WCS MASS BURN MUNICIPAL WASTE PLANTS

EQUIPMENT AND PROCESS NARRATIVE

1. PROCESS SUMMARY

The Waste Conversion Systems (WCS) MSW mass burn system major equipment normally includes gasifier chamber, receiving building, feed system, residue removal system, waste heat boiler, conditioning tower, Powdered Activated Carbon (PAC) injection, acid gas dry sorbent injection system, fabric filter baghouse, ID fan, stack, controls, and continuous emission monitors. All are based on time proven designs with the intent to create a simple, practical, and reliable plant.

The process begins with the delivery of solid waste to the site by hauling vehicles. The waste is normally weighed and then deposited on the tipping floor. It is briefly inspected and large "white goods" or unburnable items (as well as any prohibited materials, such as lead-acid batteries) are removed. It is pushed to the side, mixed for greater uniformity, and piled for storage and to make room for additional day time delivery.

A wheeled bucket loader places the refuse into the feed system. This begins with a long "walking floor" conveyor, which is large enough to accommodate most bulky items like tires and couches without size reduction. This conveyor can be elevated to facilitate possible placement of manual recycle picking stations. The conveyor transports the material to a ram which pushes it into the combustion chamber. A fire door at the entrance to the chamber seals the system from the heat and tramp air.

The WCS style gasifier chamber is a derivation of robust industrial waste gasifier first developed over 23 years ago. It is a vertical cylinder of HAC refractory of a diameter and height tailored to match the required capacity. It can withstand temperature excursions of up to 2600^{o} F. Solid waste is fed near the top of one side of a unique deep V-shaped hearth. Refuse is pushed in by the hydraulic ram and over time moves down one side of the Vee. This represents one to four tons of waste being dried and burned as it migrates down the Vee-hearth before removal as residue.

Primary combustion air is introduced along the lower portion of the feed half of the vee-hearth through a distribution of ports which can be externally cleaned. The secondary combustion air is injected through a number of ports about ten feet above the fuel bed, equally spaced around the perimeter of the combustion chamber. The secondary air is injected with a high velocity and high pressure to penetrate and violently mix with the hot, viscus gases of the chamber. This is an important factor in insuring clean and efficient combustion. Both air supplies are computer controlled to regulate air flow delivery, balancing the constantly changing requirements of feed rate, waste composition, temperature, and oxygen level.

All combustion air is pulled from the refuse storage and reception building to minimize dust and odor.

During combustion of typical municipal waste, the volume is reduced over 90% and weight over 75% (reduction can be higher depending on composition of the waste and the extent of recycling). Residue is transferred out of the gasifier to a water quench pit by pushing with an hydraulic ram. The quench pit serves to cool the residue and control fugitives during handling. After multiple ram pushes which fill the residue house. An inner door between the residue house and the combustion chamber is closed and the residue is removed by loader for transport to the landfill. An optional but more conventional system utilizes a submerged mechanical residue conveyer for automatic removal of the residue from the residue house into a hopper or truck.

Flue gases are pulled from the combustion chamber into a waste heat boiler. The steam recovered from the heat is used for power generation or process use such as lumber drying, desalination, or many industrial processes. This cooling step is also required to prepare the gasses for emission scrubbing and filtering.

Acid gas released by combustion is controlled by injection of a dry caustic sorbent (hydrated lime or sodium bicarbonate) downstream of the boiler which collects the resulting neutral salts and excess sorbent.

Particulate generated by the combustion process is carried by the gas stream to the baghouse also. The caustic sorbent, which was injected before the baghouses creates a cake on the bags which acts as the primary filter medium. The fly ash is collected on this baghouse cake which is periodically blown off into the hopper by compressed air and discharged by a rotary feeder for disposal.

Metal and organic emission controls coincide with the particulate collection system. As metal vapors condense when cooled, small particles are formed which agglomerate with other particulate in the flue gas and are collected in the baghouse. Organic compounds, such as phenols, also condense at the lower temperatures for collection in the baghouse. Powdered, activated carbon injection control dioxins/furans, mercury and other heavey metals.

