11/6/91

MEMORANDUM

To Gary Hunt

From Gautam Patnaik

Subject: Pyrolysis Technology used for Solid Waste.

Pyrolysis also referred as the "Starved Air Combustion Technology" is essentially the combustion of Organic or Carbon rich product in less than Stoichiometric air. The thermal conversion of Organic feedstock to recover energy products such as fuel gas, fuel oil & char. The major design & operation parameters for a Pyrolytic conversion are normally, temperature, Oxygen/fuel ratio, feedstock quality, residence time, number of stages, kinetics of solid & gas flow & Catalytic converter if any used. The Endothermic Pyrolytic reactions are carried out in a controlled Reactor.

Most of the work or project on Pyrolysis, Has been done by EPA. The emphasis is more on Clean Fuel from Agriculture or Forest product. Some work has been ongoing on the conversion of pulverized coal to obtain high BTU value fuel oil. Pyrolytic oils from Pyrolysis of Organic products are dark in color, ranging from brown to black with a burnt pungent odor. The boiling range is about 100C to approximately 200C at which point thermal degradation begins to occur. Pyrolytic oils contained phenolic, polyhydroxy neutral compounds and volatile acidic compounds. Most of the Gaseous products of Pyrolysis consist of carbon monoxide, hydrogen and nitrogen and trace amounts of methane and other reactive hydrocarbons. The production of high Carbon char by Pyrolysis of solid waste has been in the experimental stages.

Most of the demonstration projects were started in the 1970'S, with EPA funding most of them. Not much work has been done on the Pyrolysis of solid waste in the 80's. Some of the earlier projects in Pyrolysis of solid waste is listed below & later on the role of EPA & DOE is outlined.

The Monsanto Landgard Process.

Started by the City of Baltimore in 1972. Funded by EPA's demonstration grant award, for a 1000 tons per day (TPD) project. It employed a rotary kiln Pyrolyzer into which shredded MSW was fed at one end and air & auxiliary fuel fed at the other end. Hot fuel products of combustion contacted the MSW, and Pyrolysis gases & char were formed. The Pyrolysis gases passed on to an afterburner & were subsequently used for steam production. The plant started up in 1975 but was beset with operational difficulties (refractory failure, failure to meet Maryland's Air Pollution Regulations, etc.). Monsanto eventually withdrew from the project in 1977.

The Andco-Torrax Process.

Funded by another EPA demonstration grant award in 1970 to Erie County, New York. To allow for a partial funding of a 75 TPD demonstration of the Andco-Torrax Process. The process used a vertical "slagging" Pyrolyzer to convert incoming MSW to a fuel gas and a slag which, exited out of the bottom of the reactor. Demonstration tests continued till 1977 when it was shut down & later dismantled. Commercial Facilities were build by Andco-Torrax between 1976 and 1979 in sizes ranging from 87 TPD to 200 TPD and used in Europe & Japan.

The Occidental Liquefaction Process.

Began in 1972 under the joint sponsorship of EPA & San Diego County. A 4 TPD pilot plant led to a 200 TPD demonstration plant, constructed by 1975. The objective was to separate the inorganic from the feed, & then to convert the minus 14 to 24 mesh organic fraction (via a low temperature, entrained bed Pyrolyzer) to a highly Oxygenated (33% by weight Oxygen) fuel oil having a heating value of 115,000 BTU/Gal. The heat required for the Pyrolysis reaction was provided by the combustion of the off-gas and a fraction of the char produced. The plant was shut down in 1978 after only limited runs because of many operational problems that were encountered.

Union Carbide Purox Process.

Union Carbide Corporation began development of the Purox (waste Pyrolysis) Process in the early 1970's. A 5 TPD pilot plant led to the start up of a 200 TPD demonstration unit at Tonawanda, New York in 1974. The process used a shaft furnace to Pyrolyzer the incoming, downward-flowing MSW. Pure (about 95%) Oxygen entered the bottom of the reactor & combusted a fraction of the waste to provide the heat necessary for the Pyrolysis. Since little Nitrogen was introduced into the system, The product gas had a high heating value than that from most Pyrolysis processes. (about 300 to 390 BTU/SCF). About 0.2 tons of Oxygen was typically used for each ton of MSW fed to the process. The demonstration plant is now idle. The reactor & ram feeding system was licensed to Showa Denko of Japan. They later built a 150 unit for the conversion to fuel gas in Japan. That unit was started in 1981.

Research Done By EPA (1975 - 1980).

