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# GASIFICATION OF MSW IN SOUTH KOREA

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## ABSTRACT

Over the past 15 years, South Korea has been actively pursuing a sustainable waste management strategy, which includes the thermal treatment of non-recyclable waste. Over 18,000 tons/day of waste are thermally treated in South Korea in over 40 plants. Since municipalities are not allowed to export waste outside of their respective jurisdictions, plants range in size from 25 ton/day to over 500 tons/day.

There are currently 7 plants on 6 sites using gasification technology in South Korea, with the first plant in operation since 2001.

The purpose of this paper is to describe how the downdraft gasification technology works, integration of the technology into a complete energy from waste facility, operating history, availability, emission levels and lessons learned.

Synopsis of the technology: Curbside Municipal Solid Waste (MSW) is rough shredded and fed into the primary chamber through an air lock. The gasification occurs in the low temperature negative pressurized primary chamber where the MSW goes through drying, pyrolysis and gasification stages. The resulting syn-gas is filtered through the char bed into a secondary chamber where combustion takes place, producing a hot inert flue gas. A Heat Recovery Steam Generator (boiler) is used to recover the thermal energy from the flue gas. The char at the bottom of the primary chamber is oxidized, creating the heat for the gasification process. The air pollution control system is located after the Boiler and consists of carbon and lime injection followed by a bag filter.

Operating history, availability and emission levels are presented.

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## INTRODUCTION

Municipalities in South Korea must deal with their own waste within their respective municipalities. This has lead to the development and building of many small scale plants in addition to the more traditional larger scale mass burn facilities.

The patented SK1000 technology, owned by OE Gasification in the USA, is designed around a module capable of treating about 25 metric tons of MSW per day. The basic design parameter for the technology was based on achieving a constant energy output from a variable BTU value feedstock.

The basic system consists of the core gasification technology: primary, secondary chamber and a cyclone, a heat recovery steam generator (boiler), and a bag filter system with lime and activated carbon injection. Steam from the boiler can be used directly for industrial process heating or to generate electricity using a steam turbine generator. See Figures 1 and 2

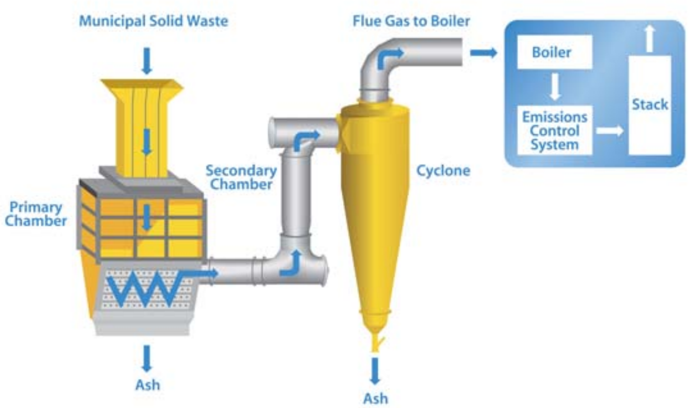


Figure 1

## THE CORE GASIFICATION TECHNOLOGY

### Fuel receiving and Handling

Curbside waste is received directly at the gasification plants. Large non-combustible materials are set aside, and the remaining waste is shredded to a nominal size of 2 inches by 2 inches by 12 inches long. Because a homogeneous feedstock is not required for the gasification plant to operate well, there is no mixing or fine grinding of the feedstock required, a basic shredder is suitable to handling the shredding requirements. Ferris metals are recovered using a magnet. Typical energy value of the MSW ranges from 2,500 to 6,000 BTU/lb, with moisture content up to a maximum of 60%.

