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ENERGY RECOVERY FROM ORGANIC RESIDUES
BY FLUIDIZED-BED COMBUSTION

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Abstract

The merits and drawbacks of energy recovery from organic residues by means of fluidized-bed combustion are discussed. A series of analytical laboratory tests are suggested as a means of analyzing potential fuels for combustion. Finally, a number of potential fuels are described, along with problems which may be encountered in the commercial application of energy recovery from the sample fuels.

Although the use of organic residues to produce energy has been well documented in such countries as Germany, Sweden, Russia, and Australia, the availability of inexpensive fossil fuels after World War II rendered this form of energy recovery too expensive to be competitive. Petroleum and natural gas provided relatively clean-burning fuels in plentiful supply to meet the demands of economic growth following the War. However, the halcyon days of a seemingly inexhaustible supply of cheap fuel were terminated by the petroleum price increases effected by the OPEC Cartel in 1973. In one stroke the era of inexpensive fossil fuels was ended. In the five years following the OPEC action, the cost of crude petroleum on the international market has increased by a factor of five.

One of the results of this dramatic change in the economics of energy use is that energy recovery from organic residues is now competitive with fossil fuels in many instances. Wastes in the food processing industry such as peach and olive pits that were once hauled to landfills are now being burned to supply process steam. The Federal government has even given strong consideration to harvesting biomass crops solely for use as a fuel.

While many organic residues are becoming competitive as fuels, engineering problems still exist in recovering energy from their combustion. Many of the residues have moisture contents which are high enough to necessitate a drying step prior to combustion if a conventional system is employed. Often these wastes have to be shredded or pulverized to assure that no unburned carbon leaves the combustion vessel. In addition, materials handling problems can arise in storing, conveying, and feeding the residues into a burner.

The use of fluidized-bed combustion for energy recovery can help alleviate many of the problems which arise. A fluidized bed consists of a mass of free-flowing solid particles contained in a vessel, through which a gas is passed upward from the base of the unit. The application discussed in this paper employs an inert, sand-like bed material with collapsed bed depth of 15 to 18 inches. A portion of the combustion air is blown up through the bed to bring about fluidization. The physical effect is analogous to the turbulence created by boiling water. Additional air is injected into the burner above the bed to provide excess air for complete combustion and to regulate the temperature of the effluent gases.

Combustion efficiency is increased by the abrasive action of the bed material on the fuel. As layers of ash are formed on fuel particles, the ash is scraped away and more unburned surfaces are exposed. This characteristic of the bed enables the burner to accept fuel with a relatively large particle size and still provide complete combustion within the vessel. The principal limitation on fuel particle size is the consideration of materials handling in storing the fuel and introducing it into the burner.

Fluidized-bed burners are capable of accepting cellulosic wastes with moisture contents greater than 60 percent without the need for a supplemental fuel except when starting the system. A number of factors make this capability possible, including the high heat capacity of the bed material and the high heat transfer rates of the system. The large amount of stored energy in the bed material allows the burner to accept fuel with an even higher moisture content on a temporary basis. For example, in the combustion of wood wastes, large chunks of ice which are sometimes fed into the burners during the winter are easily evaporated without allowing the bed temperatures to fall below the kindling temperature of the fuel.

Fluidized-bed combustion does impose certain limitations on the fuels to be used. If ash softening temperatures are low enough to be in the range of combustion temperatures in the bed or vapor space, agglomerations can form which destroy fluidization and necessitate shutting down the burner. High concentrations of elements such as sodium, potassium, and vanadium in the ash can produce low ash softening temperatures, as can the existence of eutectic mixtures in the ash.

High concentrations of ash or the formation of ash with extremely small particle size can also present operational difficulties due to the fact that all ash is elutriated with the gaseous effluent and must be separated from the product gases before they are released to the atmosphere. Fluidized-bed wood burners now in commercial operation have met existing air emission requirements with the use of cyclones or multiclones and settling regions at the end of each pass in the boiler. However, the wood wastes that are burned have an ash concentration of less than one percent on a dry weight basis. Potential fuels with higher ash contents will necessitate more extensive gas-cleanup equipment.