Because of the general lack of success at the demonstration plant EPA (still charged with Federal responsibility for developing better waste to energy processes) decided to begin afresh at the bench & pilot scales, with a more deliberate approach regarding the development of processes for Pyrolytic conversion of solid waste to Fuel gas or Synthesis gas, fuel oil and / or char. To accomplish these various small projects were funded by EPA. No big demonstration project has resulted from any of these small funded projects.

Research done by DOE (1980 - Present).

DOE continued EPA's general research approach of not proceeding to the demonstration stage to quickly. They too, initiated some small pilot projects, but no bigger projects on Pyrolysis of solid waste have resulted in any of these.

Incinerator Companies Interest in Pyrolysis.

Because of the past operational problems in most of the projects where the Pyrolysis technology was utilized. Most of the bigger companies utilizing waste-to-energy (incineration) technology, are taking a wait and see approach to the Pyrolysis technology. The advantages of such a system is not being ignored by any of them. Their opinion is if such a system was practical then they would incorporate it, into their program. Raytheon Service Company is looking at a project to produce low BTU value fuel oil or combustible gas from mixed plastic waste stream. The heat to be supplied by Carbon electrodes maintained at 3000 F. They can vary the waste/Oxygen mix to get Gas or Liquid fuel.

Total Energy System.

Saw their video tape yesterday. Their claim is that the system can produce either gas or liquid fuel, from the Pyrolysis of solid waste. The project that is being sponsored at Durham is to generate gas fuel. Other points to be noted as mentioned in the tape are, the residue will be 10% of the main stream, which will be mainly inert non-combustible & nontoxic. The heat to be supplied indirectly by radiation of the combustible gas generated in the Pyrolytic process. The temperature of the combustion chamber to be maintained at 1200 to 1400 F. No outside air to be supplied, which is questionable. Some air has to be supplied to produce carbon monoxide. The combustible gases after passing through the scrubber are quenched by water to a temperature of 150 F. No mention as to what will be done to the cooled combustible gas (which I assume will be approximately at atmospheric pressure). The solid waste is to be shredded & fed into a hopper, after which a screw conveyor feeds the material onto a couple of layers of grates, arranged one on top of the other. The infeed material falls from one grate on to the lower grate, which travels in the opposite direction, till it reaches the bottom grate. By controlling the speed of these grates, the Company claims they can have good control over the Pyrolysis reaction. The material build up in the hopper also acts as an air lock.

Sample Mass Flow Analysis of the Pyrolysis Project.

Assumptions made are based on Annual averages.

% composition in the waste stream

% Inorganic	=>	10%
% Moisture	=>	30%
%Organic	=>	50% (dry).
Total	=>	100%

Since there is no chemical composition of the dry waste stream, assume a 50-50 split between Carbon & Hydrogen molecules by weight. The weight of Sulfur, Potassium etc. are negligible. Also assume in the Pyrolysis reaction 30% of all Carbon produces Carbon di Oxide & the rest form's Carbon Monoxide. Also 30% of all Hydrogen form's Water & the rest produces free Hydrogen.

Composition of the Pyrolysis gas after the reaction (assuming no free Oxygen) (based on 1 lb. of waste).

Gas Component	% (Wet)	% (Dry)
Nitrogen	65.79	79.98
Carbon di Oxide	5.27	6.41
Carbon Monoxide	7.83	9.52
Hydrogen	3.35	4.09
Water	17.76	--
Total	100	100

Partial Pressure of Moisture => (14.7)(0.1776) = 2.61 Psia.
(Assuming gas at atmospheric)

Dew Point Temperature => 136 F.
(Saturation Temp at 2.61 Psia)

Note - The high moisture content makes the dew point temperature of the gas so high. To reduce the dew point temperature so that the gas can be further compressed without damaging the compressor.

For a safe operating dew point temperature select 60 F. The partial pressure corresponding to this temperature is 0.256 Psia. The moisture content after gas goes through a dehumidification process is 0.019 Lb of moisture per Lb of waste.

