BRI ENERGY, LLC

And

BIOENGINEERING RESOURCES, INC

GASIFICATION–FERMENTATION PILOT FACILITY (Arkansas)

Monday, November 21, 2005

Facility: BRI (Gasification-Fermentation) Pilot Plant.

Location/Site: The BRI pilot plant is located outside the City of Fayetteville, Arkansas, which is surrounded by farmland within a two-mile radius. The plant started operating the fermenter process unit in 1991 and the gasification unit in 2003. Each process unit is enclosed in separate buildings and the administration building houses the laboratory where further research continues to take place. The lot size is about 5 acres.

Feedstock: Wood, corn stover, tires, RDF (Refuse-Derived Fuel) and Material source-separated biodegradable waste (not municipal solids waste, MSW, although MSW has been successfully tested.)

Throughput: 1.5 tpd.

Conversion Technology: Thermal and Biological – Gasification-Fermentation.

Conversion Technology Supplier: BRI Energy, LLC and Bioengineering Resources, Inc.

Definition:
Gasification – Thermal conversion of carbon-based materials in the presence of internally produced heat, typically at temperatures of 1,400 to 2,500°F, and in a limited supply of oxygen (much less oxygen than is needed for combustion) to produce a synthetic gas (syngas) composed primarily of H_2 and CO with inorganic materials converted either to bottom ash (low-temperature gasification) or a solid, vitreous slag (high temperature gasification that operates above the melting temperature of inorganic components). Some of the oxygen injected into the system is used in reactions that produce heat, so that pyrolysis and some (endothermic) gasification reactions can initiate; after that, the exothermic reactions control and gasification is self-sustaining. Air emission control systems remove almost all air pollutants. After cooling and cleaning in emission control systems, the syngas can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity or used to make chemicals.

Fermentation – (formerly called zymnosis) is the anaerobic metabolic breakdown of a nutrient molecule, such as glucose, without net oxidation. Fermentation does not directly produce energy in cells; it merely allows glycolysis (a process that yields two ATP, Adenosine TriPhosphate, per glucose) to continue. Fermentation yields lactate, acetic acid, ethanol, or other reduced metabolites. Fermentation is a sequence of reactions

which release energy from organic molecules in the absence of oxygen. Ethanol or ethyl alcohol, CH_3CH_2OH, has been described as one of the most exotic synthetic oxygen-containing organic chemicals because of its unique combination of properties as a solvent, a germicide, a beverage, an antifreeze, a fuel, a depressant, and especially because of its versatility as a chemical intermediate for other organic chemicals.

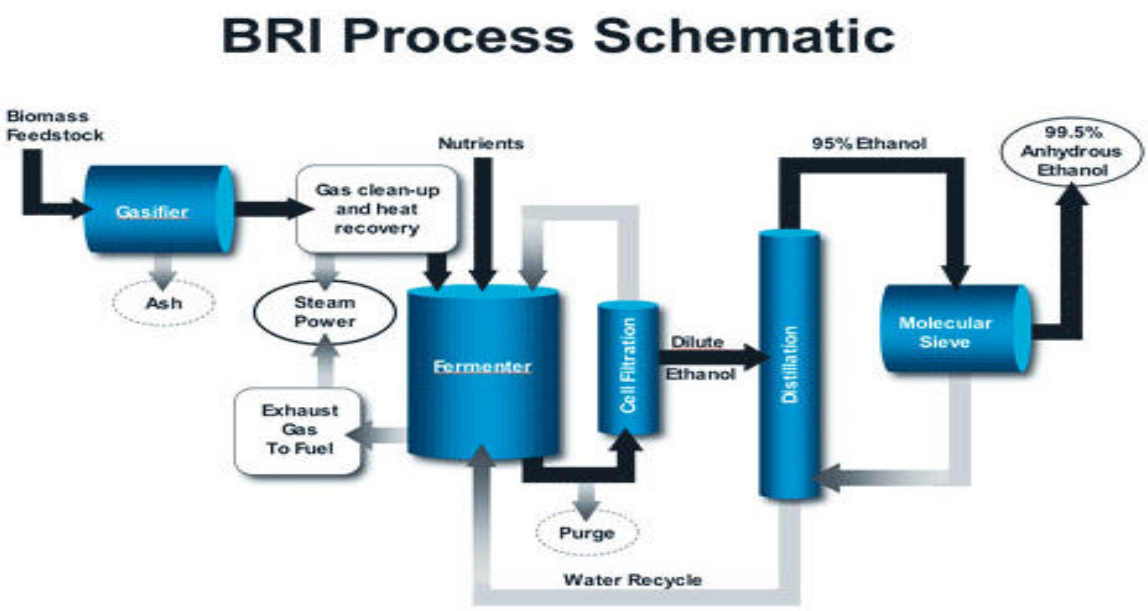
Process Description: The organics in the source-separated biodegradable waste are converted to syngas via BRI's two-stage thermal gasifier that raises the syngas temperature to over 2000°F in the second stage to enable cracking of any heavy hydrocarbons to carbon monoxide (CO) and hydrogen (H_2) maximizing the ethanol yield. There are hundreds of these units in operation, worldwide with a demonstrated reliability of 95 percent. The hot syngas is then cooled to 100°F, in the process generating steam, and it is introduced into the fermenter containing a specialized microbial population that converts the syngas into ethanol and water (H_2O). Nutrients are added to provide the cell growth and automatic regeneration of the biocatalyst. The resulting dilute aqueous stream of ethanol is continuously removed through a membrane that retains cells for recycle to maximize reaction rates. Anhydrous ethanol is produced by conventional distillation followed by a molecular sieve, using the waste heat from the process. Water, with nutrients, is recycled from the distillation bottoms back to the fermenter. Air emission control systems remove almost all air pollutants.

