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VITRIFICATION AND GASIFICATION OF PULP AND PAPER HOG FUEL BOILER ASH

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ABSTRACT

The burning of wood and bark residues in the North American pulp and paper industry generates approximately 1.3 million dry metric tonnes of ash annually (1 million tonnes in the US and 300,000 tonnes in Canada). Moreover, as more and more water treatment sludge is used in waste-to-energy systems, the amount of ash generated continues to increase. Most ash is disposed of in landfills or lagoons. The landfilling of ash consumes much space, as its bulk density is generally low (typically 0.3 kg/L). Landfilling can also result in leaching problems and special measures have to be taken to collect and treat the leachate.

PyroGenesis has developed and patented a plasma gasification and vitrification process for ash (PAGV). The process utilises a graphite arc and metered addition of air and steam to convert the organic portion of ash into a synthesis gas and the inorganic portion into an inert slag. The furnace allows for a dual mode of operation: non-transferred arc mode for pre-heating the non-molten ash and transferred arc mode for continuous melting of the ash.

The advantages of vitrification include a volume reduction of greater than 80% and a stabilization of the ash in a slag having very low leachability levels. In this process, the ash is treated immediately adjacent to its source at the plant. The arc furnace is installed as a new unit operation next to the main boiler. The ash is treated hot as it comes out of the boiler, thereby improving overall energy efficiency. The slag resulting from vitrification typically takes the form of vitreous rocks. The rocks can either be landfilled at much reduced cost or potentially used as a building material (e.g. aggregates or roadbed), thereby converting a waste into a useful product and eliminating landfilling completely.

The organic content of the ash contributes to improving the energy efficiency of the arc furnace. Pulp and paper boiler ash has been shown to contain 7 to 50% unburned organics. The PAGV process recovers the energy present in the ash by gasifying the organic portion of the ash. The energy released by the gasification of the organics provides some of the energy required for vitrification and, more importantly, the resulting synthesis gas (mainly carbon monoxide and hydrogen) can be fed back to the main combustion unit for use as a fuel.

A pilot plant capable of treating 50 kg/h of dry ash has been installed and tested for the purpose of demonstrating the process. Pilot plant trials were carried out to vitrify different types of ash obtained from Canadian pulp and paper mills. Measurements of leachability are presented. Synthesis gas composition measurements are underway, but are not presented in the current study.

INTRODUCTION

Many pulp and paper mills use hog fuel boilers to produce steam. These boilers burn bark and wood residue and generate 1.3 million dry metric tonnes of ash annually in North America. Up to now, the most widely used method of disposal for the ash resulting from burning has been landfilling. Some progress has been made in using ash residue as an agricultural soil additive (1,2). However, soils for which such treatment is suitable are limited. According to NCASI (National Council for Air and Stream Improvement), only 11% of pulp and paper ash residues can be used for as a soil additive. Moreover, some ash containing leachable heavy metals or salts can not be considered for this application.

Plasma (3, 4) and arc furnace technologies (5) have been under development for many years for the vitrification of combustion residues such as ash, in particular for municipal solid waste incinerator residues.

The patented plasma ash gasification and vitrification (PAGV) process (6) uses graphite electrodes to produce the plasma energy. The energy produced by the gasification of unburned organics to carbon monoxide (CO) and hydrogen (H_2) by dissociation of water is used to heat up the ash and synthesis gas to about 1100°C. The plasma arc energy is used to melt the ash to a slag and to increase the temperature to approximately 1500°C. Since the ash is treated hot, on site, as it comes out of the boiler, some of the latent heat from the boiler is recuperated thereby reducing the energy requirement of the plasma arc furnace. The synthesis gas can be returned directly to the boiler without further treatment, increasing the energy efficiency of the overall plant.

EXPERIMENTAL SETUP AND PROCESS DESCRIPTION

Raw Material

Ash from two different pulp and paper mills was used in these tests. For each mill, both fly ash and grate ash was evaluated (Table 1). The initial properties of the ash varied considerably in terms of moisture and volatiles content. Fly ash generally contains larger quantities of organics.

The properties of ash have been reported elsewhere to vary even more than indicated here (7). In an industry survey of boiler ash characteristics performed in 1996 (8), unburned carbon concentration was shown to vary between as much as 7 to 49%.