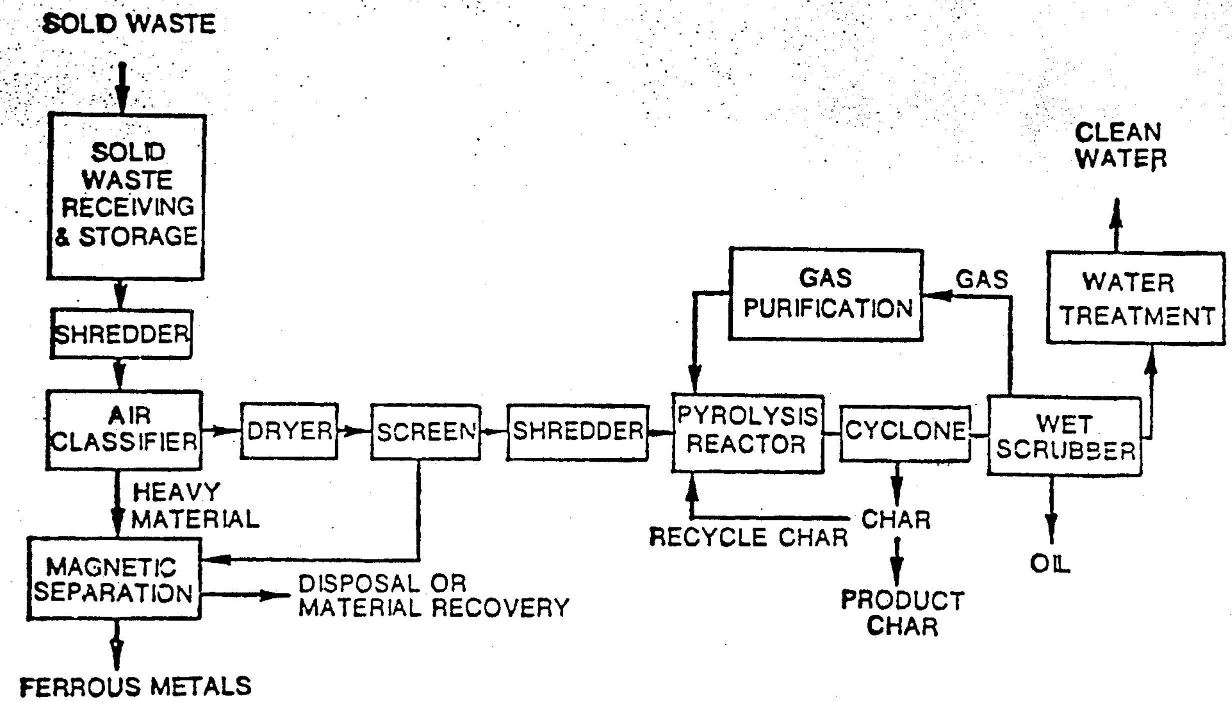
Thus the Dehumidification load is => (1.11 - 0.091)
= 1.019 Lbs of water per Lb of waste.

For a 200 TPD plant (assuming 20 hrs of operation).

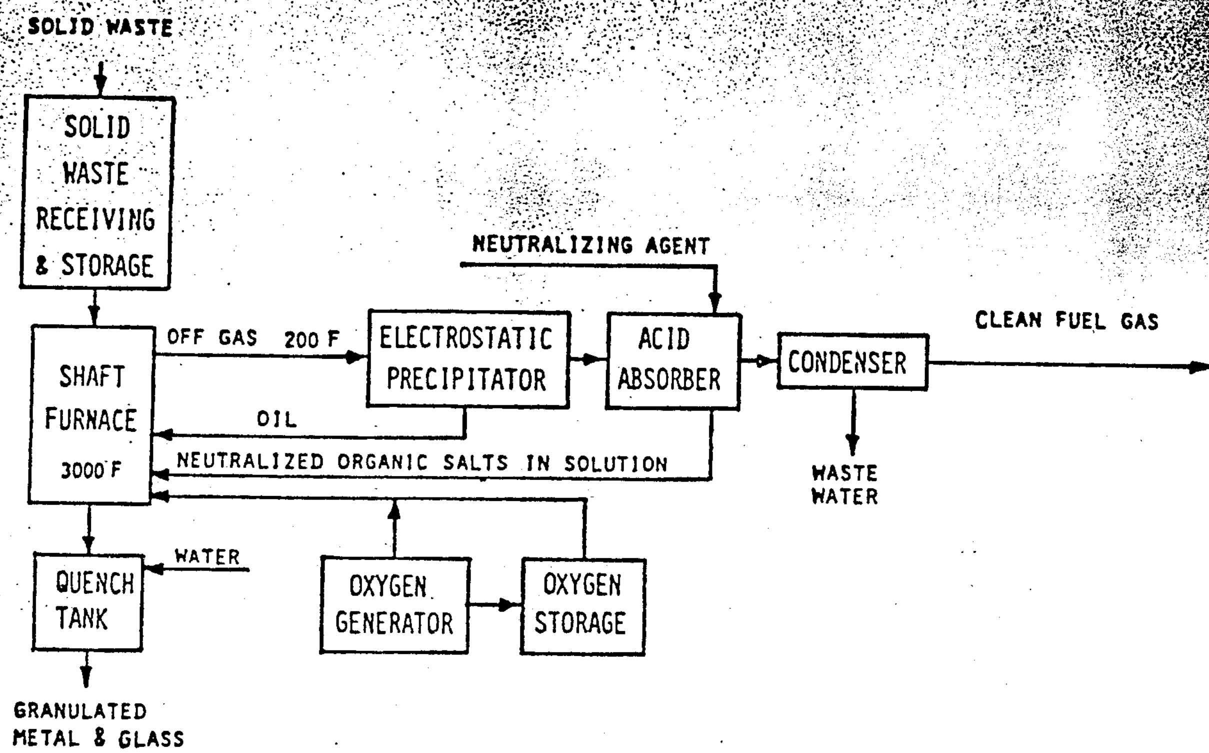
Plant load	=>	20,000 lbs/hr.
Air Requirement	=>	107,120 lbs/hr.
Gas output (wet)	=>	125,120 lbs/hr.
Dehumidification load	=>	20,380 lbs/hr.
Gas output after dehumidification	=>	104,740 lbs/hr.

