Plasma Arc Treatment of Municipal and Hazardous Wastes

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Abstract

Plasma treatment of waste materials offers a solution that could effectively and safely dispose of municipal, hazardous, and toxic wastes that are generated by the residential, commercial, and industrial sectors of our economy. Plasma arc technology uses electricity to create a form of artificial lightning with temperatures exceeding 7,000° C, which is up to three times hotter than fossil fuels. These sustained high temperatures, hotter than the surface of the sun, cause the organic compounds in the wastes to completely dissociate into their elemental components. These recombine as fuel gases and simple acid gases that are quenched and cleaned in a gas scrubber system.

The inorganic components in the waste are melted and vitrified into a glassy, rock-like solid residue, which is highly resistant to leaching. Both gas and solid by-products are potentially recyclable as useful fuel gases and road gravel. If electricity is produced from the fuel gases, about 40% would be used to operate the plasma torches and the plant, and the remaining 60% could be sold to the electric grid. Furthermore, the requirements for municipal or industrial waste landfills are eliminated. At throughput volumes of up to 1,000 tons per day, plasma arc system capital costs are about the same as traditional incineration technology. However, the advantages of plasma systems over incinerators are numerous. Prototype facilities for the plasma treatment of municipal solid waste, incinerator ash, asbestos, and medical waste have been successfully demonstrated and commercialized.

Recent technological advances in plasma arc technology permit the *in situ* transformation of most soil, rock, and waste types into a vitrified, rock-like material similar to obsidian that is durable, strong, and highly resistant to leaching. A plasma arc torch can be lowered into a borehole to any depth and be operated to pyrolyze or gasify municipal wastes and any contaminated soils. The plasma torch is slowly raised and operated at progressively higher levels to thermally convert buried wastes into a vertical column of vitrified and remediated rock-like material. *In situ* plasma vitrification (ISPV) would be directly applicable to all subterranean waste deposits such as municipal landfills, hazardous/toxic waste deposits, buried debris, sediments and sludges, radionuclides, and underground storage tanks.

Plasma arc technology is ideally suited for waste processing:

- **No other process can achieve the temperatures or energy densities of the plasma arc.**
- **Hazardous or toxic compounds are broken down to elemental constituents by high temperatures.**
- **Organic materials are pyrolyzed or volatilized – may be converted to fuel gases.**
- **Residual materials (heavy metals, etc.) are immobilized in a rock-like vitrified mass that is highly resistant to leaching.**

Hazardous Waste Destruction Applications

These sustained high temperatures can be produced in a reducing (oxygen deficient) atmosphere in which organic compounds pyrolyze and dissociate into their elemental constituents. On cooling, these gases recombine into simple fuel gases such as hydrogen, carbon monoxide and methane and acid gases such as HCl or H2S which can be easily removed in a scrubber system. Carbon is removed from the reactor vessel by reacting with steam to produce carbon monoxide and hydrogen. Inorganic components of the feed material melt and, on cooling, form a vitrified, rock-like, solid similar to natural obsidian, that is highly resistant to leaching and is suitable for use as an aggregate, thus eliminating the need for landfilling.

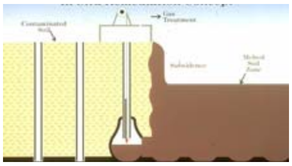
Asbestos Destruction Facility In France

GTRI Plasma Processing Demonstration System

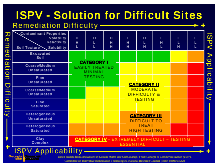
Initial applications of plasma for waste processing focused on the inorganic wastes such as asbestos and incinerator ash. Plasma has been successfully applied at commercial scale in the U.S and Europe for the destruction of asbestos and in Europe and Japan for the vitrification of ash from the incineration of municipal solid wastes. Because of plasma's unique ability to destroy complex organic compounds, there has been significant interest in the application of plasma arc technology for destruction of hazardous organic wastes such as PCBs, chemical sludges and medical wastes and for the recovery of energy from waste streams such as municipal solid waste, automobile shredder residue and used tires. To date, these processes have been demonstrated on a relatively small scale and have found limited commercial applications in Europe, the Far East (Japan and Taiwan) and the U.S. In the U.S., the Army Corps of Engineers has funded the development and testing of two systems for the processing of agricultural blast media contaminated with heavy metals and for regulated medical wastes. One of these systems has been transferred to Georgia Tech Research Institute.

