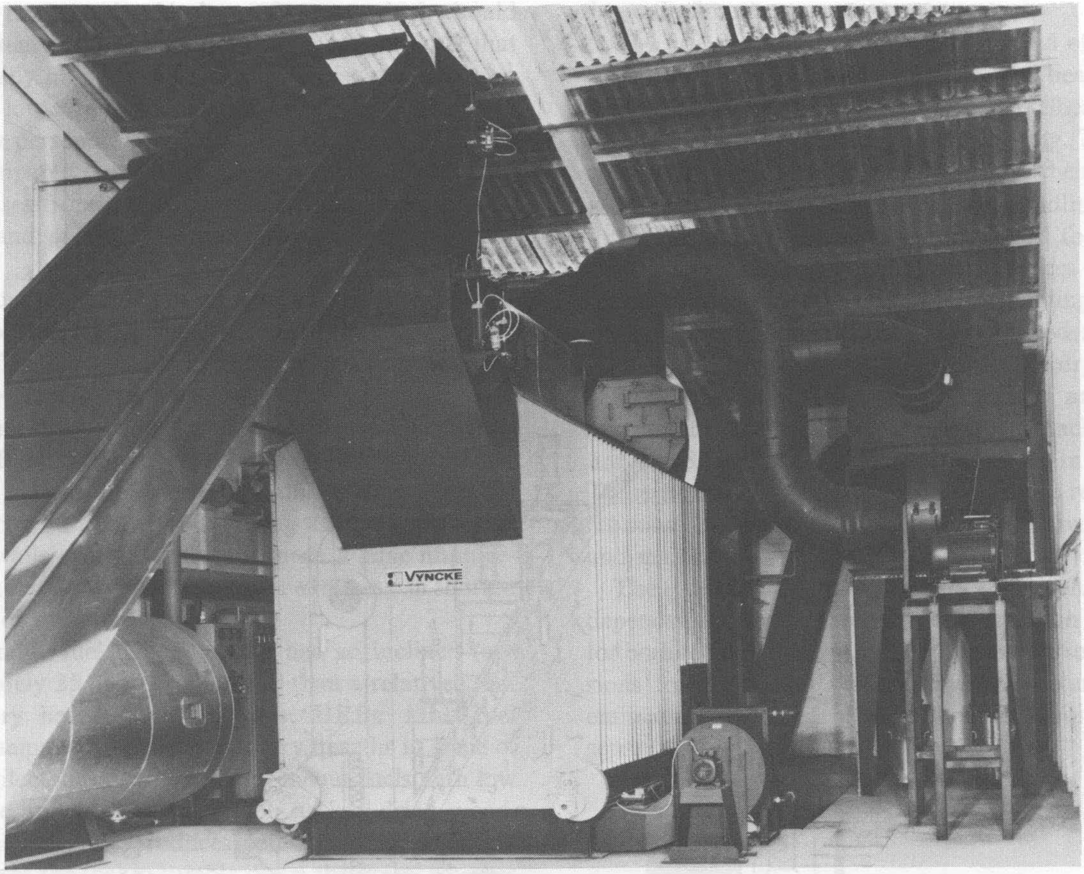

FIG. 6 PACKAGED MULTIFUEL BOILER

These two facilities have operated since early 1984 with little or no unscheduled downtime and no major operational problems.

TECHNOLOGY DISCUSSION

There is a fundamental difference in design philosophy between the multi-fuel boiler and HRI technologies. The primary design criteria for multi-fuel boilers is hot water or steam production, while the primary design criteria for HRI systems is waste incineration. Like all fossil fuel boilers and the more efficient field-erected HRIs, the furnace of a multi-fuel boiler is an integral radiant heat transfer section of the boiler while most packaged HRI's are typically an incinerator (one or more chambers) followed by a heat recovery boiler. Following is a comparison of multi-fuel boilers and HRI's.

