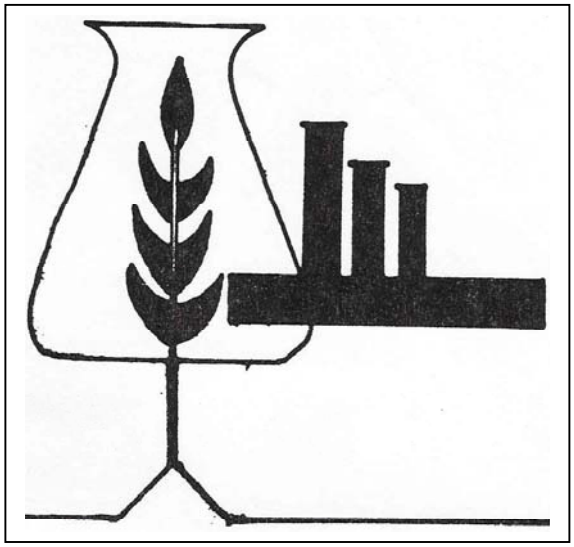
CELLULOSE CONVERSION TOWARD

FUEL BIO-ETHANOL

Report # 402



Brelsford Engineering, Inc.

Bozeman, Montana

Cellulose Conversion Toward Fuel Bio-Ethanol

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BRELSFORD ENGINEERING, INC. (BEI)

BEI Dilute-Acid Cellulose Hydrolysis Process
Cellulose Conversion toward Fuel Bio-Ethanol

Brelsford Engineering, Inc. (BEI), a Montana corporation is offering to License Patents and BEI Intellectual Property; which is for Cellulose Hydrolysis Conversion toward bio-ethanol production; which is a new, valuable, unique, un-foreseen, efficient and profitable chemical process, invented by Donald L. Brelsford. That Process is patented in the USA and Canada, and has been assigned to Brelsford Engineering, Inc. (BEI). It is titled: “The BEI Hydrolysis Process System; an Improved Process for the Continuous Dilute-Acid Hydrolysis Saccharification of Lignocelluloses in a Two-Stage Plug-Flow-Reactor System". BEI is hereby commercially offering to privately negotiate Patent Licenses.

Cellulose Hydrolysis and Reactor System (BEI-DACH&RS)

BRELSFORD ENGINEERING, INC. is a Montana Corporation from 1980. Brelsford Engineering, Inc.'s President and Principal Engineer has been since its formation, and is currently Donald L. Brelsford, P.E.; who has BS & MS University Degrees in Chemical Engineering, and is a registered Professional Engineer in Colorado and Montana. The Brelsford Engineering, Inc. (BEI) business office and chemical engineering pilot-plant facility; located near Bozeman, Montana.

In early 1980's, a significant BEI development project was for pilot-plant demonstration of the continuous dilute-acid catalyzed hydrolysis of starch into fermentable glucose sugar; which was in a continuous plug-flow reactor; followed by continuous yeast fermentation of the sugar to ethanol, and solar- assisted vacuum distillation to the fuel ethanol product. Those BEI development projects was funded by Montana's (1) Renewable Energy Grant and Loan Program, and (2) Food and Fuels from Crops and Crop Residues Program.

In the mid-1980's, several privately funded, industrial-development, renewable energy utilization systems were engineering-designed and economically analyzed by BEI. Particularly, they were for fuel ethanol production from Montana's (1) wheat & barley grains, (2) grain-straw crop residues, (3) softwood lumber mill wastes, and (4) Aspen hardwood feedstocks. Economic feasibility was not adequate at that time. However, that was before the current Federal Producers Incentives for Fuel Ethanol production which is about $0.50/gal of fuel ethanol.

During the 1980s, the several privately funded, industrial-development, renewable energy utilization systems Feasibility Study activities, of Brelsford Engineering, Inc. (BEI), provided Donald L. Brelsford, BEI President and Principal Engineer, with substantial experience and significant incentives; as-well-as an intellectual basis for his subsequent invention and chemical engineering design of a new, unique, un-fore-seen, efficient and economical industrial process known as "The BEI Continuous Dilute-Acid Cellulose Hydrolysis Process and Reactor System" (designated: BEI-HP&RS).

Submitted to the USDOC National Institute of Science and Technology's (NIST) Office of Energy Related Inventions (OERI), September 1987, for overall technical and economic review, and as a proprietary and confidential invention was "The BEI Hydrolysis Process and Reactor System (BEI HP&RS)".