An ID (Induced Draft) fan pulls gasses through the complete system and maintains a small negative pressure in the combustion chamber. Continuous emission monitor (CEMs) immediately before the ID fan measure combustion efficiency, emissions, temperature and help in the process control

2. <u>GOOD COMBUSTION PRACTICE</u> (GCP)

The primary control mechanism for clean gasification and reduced hydrocarbon and organic emissions from the system is complete and efficient destruction within the chamber, i.e. “Good Combustion Practice.” The following are elements of GCP.

Fully-mixed Layer. As part of the demonstration that the WCS primary chamber meets Good Combustion Practice, extensive development and testing was done to optimize and then show that there is a fully-mixed layer where the oxygen is never below 3% (wet) and the temperature is high at every point in the layer, that combustion is complete on leaving the layer (low CO), that the layer is at least one second thick and that these conditions can be maintained even during the potentially upset conditions of residue removal. This testing was first done with a cold flow scale model and then during full operation at the 125 ton per day research and development plant sing a water cooled test probe.

The fully-mixed layer is created by the high pressure overfire air nozzles, which inject air tangentially into the combustion chamber at high velocity. This creates intimate mixing of hot combustion gasses with oxygen. The nozzles are strategically located around the combustion chamber and aimed so they swirl the gas in a whirlpool fashion. Burning of the hydrocarbon gases released from the hot gasifying bed of waste begins near the bottom of the fully-mixed layer and is shown to be completed by the top of the layer. (See Table IV)

Completeness of Combustion. The completeness of the combustion occurring in the primary chamber was demonstrated by measuring the unburned components in the exhaust gases. The component that occurs in the highest concentration is CO. When completely burned, CO forms CO_2. Also of interest are any hydrocarbon compounds, the most difficult of which to burn is methane (CH_4). (See Table IV.)

These CO concentrations are compared to values measured at existing Municipal Solid Waste (MSW) systems and reported in Table V (U.S. EPA, 1989). The Waste Conversion System measured relatively low CO values of 3 to 20 ppm (at 7% O_2). These levels are among the lowest of the reported range of values, demonstrating very complete combustion and demonstrating an efficient basic design for the chamber.

Retention time and temperature. Retention time of the products of combustion in the combustion chamber at the required temperature can be calculated from the measured volumetric flow of exhaust gases and the physical dimensions of the chamber. At 1800^{o}F, the travel time through the fully-mixed layer is designed to be more than two seconds and there is more than five seconds total retention time to the primary combustor exit. At these very long residence times and high temperatures, even very difficult to destroy organic compounds are completely destroyed.

TABLE IV

Carbon Monoxide (CO) / Oxygen (O_2) and Hydrocarbon concentrations in the Fully-mixed Layer of the primary chamber, measured by water-cooled probe at various distances from the wall.

Lower Level of Fully Mixed Zone

(Following gasification and preceding introduction of the secondary combustion air)

	CO/O_2			CH_4	C_2H_4	C_2H_2
6"	29/7.0					
2'	11/7.4	13/10.8	122/ 9.4*	261	44	260
4'	33/5.2	2/11.7	<100/10.1*	0	2	0
6'	552/5.3	40/ 9.4				
8'	167/6.9		1500/ 7.3*	178	5	89
8'				1	0	0

Upper Level of Fully Mixed Zone

(Following introduction of secondary combustion air.)

	CO/O_2					CH_4	C_2H_4	C_2H_2
6"	10/ 8.7	13/6.6			<100/ 9.2*	0	0	0
2'	2/ 9.2	12/7.5	0/7.0	8/6.1	<100/10.1*	0	0	0
4'	0/12.1	15/7.3	0/4.3					
6'	0/11.6	10/7.4	0/5.1	8/5.9	<100/10.0*	0	0	0
8'					<100/12.5*	1	0	0
8'					<100/10.0*	0	0	0

Note: **CO(ppm)/O_2 (%)** values were measured with a direct reading instrument except those marked *, which were measured with the hydrocarbons in integrated samples by Gas Chromatograph. The lowest detection limit on the GC for CO is 100 ppm.