Pilot Plant Setup

A pilot installation capable of treating 50 kg/h of ash (mixture of fly ash and grate ash) has been used for testing the concept of ash vitrification and gasification (Figs. 1 and 2). The pilot installation includes a secondary combustion chamber,

TABLE I
Sample Properties of Fly Ash and Grate Ash from Two Different Paper Mills

Source	Moisture	Organic Content	Bulk Density (kg/m^3)
Grate Ash – Mill A	37.0%	4.9%	467
Fly Ash – Mill A	31.5%	8.6%	711
Grate Ash – Mill B (Sample 1)	39.7%	6.4%	378
Fly Ash – Mill B (Sample 1)	31.7%	14.4%	684
Grate Ash – Mill B (Sample 2)	46.1%	14.0%	640
Fly Ash – Mill B (Sample 2)	46.1%	25.7%	450

water quench and scrubber, since the unit was not installed near a hog fuel boiler and recycling of the synthesis gas was therefore not possible.

Ash preparation and feeding

As ash is received wet from the pulp and paper mill, it must be dried prior to treatment. A rotary dryer is used to reduce moisture content to a maximum of 10%. The ash is screened to remove oversized material, which is then crushed and incorporated with the bulk of the ash. Ash can be fed to the furnace as pure fly ash, pure grate ash, or a mixture of the two. Ash is stored in a hopper and fed to the furnace using a rotary valve. The valve operates in an on/off mode in order to control the flow to 50 kg/h.

Furnace

The furnace comprises a crucible, of approximately 100 liters capacity and a gasification zone above the melt which has approximately the same volume. Two graphite electrodes are used for melting the ash (Fig. 3). Initially, the electrodes are oriented close to the horizontal and a DC arc is struck between them. This is the non-transferred arc mode of operation. As the furnace heats up and the ash starts melting, a slag bath forms in the crucible. The electrodes can then be positioned approximately vertically. The slag is sufficiently electrically conductive that two separate arcs form. The resulting transferred arcs are i) between the graphite cathode and the molten slag and ii) between the molten slag and the graphite anode. The transferred mode of operation is generally more efficient in melting and maintaining a molten ash bath. Once the transferred mode of operation is established, ash can be fed continuously to the furnace.

In order to improve heat transfer to the melt, the furnace can be operated with an iron heel below the ash melt: a layer of iron, a few inches thick is present below the molten slag. In this case, electric current flows preferentially through the highly conductive iron (molten or solid) layer.

Tapping is carried out periodically (typically after eight hours of production) by opening a pre-drilled tap hole using a drill bit or steel burning bars. The slag can be poured into molds to form ingots, or granulated by pouring into a large water tank.

Off gas treatment

In the pilot installation, the synthesis gas is oxidized to carbon dioxide and water in a secondary combustion chamber (SCC). Propane burners maintain the chamber temperature at 1100°C. The SCC residence time is approximately two seconds. The gases are quenched immediately downstream of the SCC to

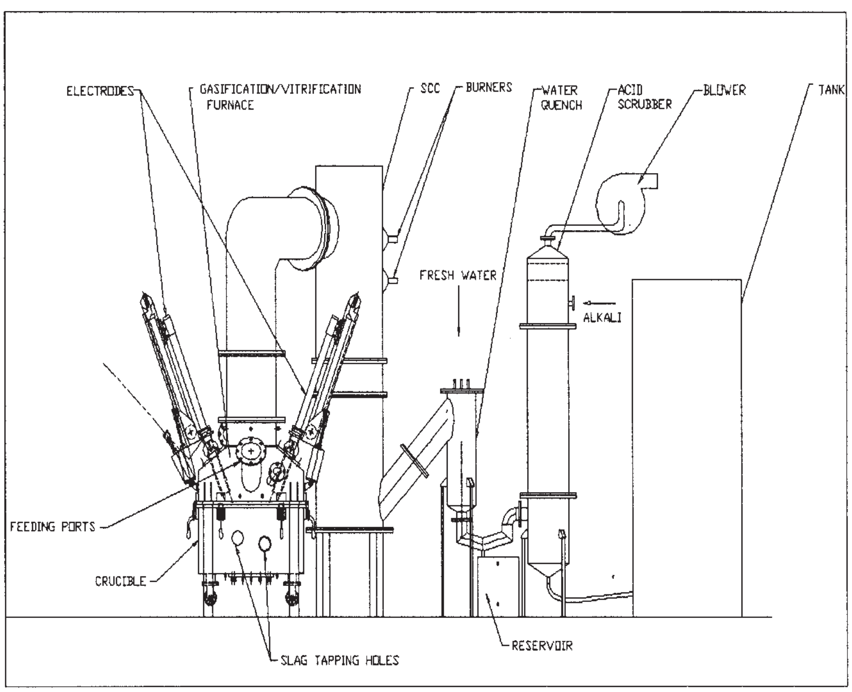


Fig. 1. Pilot plant schematic.