USDOC-NIST-OERI Technical Evaluation of the BEI-Dilute-Acid

The OERI Final Technical Evaluations Report No. 457 was reported in 14 months from its initiation. In that Final Technical Evaluation Report, Dr. J. J. Ulbrecht concluded and stated:

> "The BEI Process has a potential for achieving considerable economic savings in: (1) acid-consumption, (2) heat-energy supplied for cellulose hydrolysis, and (3) process-energy for fuel ethanol production. These process and economic

savings are likely to be partially off-set, by no more than one percent loss in total sugars yield."

"Because agricultural crop and logging residues have no food or other inherent value, their cost, as processing cellulosic feedstock, is determined only by the cost of collection and transportation; which is presently about $45/ton. In a conventional two-stage (dilute-acid) hydrolysis process, that cost of cellulosic feedstock raw material would contribute about 70% of the cost of sugar; with about 28% for acid use and recovery and 42% for energy costs; which converts to about $1.17/gallon of fuel ethanol, not including any other costs or revenues. It follows, in the case of the BEI Hydrolysis Process, the cost of acid would drop 36% and that of energy would be 30% less."

"Since the cost of delivered biomass is the same for BEI and for a conventional (known) two-stage (dilute-acid) process, the economic benefit of the BEI Hydrolysis Process is savings of about 22%, consequently with that saving the cost of Fuel Ethanol is reduced to about $0.91/gallon. Related steam-for-distillation savings would reduce it another $0.10 to about $0.81/gallon, which is about 31% in related Fuel Ethanol cost savings."

"If the sixty million tons of agricultural crop and logging residues, collected in the U.S. in 1980, were processed into Fuel Ethanol, approximately 12% of our current national oil consumption could be replaced. If all such available ligno-cellulosic biomass residues were so processed into Fuel Ethanol; it could be replacing some 78% of the U.S. oil supply consumption."

In January 1989, BEI was notified by the NIST/OERI that "The BEI Hydrolysis Process-Continuous Saccharification of Ligno-Cellulosic Biomass in Two Stages had been evaluated in-detail for possible recommendation to USDOE as worthy of consideration for possible government support". A BEI proposal to US DOE-EERE-I&IP was then prepared and submitted. Subsequently it approved and funded a BEI project to carryout the design, building and operation of the BEI-CHP&RS in the form of “The BEI Refined Engineering Prototype Pilot Plant“ at the BEI Facility, near Bozeman, MT.

BEI Dilute-Acid Cellulose Hydrolysis Process Pilot Plant Validation

In the 1990s, "The BEI Dilute-Acid Cellulose Hydrolysis Process and Reactor System" was assembled, at pilot plant scale, into "The BEI Refined Engineering Prototype" (REP) configuration. Its purpose was to carry out the chemical process pilot plant validations of The BEI Cellulose Hydrolysis Process & Reactor System (BEI DACH-P&RS); at the BEI Pilot-Plant Facility, near Bozeman, MT.

The BEI Dilute-Acid CHP&RS REP's limited operations included the dilute-acid cellulose hydrolysis processing of the Hemi- and Alpha- Cellulose fractions of feedstocks of (1) softwood lumber milling wastes, (2) DDGS corn fiber, and (3) MSW-RFD paper and cardboard. Each of those feedstock's resulted in significant dilute-acid HC and AC hydrolysate solutions; which contained their particular resulting pentose and hexose sugars; which were determined to be suitable to be fermented to ethanol.

In 1945 the intensive and accurate experimental laboratory investigations of J.F.Seaman, at the USDA-FS-FDL had determined that the chemical kinetics of the sulfuric acid hydrolysis of softwood resulted in the follow facts: (1) a 100% increase in acid concentration causes an increase of 153% in the k_1 cellulose-hydrolysis-rate kinetics constant, but that increase only caused the k_2-sugar product-degradation kinetics constant to increase 103%. (2) a 10 degree rise in C temperature causes an increase of approximately 190% in the k_1- cellulose-hydrolysis-rate kinetics constant, but then k_2-sugar-product-degredation kinetics constant increased only 130%.

