Large-Scale Plasma Waste Gasification

Jason Robert Tavares, Lakshminarayana Rao, Chawki Derboghossian, Pierre Carabin, Aïda Kaldas, Philippe Chevalier, and Gillian Holcroft

***Abstract*—The plasma resource recovery system is a two-stage plasma gasification and vitrification system used to process municipal solid waste. A transferred arc discharge is used to generate syngas from the waste, and an air plasma torch is used to polish the gasification products. Online syngas monitoring can be employed to compensate for variations in waste feed, thus maintaining both the syngas composition (quality) and production rate.**

***Index Terms*—Arc furnace, chemical engineering, energy resources, gasification, plasma applications, plasma torch, waste management.**

THE ELEVATED energy densities, temperatures, and heat transfer rates of thermal plasma have made it a viable option for waste treatment. Plasma processing has been studied extensively over the years because of its ability to vaporize a wide range of compounds and break chemical bonds [1]–[3]. PyroGenesis Canada Inc. has developed and patented a two-stage plasma gasification and vitrification system, i.e., the plasma resource recovery system (PRRS), to treat and recover energy from unsorted municipal solid waste (MSW), as well as hazardous and biomedical waste [4]. The plasma processing section from a fully functional PRRS facility is shown in Fig. 2.

An arc furnace [Fig. 2(a)] is employed in the PRRS to both vitrify the inorganic components of the waste and gasify the organic portion, converting it to synthesis gas (syngas), CO and H_2. This primary thermal processing section makes use of a transferred dc arc discharge: the molten inorganic components (slag) form a conductive pathway for the arc, thus enhancing the transfer of energy. In essence, the slag acts as a resistive element in the electric circuit, converting the electric energy into thermal energy. A picture of the arc furnace in operation, showing the arc conducting through the slagged inorganic components, is given in Fig. 3.

The long residence time of the waste in the arc furnace promotes gasification of the organic components. However, some volatile hydrocarbons can be entrained by the syngas exiting the furnace. In order to maximize efficiency, the syngas produced in the arc furnace is fed to a secondary gasification chamber [Fig. 2(b)] where an air plasma torch (APT) is used to complete the gasification of any residual organic material. The APT uses a nontransferred arc and is capable of operating at a power of 200 kW (dc). The APT is shown in Fig. 1. The nontransferred nature of the arc discharge in the APT allows for very high energy densities to be attained and makes the APT most suited to intense gas heating applications. In the PRRS, the unrefined syngas has a short residence through the secondary plasma discharge, but, because of the high energy density, the remaining long-chain hydrocarbons in the gas stream are rapidly broken down into gasification products.

The refined syngas (typical composition of 24% CO, 6% CO_2, 15% H_2, and 55% N_2) is fed through a series of gas cleaning steps (including a rapid water quench, acid gas scrubbers,

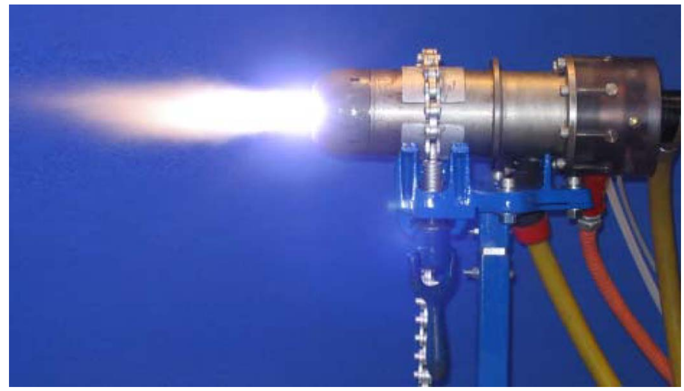

Fig. 1. Picture of the air plasma torch used in the secondary gasification chamber to refine the syngas produced in the arc furnace.

Fig. 2. (a) Picture of the arc furnace and (b) secondary gasification chamber of the 10.5-ton-per-day PRRS facility in operation at the Hurlburt Field U.S. Air Force facility.

Manuscript received December 1, 2010; revised March 22, 2011; accepted March 27, 2011. Date of publication May 5, 2011; date of current version November 9, 2011. This work was supported in part and commissioned by the U.S. Air Force Strategic Operations Command, by the U.S. Foreign Comparative Testing Program, by the U.S. Surgeon General, by the Québec Ministère du Développement économique, innovation et exportation, and by the Canadian Government TEAM program and Gulf Power.

The authors are with the PyroGenesis Canada Inc., Montreal, QC H3J 1R4, Canada (e-mail: jtavares@pyrogenesis.com; rnarayana@pyrogenesis.com; cderboghossian@pyrogenesis.com; pcarabin@pyrogenesis.com; akaldas@pyrogenesis.com; pchevalier@pyrogenesis.com; gholcroft@pyrogenesis.com).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TPS.2011.2138723