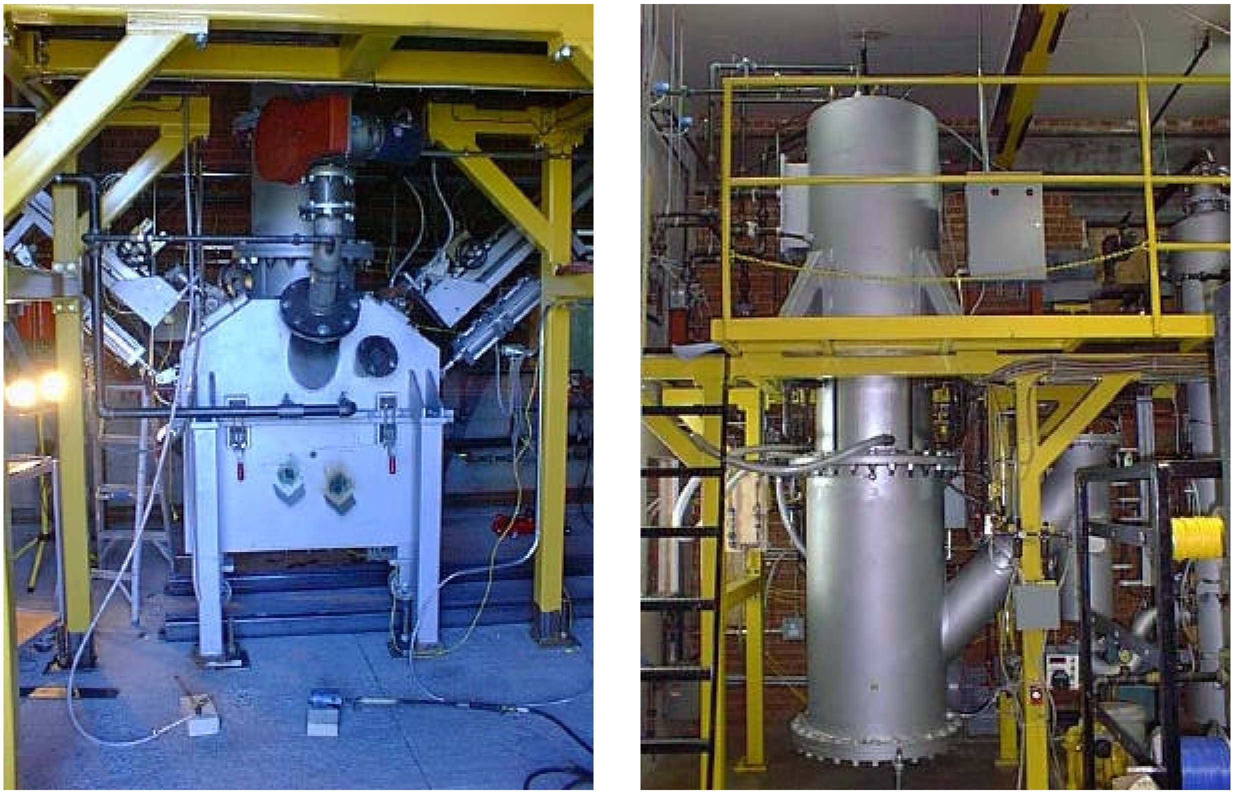


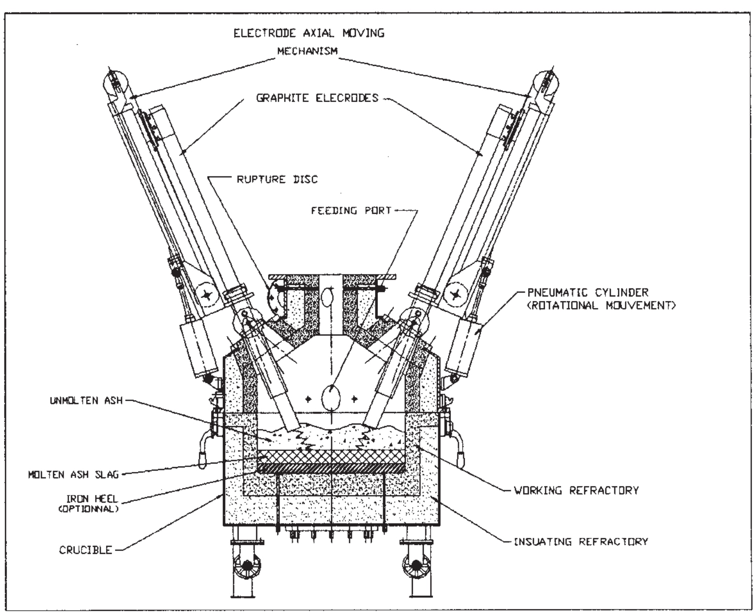
Fig. 2. View of the pilot plant: PAGV furnace (left) and off-gas treatment equipment (right).

approximately 75°C using atomizing nozzles in a quench vessel, in order to avoid synthesis of dioxins. The gases then pass through a wet scrubber (packed tower type) where the acid gases are neutralized using a caustic soda solution (NaOH). A wet bag filter is used to remove particulates. An induced draft blower vents the off-gas to atmosphere through the stack.

RESULTS AND DISCUSSION

The furnace can be operated in non-transferred and transferred arc mode under the operating conditions shown in Table II. By using an ash covered arc and by adjusting the position of the electrodes, the arc voltages could be balanced and adjusted relatively easily. Once transferred, the arcs were stable.

Five runs were done with the furnace and in all cases, ash was vitrified successfully (Fig. 4). The resulting vitrified rock had a density between 2000 and 3000 kg/m^3 depending on the operating conditions, type of ash and pouring procedure. Ash pouring was also done in water in order to granulate the slag. In this case the density of the vitrified ash granules was in the same range as that of the ingots, at 2400 kg/m^3. The bulk density, however, was lower at 900 kg/m^3.



Fig, 3. PAGV furnace schematic.

TABLE II

Furnace Operation Characteristics

Non-transferred arc characteristics	Single DC arc 100-200 V 300-700 A
Transferred arc characteristics	Two balanced short DC arcs Each arc: 50-100 V Current: 300-700 A
Furnace pressure	Slightly negative (< 1" H_2O) in order to pull gasification gases while limiting air leaks into the furnace to a minimum