The feeder for a multi-fuel boiler has an open discharge to the inclined grate in the furnace, while the feeder for an HRI pushes the new charge against previous charges. This requires the HRI feeder to push some or all of the waste in the furnace forward to a small step or the ash discharge. Since the HRI feeder must develop substantially more force, the multi-fuel boiler feeder has lower power and maintenance costs and higher reliability.

The multi-fuel boiler furnace has water-cooled walls that are an integral portion of the boiler, while the HRI furnace is completely refractory lined. The multi-fuel boiler furnace will provide higher efficiencies because of considerable radiant heat transfer. The radiant heat transfer prevents high flue gas temperature in the furnace by recovering energy from the gases when the fuel has a heating value over 5000 Btu/lb. An HRI uses considerable excess air or water sprays to prevent high flue gas temperatures when high Btu wastes are

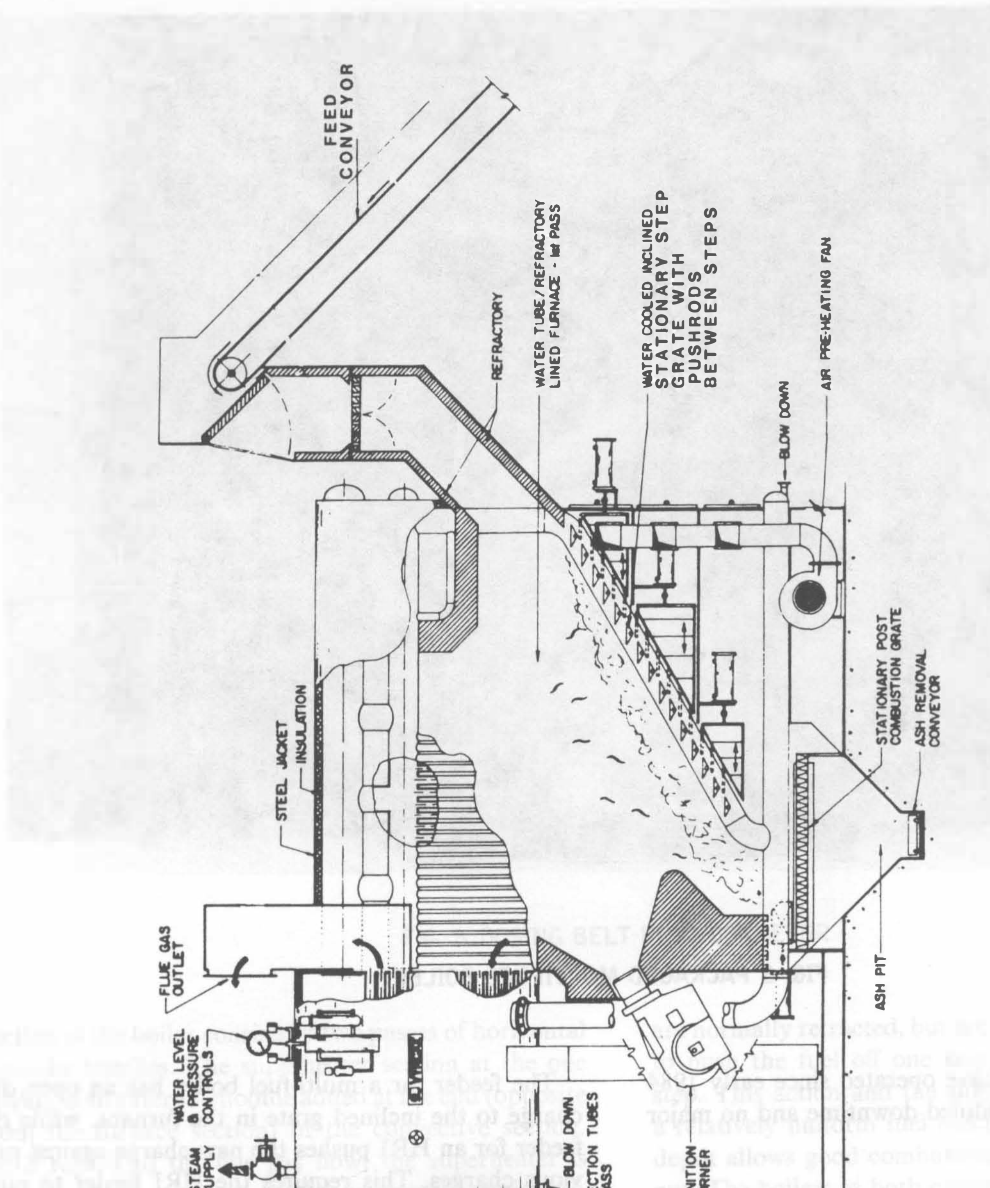

FIG. 7 SCHEMATIC OF A MULTI-FUEL BOILER

fired. Because of the waterwalls, the multi-fuel boiler furnace has considerably less refractory which should substantially reduce refractory maintenance costs that are usually high for incinerators. The waterwalls also provide low skin temperatures (150°F max.) which are safer for personnel and reduce the fire potential of the unit compared to an HRI. The waterwalls also reduce heat losses from the furnace which improves the efficiency and provides more comfortable working conditions.

Because multi-fuel boilers are operated at excess air conditions, the units have less potential ash slagging or "puffing" problems and are simpler to control than a HRI.

The multi-fuel boiler furnace chamber is higher than an HRI (approximately 10 ft vs 6 ft). The greater furnace height allows better mixing of flue gases for proper combustion without having flame impingement on the walls or ceiling of the furnace. Flame impingement on refractory or heat transfer surfaces can shorten the life of the surface.