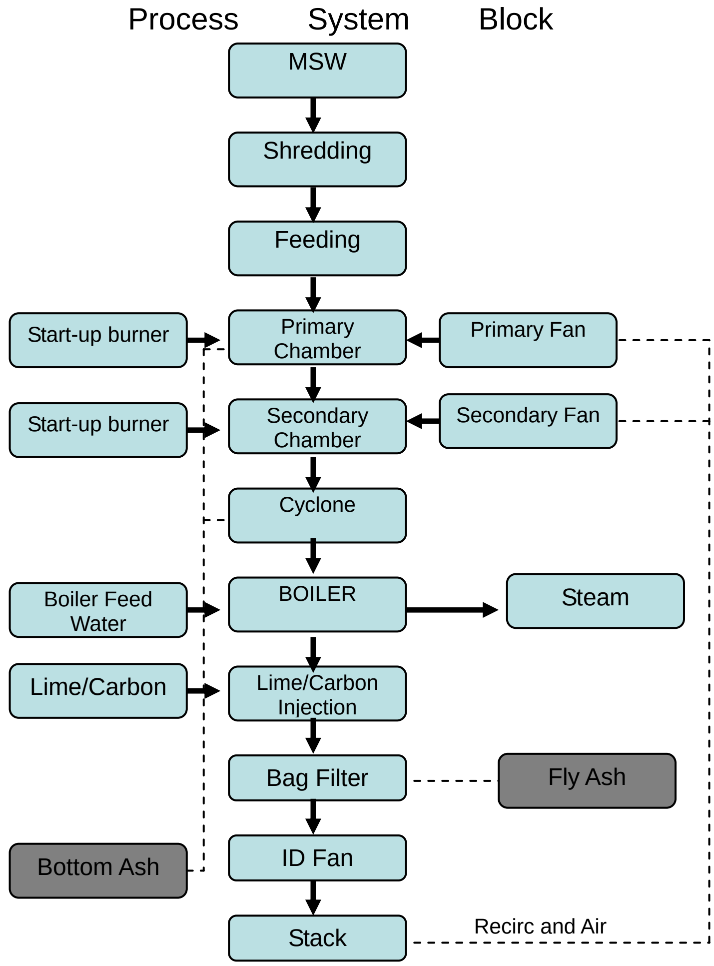


Figure 2

### Energy Production System

The SK-1000 core technology consists of a primary gasification stage, followed by a secondary combustion stage, and a cyclone for final flyash removal and combustion.

The MSW is fed into the top of the primary chamber of the gasifier. In the top half of the primary chamber the waste goes through the primary chamber in three distinct phases; drying, pyrolysis and gasification, to form the syn-gas. The top half of the chamber is oxygen starved and temperatures are controlled to prevent full combustion from occurring and the syn-gas and the remaining char are formed.

The char drops to the bottom of the chamber, were just enough air is added for a controlled combustion of the char.

As the char is exhausted of carbon, it drops further until it starts to cool and is released into a waterbed seal at the bottom of the primary chamber. The heat from the char is used to provide the energy for the drying, pyrolysis and gasification process in the top half of the primary chamber.

The syn-gas is drawn out of the primary chamber into the secondary chamber. As it does so, it moves though the bed causing a water shift reaction to occur in the char bed resulting in a higher concentration of hydrogen in the syn-gas and reducing the carbon content of the ash.

In the secondary chamber a mixture of air and inert gas (exhaust gas) is injected and the syngas is combusted. The amount of fresh air and inert air is carefully controlled to ensure that the temperature stays within the operational guidelines and to minimize NOx formation. The flue gas enters the cyclone where combustion is completed and remaining particulates are collected in a fly ash collection system.

In normal operating conditions, the primary chamber temperatures are typically below 600 Deg C and the secondary chamber is about 1,000 Deg C.

The primary chamber operates at a negative pressure. The fuel enters the gasifier at the top through a controlled pressure lock to ensure that no false air enters into the gasification chamber. The introduction of air is controlled throughout the gasification process to control temperatures and the formation of syngas.

During a cold start-up process, the primary and the secondary chambers are heated by firing diesel burners to bring the operating temperatures up to 600 deg C and 1,000 deg C, in the primary and secondary chambers respectively, prior to combustion of the syngas. This controls emission levels from the gasification of the waste during start-up to meet air emission criteria. There is no requirement for auxiliary fuel apart from the start-up of the plant.

The unique aspect of the SK-1000 technology is that the gasification and syn-gas combustion processes are separated and controlled independently from each other. The volume and mixture of fresh air/inert gas and the temperature in both the primary and the secondary chambers is very closely controlled to optimize the respective gasification and combustion processes, and to minimize the production of air emissions. This control of the process also enables the system to continuously react to changes in the energy and moisture content of the feedstock. Figure 3 shows how stack gas is mixed with fresh air to control syn-gas formation and char combustion in the primary and secondary chambers, the cyclone and just prior to entering the boiler.

