Thermochemical Liquefaction

FEEDSTOCK CLASSIFICATION

Any biomass, animal product, or organic material may be considered.

FEEDSTOCK EXAMPLES

- alfalfa
- beef tallow
- corn stover
- crop residues
- debarking waste
- edible offal
- forage grasses
- forest residues
- inedible offal
- manure (dairy)
- manure (poultry)
- manure (swine)
- municipal solid waste
- paper mill residue
- pomace, scraps and spoilage (fruit & vegetable processing)
- sawdust
- scrap/spoilage (meat packing)
- spent grains
- spent hops
- spent yeast
- switchgrass
- waste cooking oil
- waste wood chips
- wood chips

FEEDSTOCK RESTRICTIONS

Feedstocks should be of a single type, rather than mixed, to obtain a consistent product and optimum yields. For example, although municipal waste may be processed by direct liquefaction, one should separate the tires from the plastic bottles, etc., and process each stream separately. Feedstocks to biorefinery direct liquefaction processes are ground or pulped into a uniform water slurry – an advantage for wet feedstocks such as offal or manure, but extra processing for dry, bulky feedstocks.

PROCESS DESCRIPTION

Nature converts biomass materials into petroleum by applying high pressure and temperature over millions of years. The thermo-chemical direct liquefaction process converts a liquid slurry of biomass and organic materials to hydrocarbon oils and byproducts using high pressure (generally up to 200 atm) and temperature (generally up to 350 °C). Processing time is reduced to minutes. The resulting intermediates can be converted to hydrocarbon fuels and commodity chemicals for products similar to those produced from petroleum.

A variety of thermo-chemical reactions in the direct liquefaction process change the chemical structure of these biomass materials from cross-linked structures to oxygenated hydrocarbons and thermoplastic chemicals (polymers). Water in the feedstock slurry facilitates the chemical reactions. Carbon monoxide, hydrogen, and other catalysts may be added to increase the hydrogen to carbon ratio, and reduce the oxygen to carbon ratio, thereby improving the hydrocarbon yields.[1]

A wide range of process approaches have been researched and patented, initially developed for coal, peat, and wood sludge liquefaction in the 1970's. Recent developments and commercialization have targeted waste biomass. Direct liquefaction, the heat and pressure conversion process of producing a liquid oil, is sometimes referred to as thermo-chemical conversion, thermal depolymerization, or simply liquefaction. By contrast, indirect liquefaction produces a liquid fuel by gasifying organic materials to syngas, followed by synthesis to ethanol, methanol, or other chemical compounds.

The process approach commercialized by Changing World Technologies is representative of direct liquefaction. Their process consists of three main steps:[2] 1) pulping the feedstock and then heating the resultant water slurry under pressure to the 1st stage reaction temperature, 2) flashing the slurry to a lower pressure and separating the 1st stage oil from water, and 3) heating the 1st stage oil to a higher temperature to crack the oil into light hydrocarbon leaving a solid product. The process temperatures for the initial slurry phase of processing are between about 200^{o}C to 300^{o}C (392^{o}F to 572^{o}F). For the second processing stage the temperatures are near 500^{o}C (932^{o}F). Liquid and solids byproducts separated from the bio-derived oil may be evaporated and dried to produce marketable byproducts.

PRIMARY BIOBASED PRODUCTS

Primary biobased product is a **bio-derived liquefaction oil**, a free-flowing liquid that is a combustible mixture of oxygenated hydrocarbons. Depending on feedstock and process details, yields of oil can range by mass weight from 26% to 80%.[1,2] Estimated yields from processing 200 tons/day of turkey offal and grease waste at the Changing Worlds Technology biorefinery based in Carthage, Missouri show approximately 69.8 t/d (about 500 barrels) of bio-derived oil.[2]

PROCESS BYPRODUCTS

Byproducts produced include water, steam, solid minerals and metals (as present in the feedstock), carbon **char**, and inert and combustible gases. Depending on the feedstock, the solid minerals can include elements such as nitrogen, phosphorus, potassium, and calcium, and may be sold as soil amendments.[2] Inert and combustible gases vary by feedstock and process, but mainly include carbon dioxide, CO_2, carbon monoxide, CO, and hydrogen, H_2. When the combustible fuel gases CO and H_2 are produced, they may be recycled back into the process as a heating source, as process catalysts, or potentially as fuel for power generation. Steam can also be reused for process heat.