cc: Vic Young, Resource Center.

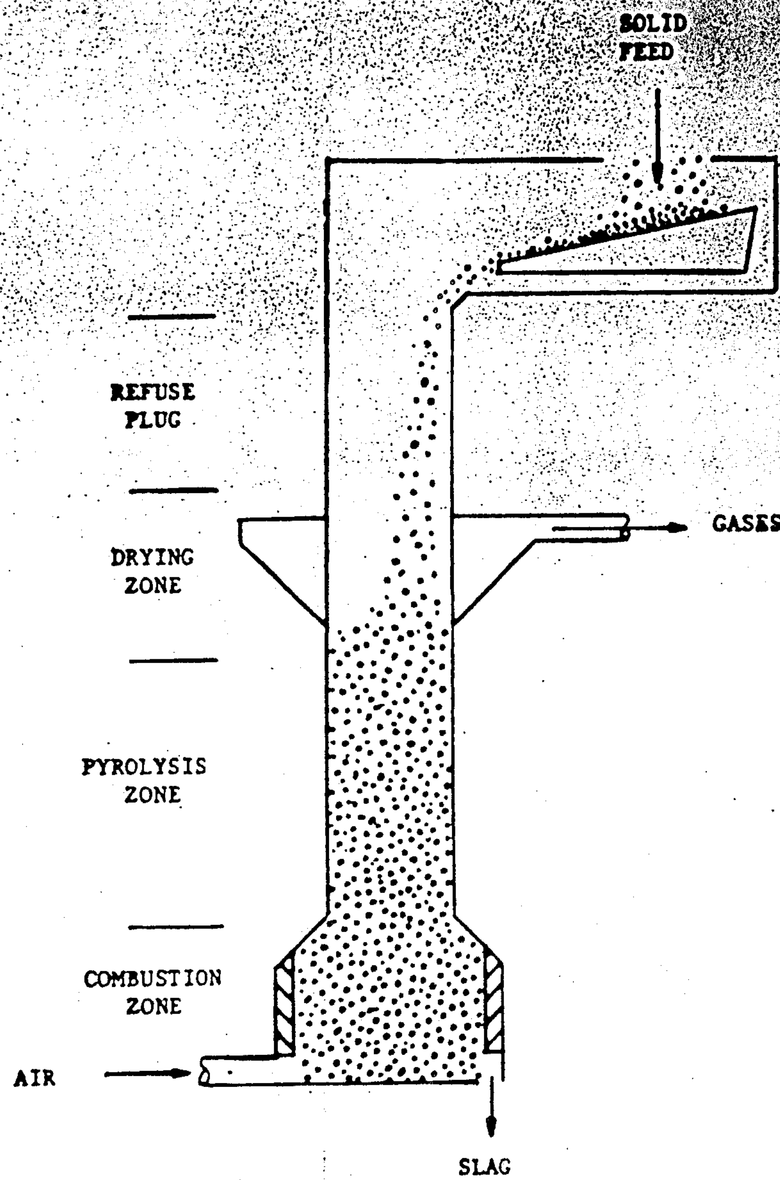
Nancy Clayton, City of Durham.



Occidental Liquefaction Process



Union Carbide Purox® Process



Schematic of the Andco-Torrax Reactor