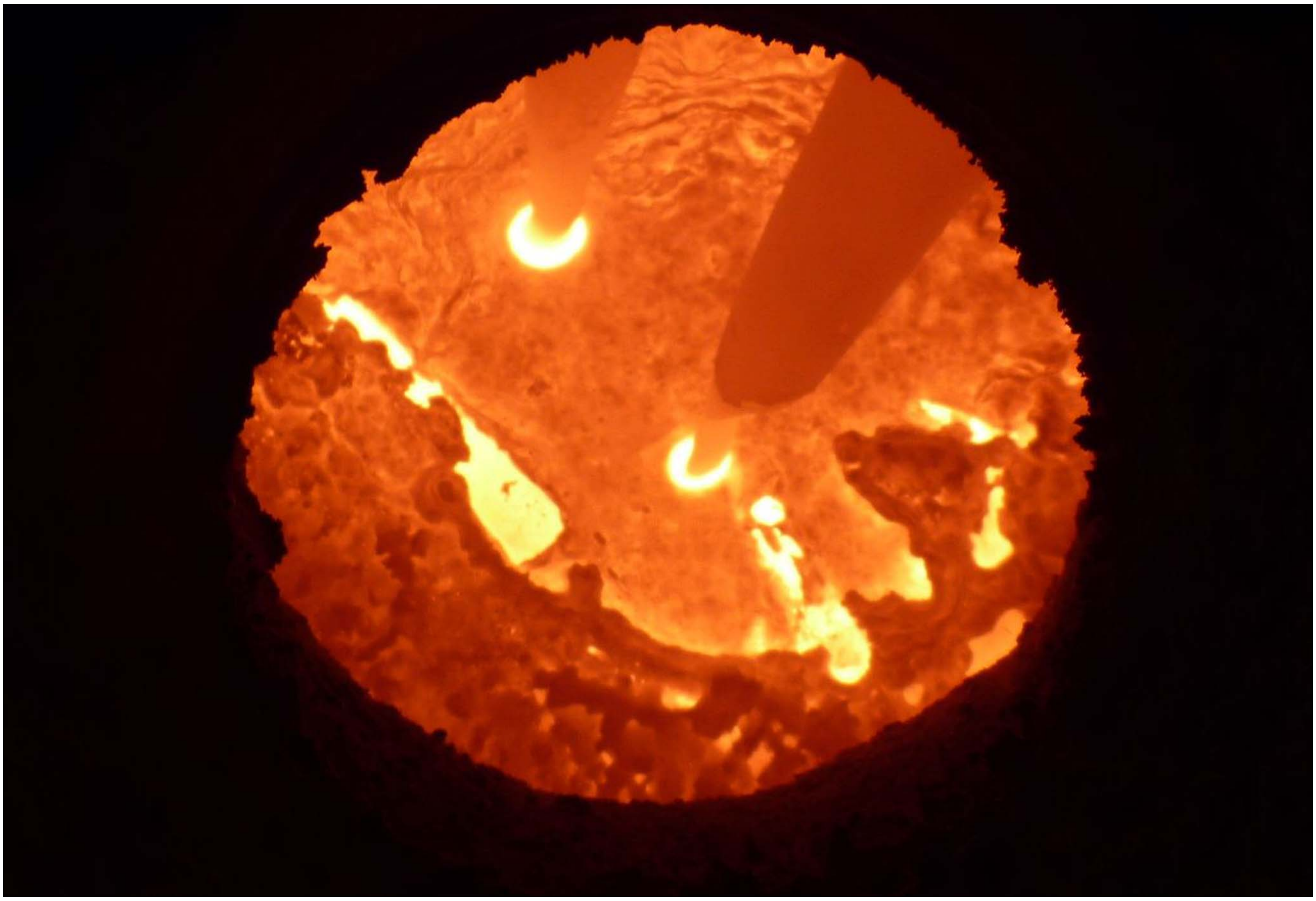

Fig. 3. Picture of the arc furnace in operation, showing two graphite electrodes driving an electric arc through slagged inorganic material and gasifying organic waste.

activated carbon, and HEPA filters) before being introduced into an internal combustion engine along with a stoichiometric amount of air. Combustion of the syngas produces electricity, which offsets the process requirements.

The moisture level and inorganic content of the unsorted MSW can vary significantly from day to day depending on the source of the waste. To assess the effect of these parameters, a computer model was developed; the results of which were validated using the experimental data obtained from pilot tests. Increases in moisture and, to a lesser extent, inorganic content were found to increase H_2 content and decrease CO production (overall decrease in the syngas' higher heating value). Moreover, the predicted mass of the syngas produced reduces as a result of such increases, given that the gasifiable organic content in the waste feed decreases proportionally.

Since variations in waste composition have a demonstrated effect on syngas quality and production rate, a continuous H_2 monitoring system (Infrared/Paramagnetic Multi Component Analyzer, Digital 600 NDIR/O_2) is employed. As such, fluctuations in waste composition can be compensated for online by varying the power level in the arc furnace.

References

[1] J. Heberlein, "Generation of thermal and pseudo-thermal plasmas," *Pure Appl. Chem.*, vol. 64, no. 5, pp. 629–636, 1992.

[2] M. F. Zhukov and I. M. Zasypkin, *Thermal Plasma Torches-Design, Characteristics, Applications*. Cambridge, U.K.: Cambridge Int. Sci. Publ., 2007.

[3] J. Heberlein and B. A. Murphy, "Thermal plasma waste treatment," *J. Phys. D, Appl. Phys.*, vol. 41, no. 5, pp. 1–20, Mar. 2008.

[4] P. Carabin, E. Palumbo, and T. Alexakis, "Two-stage plasma gasification of waste," in *Proc. 23rd Int. Conf. Incineration Therm. Treatment Technol.*, Phoenix, AZ, 2004.