In Situ Site Remediation Applications

Contaminated soils and buried wastes represent one of the most widespread and costly remediation problems in the United States and other developed countries. Recent technological advances in plasma arc technology permit the in-situ transformation of most soils, rocks and buried wastes into a vitrified, rock-like material similar to naturally occurring obsidian. A novel method for treating waste sites now under development at the Georgia Institute of Technology is in situ remediation through vitrification by means of a plasma arc torch. This process is called "In Situ Plasma Vitrification (ISPV)."



In Situ Plasma Vitrification Concept



A plasma torch can be lowered into a borehole to any depth and operated to pyrolyze or gasify organic materials and melt and vitrify rock, soils or inorganic deposits. The plasma torch is slowly raised and operated at progressively higher levels to thermally convert buried wastes into a vertical column of vitrified and remediated rock-like material that is stronger than concrete and highly resistant to leaching. ISPV would be directly applicable to remediation of all types of subterranean waste materials, including hazardous and non-hazardous waste landfills, low-level waste burial areas, buried debris, underground storage tanks, and soils, sediments and rock contaminated with organic materials, heavy metals or radionuclides.

In Situ Plasma Vitrification offers unique remediation capabilities unequaled by existing in situ treatment technologies:.

- **Performance is independent of soil/rock or contaminant characteristics.**
- **No other in situ technology can achieve the temperatures, power levels or energy densities of ISPV.**
- **All known contaminants can be remediated, especially difficult-to-treat waste materials.**
- **Contaminated soil/rock and landfill deposits can be remediated, even in saturated soils or below the water table.**
- **Contaminants at great depths can be remediated.**
- **Leaking underground storage tanks and "hot spots" can be selectively remediated, even under existing structures**

What is Plasma?

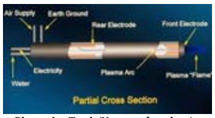
Plasma, often referred to as the "fourth state of matter," is an ionized gas capable of conducting electricity and responding to electromagnetic fields. Lightning is the most common example in nature.

Because the plasma is a gas and cannot melt, it can be used in a "plasma torch" as a resistive heating element capable of producing temperatures exceeding 7000 °C, up to three times hotter than those produced by combustion and hotter than the surface of the sun.

The first widespread application of plasma arc torches was by NASA for testing of heat shield materials for reentry vehicles. The technology subsequently found wide application in the steelmaking and specialty metallurgical process industries where the ability to produce extremely high temperatures in a controlled atmosphere facilitates the production of specialty alloys and recovery of valuable metals from waste streams such as aluminum dross or catalysts.

Recently, plasma arc technology has received increasing attention in applications for treatment and disposal of hazardous wastes and for the processing of Municipal Solid Wastes to recover energy and eliminate the need for landfilling of residual ash.

Lightning – Plasma in Nature

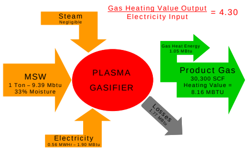


Plasma Arc Torch (Non-transferred arc)

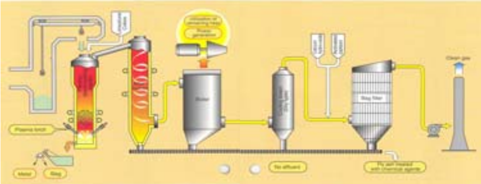
Plasma Processing of MSW for Energy Recovery

Initial hazardous waste destruction research efforts focused on using plasma torches to pyrolyze the organic materials and vitrify inorganic materials. In these reactors, carbon is removed by reaction with steam to produce carbon monoxide and hydrogen, both of which are useful as fuel gases or for synthesis of organic chemicals such as methanol. When processing organic wastes, it was noted that it is possible to recover over 90 percent of the energy value of the waste stream as fuel gases that could be used to generate more electricity than required by the plasma torch, resulting in a net production of energy. Although economically attractive in applications for waste destruction; pyrolysis systems are less well suited for energy recovery systems due to the relatively high plasma energy requirements (500 to 600 kWhr/ton of waste).

