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GASIFICATION PROCESS: AN ITALIAN CASE STUDY

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ABSTRACT

This process through the indirect use of intense heat in the absence of oxygen is able to reduce the material covered in fuel gas and organic matter. which reduces the material in a combustible gas and inorganic matter. The Thermax© pilot plant allows a thermal degradation that completely sanitizes waste destroying its toxic components through molecular dissociation. This technology also stands for zero emissions of harmful residues. The operating principle is to exploit fully the calorific value of waste, this allows to derive the syngas (Synthetis Gas, a mixing gas, composed by CO, H2, CH4 and CO2), which is then converted into electricity. Main component of this plant is a pyrolysis reactor, capable of operating at temperatures ranging from 450 to 1800 °C. The temperature control is enabled through the use of a special tungsten thermostat that allows the maintenance and control of the right temperature inside the reactor itself. A security system, high-quality service, is able to shut down the reactor in case of overheating or if he is missing the cooling water. The reactor is constructed with special materials that can withstand oxidation and corrosion. The Thermax© was constructed with a number of reactors in series, each of capacity of 25 T, this allows you to manage different types of waste. This particular constructive feature of Thermax© is a big advantage because you can work in a continuous cycle, allowing:

- waste disposal 24 hours a day;
- optimal management of the reactors without interrupting the cycle of production of electricity;
- no detention for maintenance, each reactor being independent can be stopped and cleaned while the others continue their cycle of disposal/production;
- versatility, you can start with a small plant, such as 100 T/d, and then add any additional reactors in battery thus increasing the total power plant.

Only initially in the starting phase, the Thermax© requires electrical power, then the power of its components is given that the same plant from the electricity produced during the processing cycle.

Key words: gasification; incineration; waste treatment; pyrolysis.

INTRODUCTION

The gasification process is a thermal treatment of metropolitan solid waste (MSW). The main objective is to transfer energy from a solid fuel, the MSW, to another one, the waste gas. Historically this technology has been developed using different fuels: first coal, biomass, and refuse derived fuel. However, it should be noted that the gasification is one technology trial. The process involves subjecting the stoichiometry refusing to three successive stages: combustion, pyrolysis and conversion to gas, the treatment is self-perpetuating. Gasification can be performed by different operating models depending by the type of gasification agent used (air, oxygen or steam) and the type of system used. Particular importance is the treatment by some of the same substances that could damage downstream equipment and polluting compounds. Before thermal degradation reactor accept material undergoes pre-treatment according to the waste composition, e.g. shredding, sterilizing, metal separation etc. The waste is automatically fed into the ultrahigh temperature reactor. Heated with induction electricity, this thermal reactor allowing operation temperatures between 300 – 1900 °C. With this reactor, which is operated without air or oxygen, the waste is separated into two fractions:

- energetic gas;
- inorganic, inert residue.

All organic component of the waste entering in the gaseous phase.

MATERIAL AND METHODS

Core plant is the gasification reactor. The solid fuel (wastes) is kept in suspension by an upward gas flow provided by some devices placed in the lower section of reactor. Inside the bed kept in constant motion from the gas mixture, reactions take place gasification and partial combustion of solid, its estimated that the reaction temperature in the bed of the order of 1000 °C o more. The indicative temperature of this incoming mixture is 100 – 150 °C. Its expected to obtain a fuel gas with a composition provided by:

- H2 max 15%
- CO max 25%
- CO2 max 15%
- CH4 max 2%
- N2 to completion

The syngas leaving the gasification reactor is cleaned by unburned part usually like tarry residues before further utilized. Before using a gas sample is analyzed to assess the composition, the calorific value and the combustion residue. The plan is equipped also by a waste receiving and preconditioning where the waste material can be stored separately, depending on its nature and composition. Automatic systems, for recycling purposes, are available for the separation of ferrous and non-ferrous metals and light fractions of the waste.

