Proceedings of NAWTEC16
16th Annual North American Waste-to-Energy Conference
May 19-21, 2008, Philadelphia, Pennsylvania, USA

NAWTEC16-1901

PLASMA ARC GASIFICATION FOR SOLID WASTE DISPOSAL UPDATE ON ST. LUCIE COUNTY, FLORIDA PROJECT

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ABSTRACT

Plasma arc gasification is an emerging technology for generation of renewable energy and other by-products from a variety of waste. This bold technology is under development in a number of locations around the world, although it is too early to fully know if the technology is technically feasible and economically viable on a truly heterogeneous municipal waste stream like that found in the U.S.

Plasma arc technology in the United States in other applications dates back approximately 40 years when it was utilized by NASA to test heat shield materials for spacecraft. In 1989, plasma arc technology was used in an iron melting furnace in Defiance, Ohio (USA). Plasma arc gasification has been used in municipal solid waste destruction since 1999 in Japan for destruction of solid waste and automobile shredder residue. Plasma arc gasification heats waste materials to temperatures in excess of 10,000 degrees Fahrenheit (°F) to break the molecular bonds and gasify the materials. This liberates the energy potential of the waste materials and melts the residue to an inert, glass-like slag, which may be used as an aggregate in construction and manufacturing operations. If this market can be developed, it will significantly reduce the need for landfill disposal in the future.

St. Lucie County, Florida (USA), is in the process of negotiating with a developer for the construction of a plasma arc gasification facility that will process 1,000 tons per day of municipal solid waste. The facility may be the first large scale solid waste plasma arc processing facility in the United States. Camp Dresser & McKee is assisting St. Lucie County to negotiate the agreements for this project. The project is expected to be privately financed, so the County will not be putting any money at risk.

In this paper, we will describe the plasma arc technology, present its historical applications, and discuss the St. Lucie project from initial conception to its current status.

1. INTRODUCTION

Whether it is in the form of household trash and garbage, or in the residues of industrial and commercial processes, waste is produced by all of us each day. According to the Environmental Protection Agency, in 2006 the United States alone generated about 251 million tons of municipal solid waste (MSW) or garbage every year which equates to each person generating over 4.6 pounds of solid waste per day [1]. Approximately 138 million tons is sent to landfills [1]. The United States creates and landfills over 300 million tons of construction and demolition debris (C&D), MSW and other waste streams per year.

In the late nineteenth century, continuing through the twentieth century, many processes were developed to recover the energy locked up in waste materials and return that energy to displace virgin fuels. Waste to energy combustion facilities proliferated and they were demonstrated to be a safe means of waste disposal and renewable energy generation.

In the late twentieth century and now continuing into the early twenty-first century, a process of using plasma arc gasification technology to liberate the energy potential of municipal solid waste has been developed and is gaining momentum. Plasma arc gasification technology may help advance the development of renewable energy, beneficial reuse of byproducts from waste, and reduce the need for landfill disposal upon successful commercial demonstration.

2. PLASMA ARC GASIFICATION

First, what is plasma? Plasma is often called the “Fourth State of Matter”, with the other three being solid, liquid and gas. A plasma is a distinct state of matter containing a significant number of electrically charged particles, a number sufficient to affect its electrical and chemical properties. To put things in perspective, low temperature plasmas are estimated to constitute more that 99 percent of the visible universe.

Plasma arc technology was developed and employed in the metal industry during the late 1800s to provide extremely high heat for heating, melting, cutting, and welding of metals. During the early 1900s, plasma heaters were used in the chemical industry to manufacture acetylene fuel from natural gas. This application remains the largest (150 megawatt) plasma heated industrial plant in the world, located in the Chemische Were Huls plant, Marl, Germany [3].