Slag tapping temperature	1250 – 1550 °C

Fig. 4. Vitrified block of Hog fuel boiler ash.

TABLE III

Toxicity Characteristics Leaching Procedure (TCLP) Results

Metal	**Measured Concentration in Slag Leachate (mg/L)**	**US EPA 40 CFR Ch. 1 (7-1-97 Edition) § 268.48 Land Disposal Regulation**	**US EPA 40 CFR Ch. 1 (7-1-97 Edition) § 261.24 Hazardous Waste Regulation**
As	< 0.002	5.0	5.0
Ba	< 0.4	7.6	100.0
B	< 0.3	-	-
Cd	0.006	0.19	1.0
Cr	< 0.03	0.86	5.0
Cu	< 0.03	-	-
Ni	< 0.04	-	-
Pb	< 0.06	0.37	5.0
Se	0.009	0.16	1.0
Zn	< 0.02	5.3	-
Hg	< 0.0002	0.025	0.2

The carry over of ash into the off-gas system was measured after two experiments and was shown not to exceed one percent of the total amount of ash fed to the furnace. The carry over material was collected in the off-gas duct work and treatment equipment downstream from the furnace. It was weighted against the feed material weight.

The toxicity characteristics leaching procedure (TCLP) was performed on one typical slag resulting from the treatment of a mixture of grate and fly ashes. Concentrations of the main heavy metals in the leachate were measured and are recorded in Table III. Concentrations were all significantly below regulatory limits.

CONCLUSION

The ability to vitrify pulp and paper hog fuel boiler ash in a DC arc furnace has been demonstrated using a dual transferred/non-transferred mode of operation. Good arc stability was possible using the molten ash slag to transfer the arc. Dense slag ingots were obtained by treating the ash in the PAGV furnace. Gasification characteristics and electrode consumption will be optimized in the near future to improve the process energy balance and economics.

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