MAJOR EQUIPMENT

A wide range of continuous and batch processes have been developed to conduct thermo-chemical liquefaction. Changing World Technologies has commercialized a process with major equipment for the following steps:[2] 1) pulping and slurrying the organic feed with water; 2) heating the slurry under pressure in a vessel to the desired temperature; 3) flashing the slurry to a lower pressure to release the gaseous products; 4) segmenting the solids from the volatile chemicals in a reformer reactor; 5) driving off water and producing light hydrocarbons in a heating vessel; 6) separating the end products; 7) storing oil and byproducts.

Expanding on work from the University of Arizona, Biomass Transformation Industries LLC developed a pressure vessel using an extruder feeder from the plastic processing industry to create a continuous, real-time process.[3]

ENERGY REQUIRED

For their Carthage, Missouri plant, Changing World Technologies has calculated an energy efficiency of 85% as measured by the energy in the combustible products that leave the plant divided by the total energy input. The energy input includes the energy in the dry feed, the electric power used, and any purchased natural gas that must be fired (in this case no natural gas is required).[2]

CAPITAL AND OPERATING COST

Commissioned in 2003, a $20 million facility in Carthage, Missouri will process 200 tons per day of fats, bones, feathers, grease and oils from a ConAgra Foods turkey processing operation.[4]

COMMERCIALIZATION STATUS

Commercially available, research ongoing. A commercial scale plant was commissioned in 2003 and operational in 2004 in Carthage, Missouri to process 200 tons per day of animal waste material from a ConAgra Foods turkey processing operation.[2] In 2002, Biomass Transformation Industries, LLC was seeking support for its extruder feeder liquefaction technology. Research and commercialization efforts for new reactor designs and processing are ongoing worldwide.

COMMERCIAL SUPPLIERS

Renewable Environmental Solutions, LLC is a joint venture company owned equally by ConAgra Foods and Changing World Technologies (CWT) to commercialize the CWT Thermal Conversion Process technology in the agricultural and food industries. Located at 2001 Butterfield Road; Downers Grove, IL 60515 tel: (630) 512-1000. **http://www.changingworldtech.com** (April 16, 2004)

REFERENCES

[1] Zhang, Yuanhui, Gerald Riskowski, and Ted Funk. 1999. Thermochemical Conversion Of Swine Manure To Produce Fuel And Reduce Waste, University of Illinois at Urbana-Champaign. **http://www.age.uiuc.edu/bee/research/tcc/tccpaper2.htm** (April 16, 2004).

[2] Roberts, Michael, Gas Technology Institute, James Williams, Kvaerner Process Systems, Paul Halberstadt and Don Sanders, Renewable Environmental Solutions, LLC, and Dr. Terry Adams, Changing World Technologies. 2004. Animal Waste to Marketable Products, Natural Gas Technology Conference. **http://www.changingworldtech.com/techfr.htm** (April 16, 2004).

[3] Duncan, Donn G. Chairman, Biomass Transformation Industries LLC, Santa Fe, NM; Don H. White, Professor Emeritus, Dept. of Chemical Engineering, Univ. of Arizona, Tucson, AZ. 2002. Wood-Derived Crude Oil. Presentation at "SMALLWOOD 2002: Community & Economic Development Opportunities in Small Tree Utilization." Albuquerque, NM.

[4] Changing World Technologies. 2003. Changing World Technologies Debuts First Commercially Successful Thermal Process To Convert Organic Waste Into Clean Energy. CWT Press Releases. **http://www.changingworldtech.com/newsfr.htm** (April 19, 2004).