Plasma arc technology in United States applications dates back approximately 40 years when it was utilized by NASA to test heat shield materials for spacecraft [2]. In 1989, General Motors installed six (6) Marc II 2.5 megawatt plasma arc torches manufactured by Westinghouse in Defiance, Ohio which simultaneously process over forty tons per hour of scrap metal. Plasma arc gasification has been used in municipal solid waste destruction since 1999 in Japan. The Utashinai plasma facility generates 7.9 Megawatts of electricity, selling back about 4.3 MW to the power grid [4].

Plasma arc gasification is the core of a process system where waste materials are gasified via pyrolysis (reducing atmosphere with less air than the stoichiometric amount required for complete combustion) inside a special refractory lined reactor. By utilizing the combination of pyrolysis and plasma arc, two goals are reached. First, the flow of air through the reactor is greatly reduced, thus reducing the potential for material carryover from the combustor to downstream equipment. Second, the plasma arc torches eliminate the need for consumption of virgin fossil fuels by operating the torches on electricity produced by the facility, thus dependence on outside fossil fuel sources is eliminated. The plasma/pyrolysis process converts the organic fraction of the waste material into a synthesis gas (syngas) that contains the majority of all energy contained in the waste, allowing it to be cleanly liberated in further processing steps to produce steam and/or electricity, or possibly further converted to usable materials such as hydrogen, ethanol and other materials. The high temperatures achieved in the plasma arc gasification process also melt inorganic materials and convert them into an inert glass substance (vitrification).

A plasma arc torch can reach temperatures in the reactor gasification vessel of as high as 6000 – 10,000°F and temperatures at the torch tip as high as 25,000°F. It is due to these temperature regimes (and high energy particles emitted by the plasma arc) that waste material is reduced to its basic elemental components while liberating a combustible syngas. The plasma arc gasification system is a completely non-selective processing system. A wide range of waste materials, both organic and inorganic, can be safely processed. However, it must be realized that since the release of energy from organic materials is the basic tenet of the process, processing of wastes containing higher fractions of inorganic materials will result in a reduction of the favorable economics of a processing facility. Size reduction or shredding of waste may be preferred in order to maintain a homogenous feed stock and reduce potential damage to the inside of the reactor.

The reactor is maintained under a negative pressure, or draft, at all times during operation. This allows for minor air in-leakage to be accommodated without system operational disruptions. Thus, feeding of waste can be accomplished through an airlock arrangement where elaborate sealing is not required. The negative pressure is easily provided by an induced draft fan installed in the downstream reaches of the system where the syngas is cooled and has been cleaned.

3. PROCESS DESCRIPTION

The heart of the plasma arc gasification system lies within the plasma arc gas reactor (the reactor). In the reactor, the processes of waste introduction, conversion, plasma arc gasification, and residue vitrification occur. The waste is introduced into the upper zone of the reactor, where it accumulates on top of previously introduced waste that is in various stages of conversion and size reduction. Shredded or size reduced waste is preferred to reduce damage to the inside of the reactor and maintain a homogenous feedstock. As material is converted in the lower zones of the reactor, newly introduced waste moves down to replace it and continue the reaction. The plasma arc torches fitted to the lower section of the reactor produce a plasma arc that is in the 6000 – 10,000°F range. Gases from the plasma arc gasification rise up through the upper layers of waste and that material provides somewhat of a filtering effect for control of entrained particulate and condensed tars.

Under pyrolyzing conditions, a plasma gasifier reactor syngas is produced and is composed primarily of carbon monoxide, hydrogen, nitrogen and water vapor. Since this syngas still contains the energy and much of the chemical composition from the waste materials, it has a wide potential for beneficial use in production of heat and power. Syngas may also be used as a feed-stock in the manufacture of industrial and commercial products.

The syngas exiting the reactor is ducted to a heat recovery steam generator (HRSG). In this HRSG, the gas temperature is reduced from approximately 2300°F to about 300°F. The high pressure steam produced in the HRSG is passed through a steam turbine generator to produce the electrical power including that needed for the plasma arc torches.