Combustion reactions		
1	$C + ½ O_2 \rightarrow CO$	-111 MJ/kmol
2	$CO + ½ O_2 \rightarrow CO_2$	-283 MJ/kmol
3	$C + O_2 \rightarrow CO_2$	-394 MJ/kmol
4	$H_2 + ½ O_2 \rightarrow H_2O$	-242 MJ/kmol
5	$C_nH_m + {}^n/_2\, O_2 \leftrightarrow n\, CO + {}^m/_2\, H_2$	exothermic
Reactions involving steam		
6	$C + H_2O \leftrightarrow CO + H_2$	+131 MJ/kmol
7	$CO + H_2O \leftrightarrow CO_2 + H_2$	-41 MJ/kmol
8	$CH_4 + H_2O \leftrightarrow CO + 3H_2$	+206 MJ/kmol
9	$C_nH_m + nH_2O \leftrightarrow nCO + (n + {}^m/_2)\, H_2$	endothermic
Reactions involving hydrogen		
11	$C + 2H \leftrightarrow CH_4$	-75 MJ/kmol
12	$CO + 3H_2 \leftrightarrow CH_4 + H_2O$	-227 MJ/kmol
Reactions involving carbon dioxide		
13	$C + CO \leftrightarrow 2CO$	+172 MJ/kmol
14	$C_nH_m + nCO_2 \leftrightarrow 2nCO + {}^m/_2\, H_2$	endothermic
Decomposition reactions of tar and hydrocarbons		
15	$pC_xH_y \rightarrow qC_nH_m + rH_2$	endothermic
16	$C_nH_m \rightarrow nC + {}^m/_2\, H_2$	endothermic

Table 1. Main reactions of the gasification process.

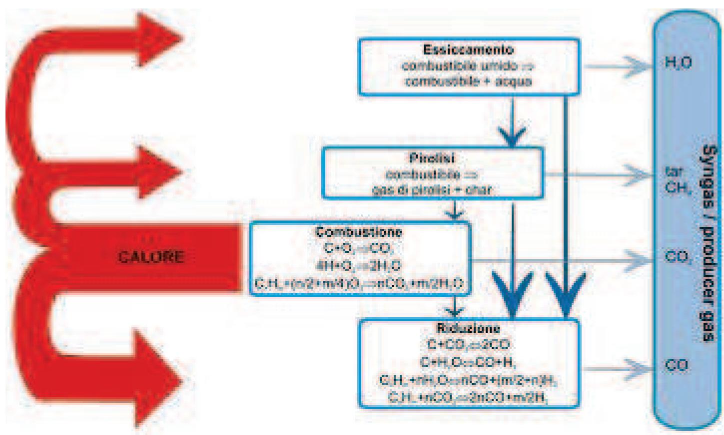

Figure 1. Gasification process.

The Thermax unit is equipped also by a pre-shredder system that break down the delivered waste material to the extent that trouble-free operation of the subsequent equipment can be ensured. In the fine shredder (secondary shredder) the waste material is further crushed into grain size particles, max 2.5 cm, to obtain the most practical size for homogenization and possible addition of substances to obtain best results during the gasification process.

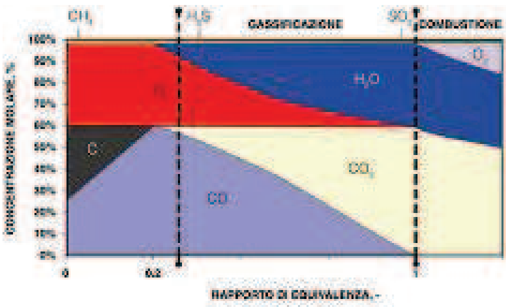

Figure 2. Qualitative evolution of the composition of gases produced by combustion.

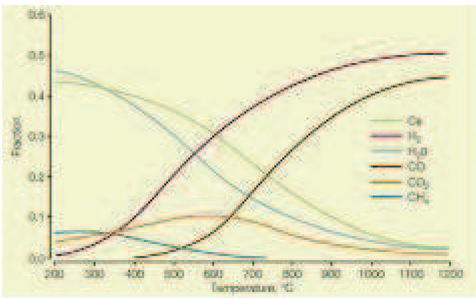

Figure 3. Equilibrium diagram for the gasification of a mass of MSW (formula C20H32O10) in the presence of 2 to 6 moles of oxygen and steam.