TABLE V (U.S. EPA, 1989)

Reported Average CO Concentrations at Various MSW systems (normal operating conditions corrected to 7% O_2)

Facility	CO (ppm)
Millbury, MA	38
Pinellas County, Fl	4
Westchester County, NY	15
Saugus, MA	40
North Andover, MA	43
Commerce, CA	16
Marion County, OR	18
Alexandria, VA	18
Tulsa, OK	22
Chicago, IL	215
Hampton, VA	24
Claremont, NH	55
Long Beach, CA (SERFF)	118
Quebec City, Quebec	33
Portland, ME (North Unit)	41
Portland, ME (South Unit)	75

The above tables dramatically show the effectiveness of the WCS combustor Fully Mixed Zone in promoting good combustion. CO and hydrocarbon levels are very low at the exit of this combustion zone. These combustion conditions and long retention time are important in yielding some of the lowest emissions possible. Cleanliness of the final gasses emitted from the stack is much improved if the downstream scrubbing equipment receives gasses which are already relatively clean from the combustion process.

Some of the reasons for the excellent results from emissions are: 1. The round combustion chamber which has no corners for “dead” zones where dioxins can for or Products of Incomplete Combustion (PIC’s) for. 2. The hot refractory wall rather than cold water walls. 3. The two stage combustion resulting from the secondary air injection physically separated from the bed. 4. The long retention time from the large chambers. 5. The excellent results caused by the GCP, “Good Combustion Practices.”

Automatic controls. One of the elements in Good Combustion Practice is a computerized system to automatically control combustion air and waste feed. The WCS control system is based on O_2 and temperature measurements at the exit of the combustion chamber. The temperature signal and a measurement of primary air flow control the MSW feed. O_2 measurement is the main control of overfire air. Very simply stated, a decreasing temperature increases underfire air, increasing O_2 increases the feed rate, and decreasing O_2 increases the overfire air.

If the temperature cannot be maintained above a desired target minimum because of wet or low heat value waste, an auxiliary burner is automatically turned on. Optional preheated combustion air equipment is also available when waste is regularly wet.

No fully automatic system, however, can accommodate for the extreme variability found with municipal waste with out help from a trained operator. The variables of moisture content, BTU content, and unburnables can be minimized by conscientious mixing on the tipping floor by the helper, but manual adjustments will occasionally be required by the operator monitoring the fire, burn pile size, temperature, emissions, and other parameters. A remote camera focused within the combustion chamber is provided and is very useful in combustion monitoring and control.

3. VEE-HEARTH

The unique Vee-Hearth configuration for the bottom of the primary chamber is a key to the WCS systems simplicity and ease of maintenance. It also promotes a two stage combustion process, i.e. bed gasification separated from and followed by the fully mixed excess air zone combustion. This gasification zone is believed to be responsible for inherent low NOx emissions.

Residue removal is greatly simplified by this Vee-Hearth configuration. As the waste burns, it migrates to the bottom of the Vee as residue. A hydraulic actuated ram periodically pushes through this bottom area, removing the residue into the residue house and water quench pit. It is removed from the residue house by bucket loader or automatically by submerged drag chain conveyer.

This simple refractory vee-hearth design avoids the high maintenance problems occurring with the moving metal grates used in most incinerators. The abrasion resistant hearth will require periodic repair or replacement, which is facilitated with its modular construction.

4. ACID GAS CONTROL WITH DRY SORBENT INJECTION

The combination of Dry Sorbent Injection (DSI) coupled with a reverse-pulse baghouse is the most efficient method of acid gas and particulate control. The US EPA now calls this BACT, i.e. the Best Available Control Technology. Especially for the medium sized systems, this dry injection process with sodium bicarbonate or hydrated lime has significant advantages.

The process works by injecting a finely ground caustic sorbent continuously into the post combustion ductwork, following the boiler and conditioning tower, and preceding the particulate control device. The sorbent reacts with the acidic gases to form neutral salts which are captured along with excess sorbent and particulate and removed as residue from the baghouse hoppers.

The advantages of the dry injection process will provide the best overall economic control technology for most applications. Some of these advantages are:

- Low capital investment
- Small space requirements
- Simplicity and dependability of operation
- Low maintenance costs
- No scrubbing water requirement or waste water disposal requirement
- Good sorbent utilization
- Works better with baghouses because of the sorbent coating on the bags
- Coating of the bags improves fine particulate capture
- A small quantity of residue is generated to dispose of

The levels of HCl and SO_2 leaving the primary chamber are related to the burning conditions in the chamber. High SO_2 concentrations can be generated by tires, sheet rock, composition shingles and other sulfur-containing waste in the feed. Low 0_2 concentrations in the primary chamber also appear to correlate with high concentrations of $S0_2$. Gypsum and other sulfate materials in the bed may be liberated as reduced sulfur under low 0_2 conditions. These gases would then be oxidized in the flame zone to SO_2. Under normal high 0_2 (oxidizing) conditions these materials would remain in the bed as sulfate residue and would be disposed of in the bottom residue. Plastics and other chlorinated materials cause high HCl concentrations in the exhaust gases. Thus, effective control of acid gas emissions requires more than just sorbent injection.