The solid residue from the plasma arc forms a glass-like material called a vitrified mass. Ordinary vitrification involves the mixing of residues with glass precursor material such as silica at high temperatures (1,300 – 1,500°C) to form a single-phase amorphous glassy material. Coke may be added into the reactor to stabilize the quality of the syngas for uniform energy content and ensure a reducing environment in the reactor pyrolysis zone. Limestone may also be added as a flux to lower the melting point of the inorganic components and stabilize the slag which is produced in the bottom of the reactor. This results in chemical bonding of inorganic species in the residues with glass-forming materials and encapsulation of residue constituents in a layer of glassy material.

4. REACTOR GAS CLEANING

The reactor gas that exits the HRSG is greatly reduced in temperature, but it still contains the energy and chemical composition released from the waste in the reactor. The syngas, although it is relatively clean, is not yet clean enough for further processing into electricity by a gas turbine generator or use as a chemical feedstock.

In order to clean the syngas, it must pass through a series of chemical adjustments, reactions and filtration steps. Having reduced the temperature of the gas in the HRSG, the cleaning process is greatly aided. The gas cleanup process is also aided by the lower volume and flow rate of syngas, compared to gas cleanup of much larger volumes from post combustion systems.

The first step in the proposed St. Lucie gas cleaning system is to pass the syngas through a dry scrubber where it reacts with lime to neutralize any acidic gases. The lime enriched gas is passed through a fabric filter where the reacted lime and solid particulate matter is filtered out of the gas. The gas clean up residues are returned to the reactor where they are mixed with and bound up in the vitrified residue. The cleaned syngas is then ready for beneficial use in gas turbine generator. Net energy that is received from the HRSG is routed to a steam turbine generator and used to power the Plasma system torches.

5. REACTOR SYNGAS USAGE

The reactor syngas has a multitude of potential uses. In the case of St. Lucie County, the cleaned syngas can be ducted directly to the inlet of a gas turbine generator for use in electricity production. Since the gas has passed through cleaning steps, it does not cause undue erosion/corrosion wear on the internal components of the gas turbine. Electricity produced in the gas turbine generator can be sold to local utilities. A secondary HRSG installed on the exhaust duct of the gas turbine can be used to produce high pressure steam that can be piped to the inlet of the primary HRSG steam turbine, where it will be combined with the primary HRSG steam to increase electric power production. Although this method of reactor syngas usage to produce electricity is fairly straightforward and utilizes many commercially available, proven components, it may not be the optimum use of the energy potential of plasma arc gasification. Local markets may dictate process variations in order to capitalize on available syngas users and economic factors.

6. ST. LUCIE COUNTY

A plasma arc gasification facility is proposed and under development in St. Lucie County, Florida to transform the currently landfilled solid waste into syngas and an inert slag that could be used as an aggregate for road and construction products. The supply for aggregate materials is becoming limited in areas of Florida with costs increasing rapidly due to transport and environmental opposition to rock quarries. Low pressure turbine exhaust steam may be sold to a neighboring industry to power their turbines or utilized onsite. Using two plasma arc-equipped cupolas, the plant may be the first commercial scale facility in the nation and is planned to process 1,000 tons of municipal solid waste a day. The facility will be designed to allow expansion to process 3,000 tons per day after start-up, testing, and operation of the initial facilities. The processable waste will consist of C & D, MSW and vegetative waste from the County. Syngas produced from the plasma arc process will be used to run gas turbines to generate electricity. A majority of the electricity will be sold to the bulk electric grid, while approximately one third of the power will be used to run the plasma arc facility. Potential markets for the solid by-product include aggregate and road base material. Other uses are currently being evaluated.

To date, the County and the Vendor, Geoplasma, LLC of Atlanta, Georgia, USA have executed a letter of Interest and a Developer Agreement for the proposed project. Preliminary engineering and several meetings have been held with the applicable regulatory agencies. Negotiations with power providers are also ongoing by the Vendor. The parties are currently finalizing negotiations of the Ground Lease for the proposed facility. Upon successful negotiations, the vendor proposes to aggressively complete final design, permitting and construction in 24 to 30 months.