The shredding system provides a choice of screen sizes for optimum handling of all kinds of waste. The plant is equipped of monitoring system of temperature, pressure and volumetric flow of gas streams entering. Particularly monitoring of temperature gasifier in the reactor is made through a series of thermocouples placed along the reactor. The pressure measurement is carried out in several places, particularly upstream and downstream of the nearest gasification agent. The sampling of the solid is carried out in two points of the bed hot, through flange openings that allow withdrawals during operation. Before being sent to the reactor, wastes can be dried in a compact twin-line cascade drying system, whereby two units are operating simultaneously to dry the infeed material from approx 80% to approx 25% humidity. The waste is transported through heated pipes by augers. The heating of the cascade dryer is possible by utilizing the syngas from the Thermax© plant, which saves at least 100 l/h of diesel oil per 20T of waste. Emissions created by the drying process are cleaned with a scrubber and the fumes are treated with a bio-filter, which, after saturation, can be disposed of in the Thermax© ultrahigh-temperature gasification reactor.

The Thermax© carbonizer is designed to increase the throughput of the gasification unit and to obtain better energy efficiency. This carbonizer is composed of two stage places as much heat as possible into the gas streams entering the carbonizer to drive off volatile matter and reduce tars and oils by thermal cracking which is enhanced by the adition of sorbent. The carbonizer operates as a fluidized bed with a combustor providing flue gas as one fluidizing medium and preheated air as the other. This allows the coal to be devolatilized and the tars and oils to be thermally cracked due to the direct contact with the coal and hot flue gas. The device is designed to operated at high pressure from about 12 – 20 atmospheres, and will heat the material to a temperature of approx 400 °C. This temperature level will thermally convert to MSW volatile matter from a solid waste to a gas or vapour and then back to a distilled liquid, gas and treated residual solid (charcoal and glass) for delivery to the final high temperature gasification process. The Thermax© carbonizer will tumble, crush, heat and dried at 400 °C with a dwell time temperature of a least 3 minutes for complete sterilization of all pathogens and the elimination of odor. The primary process unit will also accomplish the majority of the overall volume reduction of the solids. The reduced volume of solid material is now odor free, semi crushed and is considered sterilized and preheated primary waste, suitable for injection into the secondary process unit of the Thermax© carbonizer for the final thermal conditioning. The gas will through a particulate filter system to remove any particulate material from the vapour gas stream. The particulate free gas will then proceed to the chiller and condenser units for distillation back to a liquid. The condenser system also produces a non-considerable off gas which will be transformed to the syngas storage unit. Waste material can be stored separately, this provides the option of combining the various types of waste later the process to obtain an optimum composition for gasification. In most cases a ground scraper insures proper forwarding of the material. The feed system is designed to allow a continuous and smooth feed of the waste stream into the gasification reactor. Its a transport system in form of either, a conveyor or a bucket feeder; an auger conveyor into the first storage bin which is airtight and gas-purged, and disposes of automatic level controls and safety valves. An oxygen detection system is included as well as a transport system with preheating possibilities, equipped with temperature control.