Plasma Pyrolysis of MSW



Westinghouse Plasma Corporation (WPC), originally a subsidiary of Westinghouse Corporation and now an independent company, is a leading supplier of plasma torches for metallurgical applications. Based on its familiarity with metallurgical applications, WPC developed the **Plasma Direct Melting Reactor** based in large part on the cupola design used in the successful metallurgical application at the General Motors foundry in Defiance, Ohio that has been in operation since 1989. This unique reactor design permits a significant reduction in the plasma torch power required for waste processing (typically less than 250 kWhr/ton) as well as a continuous discharge of molten residue. This is accomplished by adding metallurgical coke (approximately 4 to 7 percent by weight for MSW) and limestone (less than 1 percent by weight) to the feed stream as it is introduced into the top of the vertical, cylindrical reactor vessel. As the feed stream moves downward through the reactor, the coke helps to maintain the bed porosity and ensure uniform distribution of the hot gases which produce the pyrolysis reaction. The limestone acts as a flux to improve the fluidity of the vitrified reside and permit its continuous discharge from the bottom of the reactor. The molten residue is discharged into a water stream where it solidifies. The rapid cooling of the molten stream causes the vitrified material to fracture into sand-like particles while the residual metals form nodules that can be separated from the vitrified residue for recycling with the sand-like material suitable for sale as aggregate. This process has been implemented at three facilities in Japan including, a 200 ton per day plant in Utashinai that sends 4.3 MW to the electrical grid.



Westinghouse PDMR Process

Hitachi Metals 200 tpd PDMR MSW Facility in Utashinai, Japan

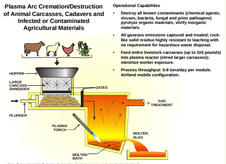
Advantages of Plasma Processing of MSW using the PDMR Process

At volumes of approximately 1,000 tons per day, costs for PDMR processing of MSW are about the same as for traditional incineration technology. However, plasma processing offers several significant advantages over incineration, including:

- **Ability to process a wide variety of solid and liquid MSW with little or no preprocessing;**
- **Ability to process several MSW streams which are normally not acceptable for incineration;**
- **Ability to process medical wastes and household hazardous wastes;**
- **Production of salable by-product materials including recyclable metals and aggregate;**
- **Elimination of requirements for landfilling of fly or bottom ash;**
- **Elimination of wastewater discharges.**

The U. S. Environmental Protection Agency Office of Solid Waste has recently established goals to provide incentives for industry "to build gasifiers to convert hazardous and solid waste into energy." Their cited advantages of gasification technology include the complete destruction of waste, reduction in pollution and air emissions, and capture of problem materials in the rock-like, leaching resistant, and salable residue. The EPA noted that this technology had "considerable promise" and that the technology is currently available, citing the existing facilities operating in Japan, to include the Hitachi Metals plasma processing plants.

PDMR gasification of MSW would provide a highly efficient and cost effective alternative to conventional Waste to Energy incineration. Collocation of a PDMR gasification facility with an existing coal or oil fired power plant could significantly reduce the capital and operating cost of the gasification facility while reducing the consumption of fossil fuels and reducing emissions and residues.



With appropriate controls and permitting, PDMR systems could also be adapted to process a wide range of hazardous wastes in combination with MSW. PDMR systems could also be designed to permit processing of agricultural materials, including animal feed, plant products, or animal carcasses, contaminated with biological or chemical agents as a result of accidents or terrorist actions.