The County will continue baling operations and landfilling of waste at the site until the facility is completed. Expected site build-out is projected beyond 2030 under current operations.

7. PROJECT CONSIDERATIONS

The St. Lucie County plasma arc gasification facility is to be built, owned, operated, and financed by the vendor. Design, permitting, construction, and operation of the facility must be completed with payment through energy production. Favorable rates for electricity, steam and solid by-product are necessary in order to achieve beneficial profits for the facility and ensure an affordable tipping fee to the rate payers. Additionally, St. Lucie County must ensure that labor, landfill closure and long term care, debt service, and other factors are accounted for in their long-term economic plans.

Challenges to the project include securing the necessary permits, garnering public/community support, delivering upon the promise of the anticipated emissions, achieving the estimated waste reductions, and successfully demonstrating the ability to economically pre-process the waste feedstock and reactor feed systems. St. Lucie County and the Vendor have fostered open communication through public workshops and presentations to several community groups. Public education of the technology and the benefits to the community have been well received to date. Additional discussions regarding anticipated emissions in relation to similar power generation facilities and state requirements have been made at several meetings.

Another challenge to plasma arc waste to energy facilities is the waste feedstock mix and size. The feedstock should be homogenous, if possible, to avoid spikes or dips in energy production. Coke and/or limestone may be added to enhance the reactor conversion process. Feeding the various wastestreams into the reactor must also be considered to prevent damage to equipment and the reactor. Size reduction or perhaps shredding of waste may be advantageous to achieve both purposes. As an item of note, municipal solid waste and automobile shredder residue is size reduced prior to feeding the reactors at the Geoplasma reference facility in Utashinai, Japan.

Various permit applications must be prepared and submitted to state and local regulatory agencies. Modifications to existing site permits (solid waste, water, wastewater, air, etc.) must be obtained. The State of Florida air quality permit will establish emission quantities and requirements for the facility. Additional permits to address cooling water needs, pipeline routing, and local land use regulations may also be required.

St. Lucie County stands to benefit from the conversion of municipal wastes into renewable energy. Extension of useful landfill capacity at the existing County site and/or elimination of acquisition of property for future waste disposal facilities may also be realized. If implementation of the project is successful, renewable energy produced by the facility will help promote renewable energy in Florida and offset greenhouse gas emissions from existing fossil fuel sources. Aggregate produced may be utilized to supplement a limited local supply for road construction material. Finally, the successful scale up and development of the plasma arc gasification facility at the existing landfill site provides a mechanism for continued revenue following the landfill's closure while maintaining existing rate paying customers.

8. CONCLUSIONS

Potentially a waste processing facility utilizing plasma arc gasification technology represents a leap forward in the state of the art of waste treatment technology. The conversion of organic materials into a renewable energy source and the conversion of inorganic materials into a non-leaching glass material may significantly reduce the need for landfilling of any type of waste. Municipal solid waste, construction and demolition materials, industrial and municipal sludges, even hazardous and medical wastes potentially may be safely processed with a positive environmental benefit.

A plasma arc gasification plant holds the potential to add to the supply of renewable energy in these times of uncertain energy supplies and politically charged energy policy debates.

Plasma arc gasification technology may be capable of helping expansion of renewable energy, thereby freeing up our dwindling petroleum supplies for higher end uses such as lubrication, chemical products and consumer products.

In most cases, plasma arc gasification facilities can be located on available land at or adjacent to the very landfills that will provide backup waste disposal service on a much limited use.

Plasma arc gasification technology has been demonstrated on a small scale. Larger and regional facilities are emerging and under development. Coupled with a changing energy market that places a higher value on renewable energy and greenhouse gas emission reductions, plasma arc waste treatment facilities, may evolve to become an additional economically viable solution to the world's waste management problems in many locations.

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