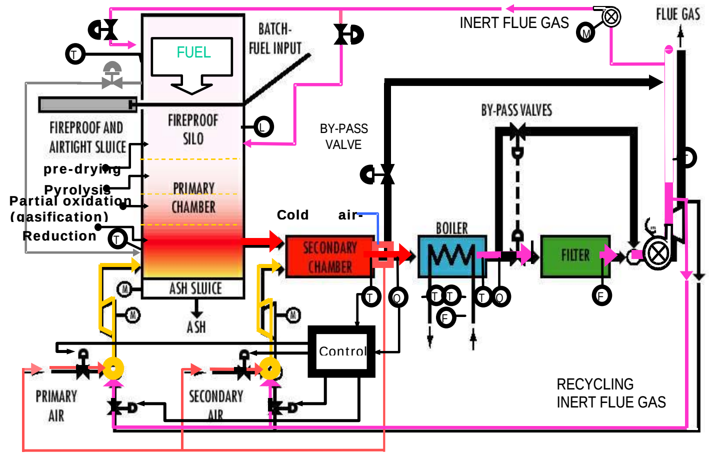


Figure 3

## ENERGY RECOVERY SYSTEM

Hot inert flue gas is discharged into a boiler at about 850degC at an estimated flow of 9,000 kg/hour per module. Depending on the how the energy will be used: different boiler designs are:

- firetube for low pressure steam or hot water
- watertube boiler for high pressure steam

The current operating plants use both boiler systems quite successfully. The primary purpose of the boiler is to recover energy and reduce the flue gas temperature prior to lime and carbon injection and the bagfilter. Boiler design is done to minimize the reformation of dioxins and furans during the cooling of the flue gas.

Air Emissions Control System.

One of the fundamental philosophies of this gasification system is to control the emissions in the gasification and combustion process and to minimize the amount of emission control equipment necessary. For example, most hazardous materials such as dioxin and furan are destroyed in the secondary chamber in high temperatures of about 1,000 Deg. C, and reformation is minimized through boiler design. The low temperatures in the primary chamber minimize the amount of volatile heavy metal in the flue gas, and the very careful control of air in the primary and secondary chambers minimize the formation of CO and NOx.
After the boiler, the flue gas goes through a dry reactor where activated carbon and lime are injected into the flue gas and thoroughly mixed before entering into the bagfilter system for final clean-up before going to the stack.

In South Korea, a government mandated continuous emission monitoring system is required (the data transferred is password protected to allow the government to obtain actual data) with online reporting to the central authority for NOx, SOX, HCL, CO and dust.

The continuous monitoring system starts from the day that the plant first starts operating, and there is no allowance for exceeding the guidelines during start-up.

Government authorities inspect and calibrate the continuous monitoring equipment at the initial start-up of the plant. The central authorities must be notified ahead of time when there will be a scheduled shut down for maintenance followed by a cold start-up.

Both the primary and secondary chambers are brought to up temperature prior to the introduction of the MSW to prevent the syn-gas from exceeding emission levels.

Please see Figure 4 for typical APC application

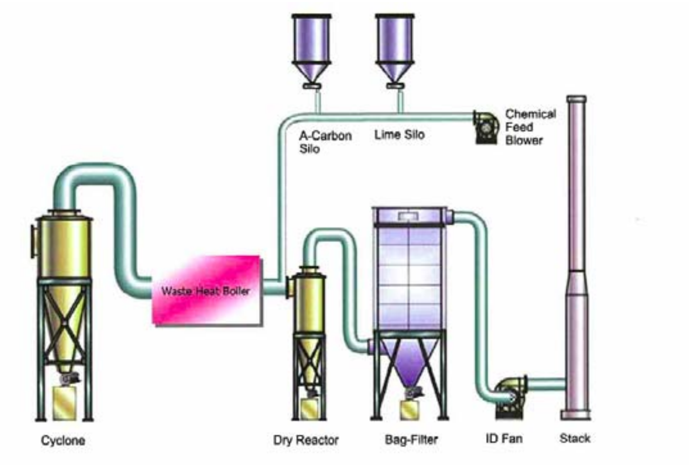


Figure 4

## CONTROL SYSTEMS

The control system is PLC based and automatically monitors and controls the gasification plant including the following aspects:

- Primary and secondary fans and the automated valves controlling the amount of inert gas and fresh air into the primary and secondary chambers.
- Fuel feed and level in the primary chamber.
- Temperatures and pressures throughout the gasification train
- Ash system control
- Process safety monitoring

The Human Machine Interface (HMI) is located in the control room and linked to the individual PLC units controlling gasification, boiler, bag filter and continuous emission monitoring system. The HMI is equipped with "lntellution iFIX with SMS alarming.

## PLANT OPERATIONS

Plants typically operate 315 days per year, or 86% availability. A shut down is planned about every 2 months, with the $6^{th}$ shutdown planned for 2 weeks. With improvements in operating procedures and equipment selection, plant availability is being increased.

For the calendar year 2008, the average availability of the 6 plants was 83%, ranging from a low of 70% for the Hapchon plant to a high of 90% for the Pyungchang plant. See Appendix 1 for the plant by plant data. Ash from the primary chamber is typically less than 5% of incoming waste.

Day to day operation of the plant requires a single operator. A full staff complement is 9 people for 24/7 operation and includes a station manager/steam chief, maintenance manager and an administrative support person.

## EMISSION LEVELS

Emission levels are well within Ontario, Canada's A-7 guidelines, and outlined are also outlined in Appendix 1 . These are generally consistent with European and USA standards.

Plant emission levels at the Plant in South Korea all fall well within the permitted North American emission levels, and are significantly under the limits for a number of parameters including heavy metals, SOx, NOx and particulate matter.

## BENEFITS OF THE TECHNOLOGY

There a number benefits to the technology, it accepts a variable feedstock with minimal pre-treatment, it modular and compact, and permitting and siting may be more politically acceptable. A summary of the technical differences between small scale gasification and larger units is listed in Figure 7

| COMPARISON OF WASTE-TO-ENERGY GASIFICATION TECHNOLOGIES | | |
|---|---|---|
| **SYSTEM Variables** | **OTHER TYPICAL GASIFICATION** | **OE GASIFICATION SK1000** |
| **System Size** | Large-scale | Small-scale |
| **System Configuration** | Fixed | Modular / Scalable |
| **Fuel Type Capability** | Single-fuel | Multi-fuel |
| **Fuel Mix Capability** | Fixed | Variable |
| **Process Temperature** | High | Moderate / Controlled |
| **Reactor Type** | High-pressure | Under-pressure, Downdraft |
| **External Fuel or EnergySource** | Required | Not required |
| **Ash Output** | Solid / Glasified | Loose |

Figure 7

Accepts a variable feedstock.

Many gasification technologies require a fairly homogenous feedstock to operate. This is because the syn-gas is either cleaned so that it can be combusted directly in a recip engine, or is refined to produce ethanol or other products.

Because the chemical composition of the syn-gas is very dependant on the composition of the feedstock, for those processes to work effectively, the composition of the feedstock must also be very closely controlled. Extensive shredding and pretreatment of the waste is usually required to make a homogenous feedstock.

However, with the SK1000 system, because the syn-gas is combusted in the secondary chamber, the precise composition of the syn-gas is not critical. Therefore changes in the feedstock do not have a significant impact of the overall operation of the process. Moisture content can be as high as 60% and vary though the day or season. The control system maintains a constant energy output by adjusting for the variation in the feedstock energy value and composition.

Compact Size and Modular Approach

The technology is based on modular approach to the thermal treatment of MSW, with each module capable of processing approximately 7000 tons of MSW per year and producing approximately 6.2MMBTU/hour of steam/hot water energy.

A three unit plant processing 20,000 – 25,000 tons of waste per year is about 100 ft by 150 ft in size, see appendix 2 including the waste receiving pit. Given this small size, this plant can be located adjacent to existing steam/hot water users like food manufacturing plants, chemical processing plants, hospitals and the such. Unlike large mass burn systems, additional capacity can be added or subtracted in small increments as conditions change.