BRI pilot plant processing building; with temporary flare in the background

Technical Meeting and Facility Tour with: William F. Bruce, President; James L. Stewart, Vice President; and James L. Gaddy, Ph.D, President of Bioengineering Resources, Inc.

Owner/Operator: BRI Energy, LLC and Bioengineering Resources. Inc.

Technology Description:



The BRI pilot unit can process a maximum of 1.5 tons per day of various feedstocks, which include pre-sorted MSW (after removal of plastics, metals, and glass) and shredded to a size of 2 inches and 5 to 10 percent moisture content. The entire process claimed by BRI from gasification to distillation is approximately seven minutes. Due to its maximum process feed rate of 2 lb/min, the pilot unit must be fed manually. The overall processes are as follows (shown in the diagram above):

1. Pre-sorted MSW Treatment
   - Pre-shredding (hand fed)
   - Two-stage Gasifier
   - Byproducts – ash

2. Gas Scrubbing
   - Gas cooling
   - Gas cleaning
   - Byproducts – clean syngas

3. Fermenter – Microbial Process
   - Syngas feeding
   - Nutrients
   - Separation
   - Concentration
   - Evaporation
   - Byproducts – 2% ethanol solution

4. Ethanol Concentration
    - Cell Filtration
    - Distillation
    - Final Product - 99.5% anhydrous ethanol

Feedstock in auger mixer

conveyor belt feeds Gasifier

The feedstock is fed into auger mixer and conveyer belt and moves it into the two-stage gasifier. Stage-one of the gasifier is an incineration process unit where the feedstock is process under a direct flame at a temperature of 1000°F. The gases from the first-stage are routed to the second-stage (the gasification unit) where the gases are superheated to a temperature over 2000°F to produce the syngas and pure oxygen is injected reduce the amount of nitrogen, which reduces the overall syngas volume. The second stage-enables cracking of any heavy hydrocarbons to carbon monoxide (CO) and hydrogen (H_2) and is used as a food source for the microorganism in the fermenter unit. The syngas produced from using RDF are in the ranges of 10-24 percent CO and 8-22 percent of H_2 (most of the H2 exits the fermenter unprocessed). The quality of the ash produced in the gasifier has tested below TCLP (Toxicity Characteristic Leaching Procedure) limits.

Two-stage gasifier

The hot syngas is then cooled to 100°F, in the process generating steam, and it is introduced into the fermenter containing a specialized microbial population that converts the syngas into ethanol and CO_2. The pilot facility utilizes only 75 percent of the generated syngas the remaining 25 percent of the syngas must be flared with appropriate emission controls system. Flaring will not be needed at a fully operational facility.

Syngas pipe routed to gas cleaning system

Heat exchanger to recover heat and cool off the syngas

Flaring of syngas with appropriate emission controls system

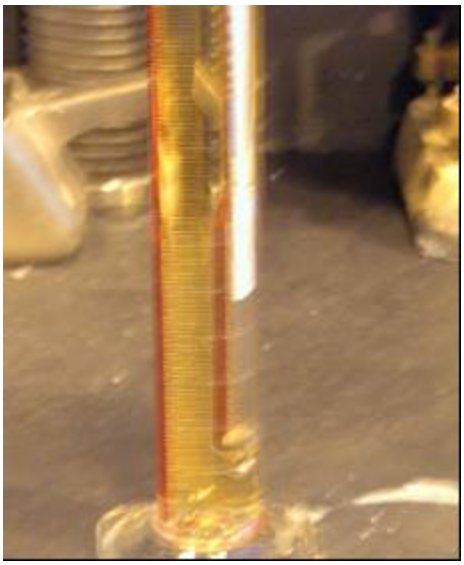
The cooled syngas is fed to the continuous stirred tank reactor (CSTR) to achieve a proper mass transfer- mixing of the syngas with the microorganism (named "Clostridium Ljungdahlii"). The microorganism will ingest most of the carbon monoxide to produce dilute aqueous ethanol at 2% concentration. The microorganism is fed nutrients for cell growth and automatic regeneration of the biocatalyst. The resulting dilute aqueous stream of ethanol is continuously removed through a membrane that retains cells for recycle to maximize reaction rates.

CSTR bioreactor (ethanol production)

Filter membrane that retains cells

The last step is to separate the ethanol from the hydrogen and water. This process is accomplished through the same distillation process that is currently being used in traditional corn and sugar-to-ethanol plants. Anhydrous ethanol is produced by conventional distillation followed by a molecular sieve, using the waste heat from the process. Water, with nutrients, is recycled from the distillation bottoms back to the fermenter.

Distillation vessels followed by a molecular sieve



Final product: Anhydrous Ethanol

Products: Anhydrous ethanol production from this facility (1.5 tpd), if operated year around, 50,000 gallons per year. The steam and hydrogen can generate electricity.