In 1973 Energy Incorporated developed the Fluid Flame^{TM} energy system to recover energy from wood wastes in the forest products industry. Energy Products of Idaho, EI's majority-owned subsidiary, was formed to sell, design, and install these fluidized-bed systems. Twenty-two units are now in commercial operation in the United States and Canada, with one burning olive pits and the rest using wood wastes. These units range in size from 7½ to 22 feet in diameter and provide from 12 to 120 MM Btu/hr of hot gases for drying or steam production.

In its pilot plant in Idaho Falls, Idaho, Energy Incorporated operates two fluidized-bed burners, one six inches and the other eighteen inches in diameter. These units are used with potential fuels for scoping and parametric tests and for obtaining design data for commercial-size units. EI has found that there is close to a one-to-one ratio in scaling up from an eighteen-inch unit to one as large as eighteen feet for the combustion of wood wastes.

Prior to performing combustion tests in one of the burners, EI's Analytical Laboratory runs a series of tests to ascertain whether the residue will be an effective fuel and to determine whether problems may be anticipated during combustion - e.g., low melting eutectics. Even after these tests are performed, a demonstration of the feasibility of combustion must be made in one of the units to ascertain operational characteristics for each fuel.

The tests performed by the Analytical Laboratory include determinations of the heating value, the moisture content, a proximate analysis, and an analysis of the concentration of ash constituents. The proximate analysis is a determination of the percentages of volatile matter, fixed carbon, and ash. In the typical ash analysis, concentrations of the following are determined: Al_2O_3, CaO, Fe_2O_3, MgO, Na_2O, K_2O, SiO_2, V_2O_5, and TiO.

Successful combustion of a number of organic residues has been demonstrated in the pilot plant. Among those tested were corn cobs and husks, date and peach pits, olive pits, tomato pomace, sawdust, straw, paper mill sludges, commercial wastes, and the light fraction from shredded, air-classified municipal solid wastes. Of these fuels only the tomato pomace and the sludge had moisture contents which were too high to allow combustion of the fuel as received. The tomato pomace was dried before the tests, and the paper mill sludge was burned along with wood wastes to effectively reduce the net moisture content.

Of the residues mentioned, in-bed feeding was found to be more effective with tomato pomace, straw, commercial wastes, and refuse-derived fuel. All of the other fuels performed well with above-bed feeding.

During the combustion of corn wastes, agglomerations were formed in the bed and were believed to be caused by the high concentration of potassium in the ash. Not only did the potassium oxide soften while in the bed, but much of the oxide was elutriated with the effluent gases in the form of a particulate with extremely small particle size.

The glass concentration of the refuse-derived fuel was found to be approximately 1.25 percent. When efforts were made to maximize the temperature of the effluent gases during combustion, deposits were formed in the vapor space of the combustion vessel and in the ducts to the cyclone. Most of the glass remained in the bed, causing a buildup of bed material and necessitating intermittent removal of excess bed material during combustion.

Energy recovery from organic residues by employing fluidized-bed combustion has a high potential when the costs of competing energy sources are considered. Widespread applications of this technology are expected during the next decade.

BIOGRAPHIES

Dr. V. F. Baston is currently Director of Research and Development for Energy Incorporated in Idaho Falls, Idaho. He is in charge of the analytical laboratory and all fluidized-bed testing in the pilot plant. Projects have included fluidized-bed combustion with energy recovery, analysis of gettering techniques for corrosive and pollutant species, and calcination of phosphate ores.

L. G. Gale is a Senior Mechanical Engineer with sixteen years of experience in nuclear power, combustion, and radioactive waste handling. He has developed systems for a variety of fluidized-bed applications including combustion, calcining, and other processes. Mr. Gale has recently completed the engineering design for a system to dispose of contaminated tributyl phosphate through fluidized-bed combustion.

W. L. Hurt is a Senior Engineering Technician with nine years of experience in the areas of pilot plant construction and operation and nuclear plant operation and maintenance. He has recently completed the design of a new eight-inch pilot plant for the Idaho Falls facility.

J. W. Stallings is a Chemical Engineer with eleven years experience in chemical engineering and economics with special emphasis on economic development and marketing. He has been the Project Engineer for a series of combustion tests with organic residues, including tomato pomace, peach pits, and dried paper mill sludge.

C. M. Young is the Supervisor of the Analytical Laboratory at Energy Incorporated's offices in Idaho Falls, Idaho. He has six years experience as a chemical process research chemist. Mr. Young has developed various new methods of analysis employing titration and atomic absorption techniques, both flame and flameless.