In the US DOE-EERE-I & IP Project, the BEI dilute-acid cellulose hydrolysis process reaction conditions, for the three previously indicated feedstocks (soft wood, corn fiber, MSW paper) are included in the following: (1) dilute sulfuric-acid @ 1.0%, 1.75% and 2.5%; (2) liquid to solids ratio of 12:1, 10:1 and 8; 1; and (3) reaction temperatures of 140C and 150C for Hemi-Cellulose Hydrolysis (HCH); and 170C, 180C and 190C for Alpha-Cellulose Hydrolysis (ACH). The related chemical processing pilot-plant runs provided BEI with the chemical processing reaction ingredients, conditions, and results for the Pilot Plant Process Validations of the BEI CHP&RS which BEI reported.

An example of the BEI determined dilute-acid cellulose hydrolysis reaction time, for the maximum pine soft-wood Hemi-Cellulose hydrolysis is 7.7 minutes @ 140C, w/ 1.75% dilute sulfuric acid for which BEI achieved an 0.80 Hemi-Cellulose hydrolysis conversion yield,

An example of the BEI Pilot-Plant processing determined dilute-acid cellulose hydrolysis reaction time, for a maximum pine softwood Alpha-Cellulose hydrolysis; is 6.3 minutes @ 180C, w/ 2.5% dilute sulfuric acid which achieved a 0.60 Alpha-Cellulose fraction conversion yield, in a single-pass, in the BEI pilot plant; for the BEI CHP&RS Pilot Plant Process Validation. Fortunately, a 0.70 Alpha-Cellulose fraction conversion yield was achieved when 50% of the unhydrolyzed AC-Lignin residue was recycled; which provided for repeated exposure of unhydrolyzed Alpha-Cellulose residue to hydrolysis processing condition.

BEI Cellulose Hydrolysis Process & Reactor System (BEI-CHP&RS)

The BEI Cellulose Hydrolysis Process & Reactor System (BEI CHP&RS) is comprised of two double-tube heat-exchanger plug-flow reactors; which are assembled to act as a system of two-stages in series. Therein, is achieved a higher than Known-Art for Dilute-Acid catalyzed hydrolysis conversion of cellulosic feedstock into fermentable sugars. This is accomplished with the reverse interstage transfer process flow, from the second stage, of all reaction ingredients in a combined slurry of: (1) Alpha-Cellulose Hydrolysate (ACH), (2) recovered second-stage Process Heat, and (3) second-stage Dilute-Acid solution, all of which had been flashed and separated from the unhydrolyzing Alpha-Cellulose-Lignin Residue. After which, in the first stage, the solids-free solution passes to mix with the fresh Cellulosic Feedstock to provide for the hemicellulose hydrolysis into the Hemi-Cellulose hydrolyzate (HCH) solution, combined with the ACH solution.

BEI CHP&RS processing provides the following unforeseen breakthrough results:
(1) Dilute-Acid requirement: down 34% to 66 % of Known-Art,
(2) Process Heat requirement: down 30% to 70% of Known-Art,
(3) Alpha-Cellulose Hydrolysis conversion to glucose: up 10%, to 70% to 130% of Known Art,
(4) The HCH and ACH solutions combination into a single liquid product.

That single liquid product has a 110% higher soluble fermentable sugars fraction, than Known-Art; resulting in stronger beer, and substantially reduced distillation costs for the BEI Cellulose to Bio-Fuel Ethanol product recovery.

The benefits provided by the BEI CHP&RS include the following:
(1) Unforeseen cost reductions based on double use of the acid, the energy and water.
(2)
(2) Total capital costs, and total production operating costs are reduced to about 70%.

(3) USDOC NIST-OERI recommended BEI CHP&RS to USDOE for Federal Funding.

(4) USDOE-EERE I&IP financed The BEI Refined-Engineering Proto-Type Pilot-Plant design, construction and operation for the BEI CHP&RS Process Validation at pilot-plant scale which involved the Dilute-Acid Cellulose Hydrolysis (DACH) of: (a) Pine softwood sawdust cellulose, and (b) Corn DDGS &CGF fiber cellulose.

(5) Brelsford Engineering, Inc. holds the U.S. and Canadian Patents; which covers the BEI Dilute-Acid Cellulose Hydrolysis Process and Reactor System (BEI CHP&RS).

BEI's related funding was from the USDOE Energy Efficiency and Renewable Energy (EERE), Inventions and Innovations Program (I&IP). (See: Project Fact Sheet http://www.eere.energy.gov/inventions).

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