Simplified permitting and public acceptance

Permitting and other regulatory requirements may be simplified with a small scale system. In Ontario, for example, only a certificate of approval (CofA) is required if the plant size is less than 100 tons per day and the steam/hot water is used as an input to a manufacturing process. An environmental assessment is not required.

Municipalities that have limited capacity in their landfills have a limited number of solutions. They have to either build a new landfill, which is expensive and politically unpopular, or thermally treat waste, which is also politically unpopular. Rather than having to build a large and expensive centralized thermal treatment facility, municipalities or district as small as 50,000 people can have a cost effective thermal treatment waste option. The political compromise becomes that a small scale thermal treatment facility may be acceptable, as long as we are not importing waste from outside our jurisdiction: it become a locally made solution.

For larger municipalities, a number of small scale facilities will provide greater flexibility and security. With a single large unit, an unplanned shutdown could cause a significant, disruption. With a number of smaller independent plants the impact of an unplanned shutdown can be more easily distributed to the other facilities.

## SUMMARY

The SK1000 technology has been operational in 2001. The technology is well understood, and provides a good alternative when small scale applications are required.

## Appendix 1

**Operating Plant Data Gasification Plants in South Korea using the SK1000 technology**

| Parameter | Emission Limit | Typical EFW | Unit | Heanam | Gangjin | Bosung I&II | Pyungshan | Hapchon |
|---|---|---|---|---|---|---|---|---|
| Rated Capacity | | | tonnes/day | 20 | 25 | 45 | 25 | 20 |
| Estimate energy value of the waste (k Cal/kg) | | | kCal/kg | 2,400 | 2500 | 2,200 | 2500 | 3000 |
| Actual Material Processed (2008) tonnes | | | tonnes | 7,200 | 6500 | 13,300 | 8200 | 7100 |
| Days available ( not down for maintenance), 2008 | | | days | 300 | 295 | 315 | 330 | 290 |
| Primary/cyclone ash tonnes for 2008 | | | tonnes | 324 | 325 | 465 | 287 | 213 |
| Bag house ash tonnes for 2008 | | | tonnes | 112 | 101 | 186 | 92 | 70 |
| **Emissions** | **Ontario, Canada A-7 Emission Guidelines** | | **Units Korean Plants** | **Heanam** | **Gangjin** | **Bosung I&II** | **Pyungshan** | **Hapchon** |
| Average daily emmission levels | | | | | | | | |
| particulate matter (PM) | 17 mg/Rm$^3$ | 6.9 mg/Rm$^3$ | mg/Sm3 | 6.09 | 12.99 | 5.33 | 8.03 | 6.02 |
| cadmium (Cd) | 14 µg/Rm$^3$ | 4.9 µg/Rm$^3$ | µg/Sm3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| lead | 142 µg/Rm$^3$ | 44.5µg/Rm$^3$ | µg/Sm3 | <3 | <3 | <3 | <3 | <3 |
| mercury | 20 µg/Rm$^3$ | 10 µg/Rm$^3$ | mg/Sm3 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| dioxins and furans | 0.14 ng/Rm$^3$ as ITEQ | 20 pg/Rm$^3$ as ITEQ | ng/Sm$^3$ as ITEQ | 0.04 | 0.04 | 0.07 | 0.02 | 0.04 |
| hydrochloric acid (HCl) | 18 ppmv (27 mg/Rm$^3$) | 9.2 mg/Rm$^3$ | ppm | <13 | <13 | 12 | 10 | 11 |
| sulphur dioxide ($SO_2$) | 21 ppmv (56 mg/Rm$^3$) | 10.8 mg/Rm$^3$ | ppm | <10 | 8.1 | 5 | 11 | 9 |
| nitrogen oxides ($NO_x$) | 110 ppmv<br>200 mg/m3ndg | 94.8 mg/Rm$^3$ | ppm | 41 | 45 | 23 | 30 | 33 |
| organic matter | 100 ppmv undiluted (as methane) | | CO ppm | <10 | <10 | 5 | 4 | 6 |
| | | | Source: Kentec Files | | | | | |

# Appendix 2

Typical plant layout for power generation:  overall dimensions 110ftX120ft