The multi-fuel boiler furnace has an inclined (approximately 25 deg.) grate rather than a relatively flat refractory hearth found in most HRI's. Multi-fuel boiler manufacturers use refractory hearths in some of their boilers, but only for homogeneous fuels with low moisture and ash contents such as kiln-dried wood. The inclined grate produces better fuel bed agitation and allows the fuel to tumble down the grate, whereas the wastes must be pushed through most packaged HRI's. The pushrods between the grates of the multi-fuel boiler require very little power because they only have to push a small amount of waste a small distance before it falls to the next step. The massive refractory rams in most packaged HRI units must push large amounts of waste for up to one-half of the entire length of the primary combustion chamber. A considerable force is required to move these rams which are usually operated using high pressure hydraulic systems. The pushrods used in the multi-fuel boiler are operated pneumatically using a small compressor. The openings for the pushrods also provide an even distribution of the underfire air.

The use of a water-cooled grate instead of a refractory hearth has many advantages. The heat transfer from the fuel bed improves the boiler efficiency and also reduces the potential for ash slagging. The water cooling keeps the grates cool to extend their life.

Multi-fuel boilers use a dry ash handling system instead of a quench tank commonly used for package HRI systems. The dry ash system reduces corrosion problems and eliminates the cost of hauling and disposing the water in the ash. If concerned about hot ashes, quench spray can be added to the dry system.

Since the multi-fuel boiler furnace is an integral portion of the boiler, there are no dump stacks or long hot gas ducts to a waste heat boiler as in an HRI. These hot ducts on HRI systems can be responsible for considerable heat losses and are expensive to install and maintain.

The type of air pollution control equipment required depends upon the fuel and the local emission standards for both technologies. However, the uncontrolled emissions from an HRI are approximately equal to the emission from a multi-fuel boiler with a multicyclone separator.

CONCLUSIONS

(a) Select wastes and waste-derived fuels can be effectively utilized as an alternative fuel for a multi-fuel boiler facility.

(b) Multi-fuel boilers are an attractive option to energy users that generate little or no combustible wastes of their own.

(c) Multi-fuel boilers are an economically attractive alternative to incinerators with heat recovery boilers for select wastes, minimally processed wastes, and waste-derived fuels.

Key Words: Boiler; Cogeneration; Energy; Fuel; Refuse Derived Fuel