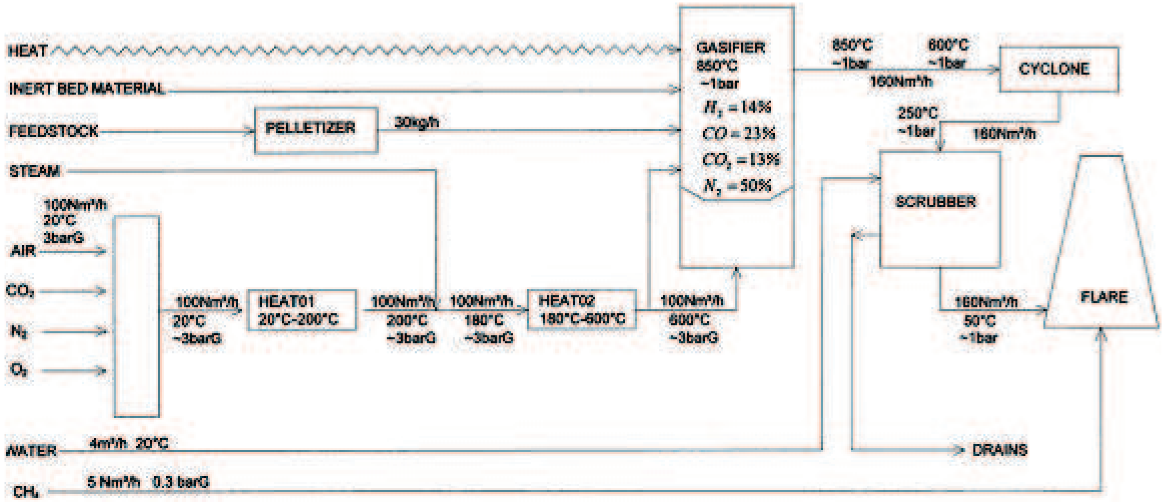

Figure 4. Thermax© plant: flux scheme

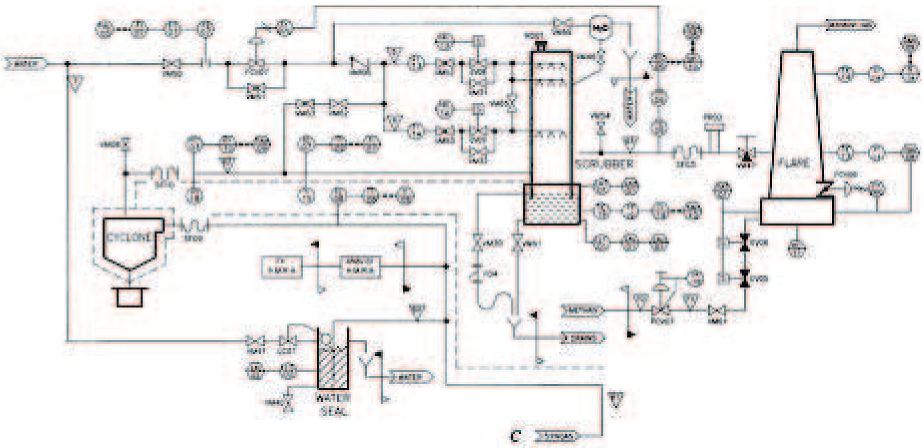

Figure 5. Thermax© gas treatment plant

The Thermax© ultra-high temperature degradation unit is working under neutral atmosphere, allowing the complete gasification of the feed material. Organics are converted to a syngas, inorganic to an inert, non-leachable, recyclable material. The energy for the reactor is provided by a specially tristate which produces induction electricity to heating the core of the reactor to temperatures adjustable up to 1500° C. The temperature control is provided by a special Tungsten thermostat, permitting precise keeping of temperatures in the reactor. The integrated security system will switch off the reactor in case of overheating or failure of the water cooling. An alarm system is also included for temperature failures. The solid residue is transported out of the reactor with an auger and collected in a container. The first auger transporting the residue out of the Thermax© gasification unit is appropriately cooled; by a secondary auger and a rotation valve, the material is forwarded and over 3 additional augers collected in the disposal bin. Thermax© plant is equipped by a gas train, the system comprises a standard wet scrubber with a particle collection system, including a cyclone and a liquid cleaning and neutralization system.

Temperature sensors, recoil valve and afterburner fulfill the security requirements. The liquid residue coming from the wet scrubber may has to be cleaned to recover heavy metals, hydrochloric acids and/or various salts. This equipment is only needed if such elements are founded in the gas. In the afterburner gases pass through a secondary chamber where natural gas flames combust any remaining organic material in the gases. The temperature of about 1800 °C, which arises from the reaction together with a residence time of about 0.3 seconds; after this time the remaining organic pollutants are totally decomposed in exhaust gas.

RESULT AND DISCUSSIONS

The advantage of Thermax© plant is that using the syngas is potentially more efficient than direct combustion of the original fuel because it can be combusted at higher temperature or even in fuel cells, so that the thermodynamic upper limit to the efficiency defined by Carnot's rule is higher or not applicable. Syngas may be burned directly in internal combustion engines, used to produce methanol and hydrogen, or converted via the Fischer-Tropsch process into synthetic fuel. The MSW introducing in this plant like a fuel are transformed thanks the high temperature combustion that refines and corrosive ash elements such as chloride and potassium, allowing clean gas production from otherwise problematic fuels.

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