5. BAGHOUSE

Of the two scrubber options most common for MWC's, the highest performance technology is provided by the fabric filter (baghouse), compared to that of the ESP (electro-static precipitator). The baghouse achieves significantly better control and collection of particulate (especially PM 10, the finest sizes), organics, metals, and acid gas.

The boiler, gas conditioning, and acid gas control systems are followed a multiple cell, reverse pulse baghouse to collect particulate and augment the scrubbing process. The particulate and injected lime collects on the outside of each of hundreds of bags. As the cake of particulate builds up on the bags, pressure drop across the bags increases. This higher pressure drop triggers a periodic pulse of compressed air into the clean side of the bags knocking the collected cake off into the hopper for removal.

Approximate air-to-cloth ratio used will be between 3 and 4 to 1. Normal bags used are woven fiberglass with acid resistant finish, although bag material must be tailored to the specific application. There are some excellent new technology bag material that may be used. Designed normally operating pressure drop across the bags will be approximately 5" H_2O. This will be regulated by a Magnehelic gauge and automatic controls to minimize the pulse cleaning commands and minimize bag wear. Maintenance of a minimum level of pressure drop rather than zero is important to ensure retention of a small filter cake of particulate and lime on the bags. This cake both protects the bags and improves filtering efficiency.

The baghouse steel shells are insulated for protection from condensation of the acidic gasses inside. Optional hopper heaters can help keep the cells dry during shutdowns. Heaters also permit the baghouses to heat up quickly at the startup and to cool down slowly on shutdown to avoid condensation and resulting bag blinding and cell corrosion. Multiple cells in larger installations allow on-line maintenance by permitting isolation of each cell individually without shutting down the total combustion process.

6. <u>ID FANS AND STACKS AND DUCTING</u>

The ID (Induced Draft) fan is placed downstream of the baghouses, i.e. on the clean side after all particulate and acid gasses have been removed. This protects the fan from erosion and corrosion. It is designed for continuous, high temperature operation. CEM's (continuous emission monitors) are located in this clean area also.

Its inlet vane damper (or optional variable speed control) is regulated by signal to maintain a slight negative pressure in the primary combustion chamber. This arrangement automatically matches system gas flows to the rate of combustion. The location of the fan at the end of the combustion train causes all equipment to operate in a negative pressure condition, thereby preventing leakage of fugitive gasses to escape to atmosphere.

The stack following the ID fan is insulated or refractory lined because of the relatively cool nature of the gases at this point and the tendency for corrosion. All ducting for gasses is insulated for protection against condensation and heat loss.

7. <u>DE-NOx & WET SCRUBBER</u>

To meet EU Emission Standards or other stringent emission regulations, we add a dry urea injection system to control NOx. And install a Wet Scrubber to control HCl's. So, WCS is able to adapt to ever changing emission control standards.

8. <u>COGENERATION</u>

Cogeneration can be provided, and it normally provides a very attractive payback. MSW is a very valuable waste if productively used to recover its potential energy and generate power and/or steam. The energy efficiency of cogeneration can be twice that of the large, mainline fossil fuel power plants. If an extraction turbine is chosen and the steam is used for some type of process heating such as desalination, the electric power available is less but the value of the total energy recovered is significantly higher.

With world headline news recently focusing on the negative effects of CO_2 emissions and global warming, it is very significant to understand that combusting MSW emits far fewer harmful greenhouse gasses than emitted by sending the equivalent waste to decompose in a landfill.

In addition to emitting less harmful greenhouse gasses than landfilling, recovery of the energy from MSW displaces irreplaceable fossil fuels which otherwise would have been burned to produce this energy. Thus waste-to-energy plants from MSW are very valuable for environmental reason and need to be strongly encouraged from this important perspective.