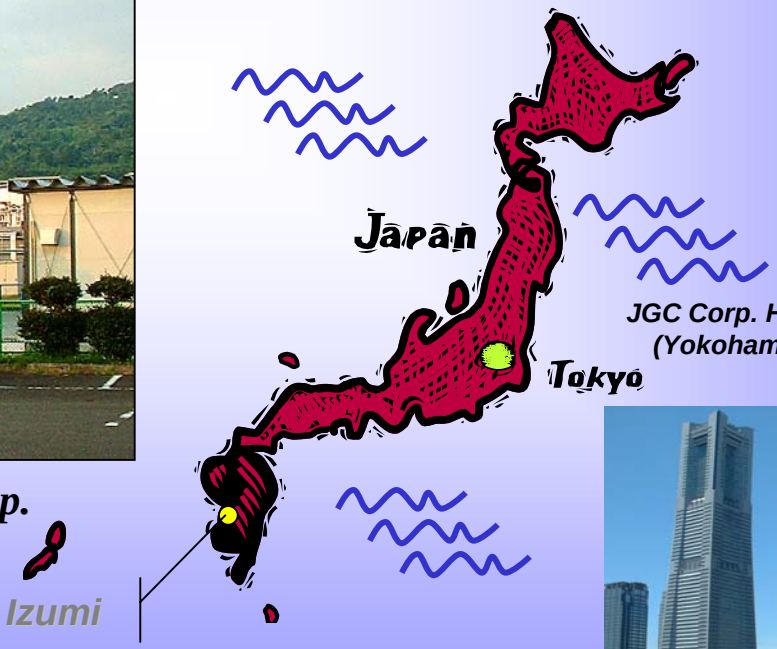
- Izumi Biorefinery –

(*in operation since 2002*)

"NEDO's Application of Arkenol's Concentrated Acid Hydrolysis Technology for the Conversion of Biomass to Ethanol"

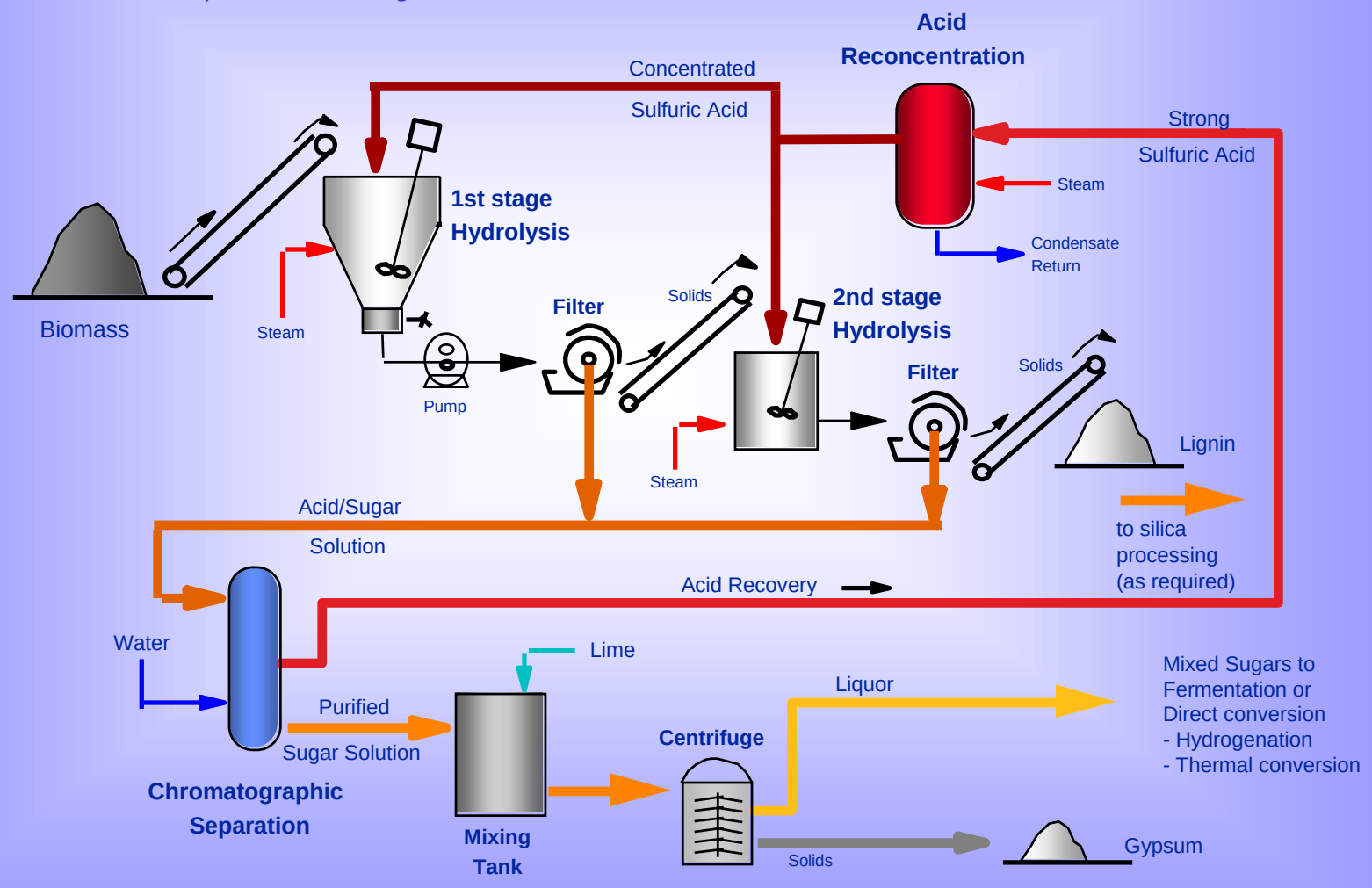
…a collaboration of Arkenol and JGC Corp.



JGC Corp. HQ (Yokohama)

Conversion of Cellulose/Hemicellulose to Mixed Sugars Using Arkenol's Concentrated Acid Hydrolysis

Simplified Flow Diagram



Arkenol….12 years from "idea" to "deployment"!

It starts with the search for a portable thermal host…

Pilot Plant- Orange, CA
1 TPD x 5 years
continuous operation!

JGC/NEDO Due Diligence and Pilot Operation

Exclusive Licensee in SE Asia!

JGC CORPORATION

Arkenol Incorporated

pre-1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002

Arkenol Fuels, Inc.

NREL CRADA Fermentation Trials

Completion of Project Development for Sacramento – *not financed!*

Due Diligence and Benchscale Investigations Begin

MTHF Process Development – U.S. Patent Allowed

Development of Glucose/Xylose Separation – US Patent Allowed

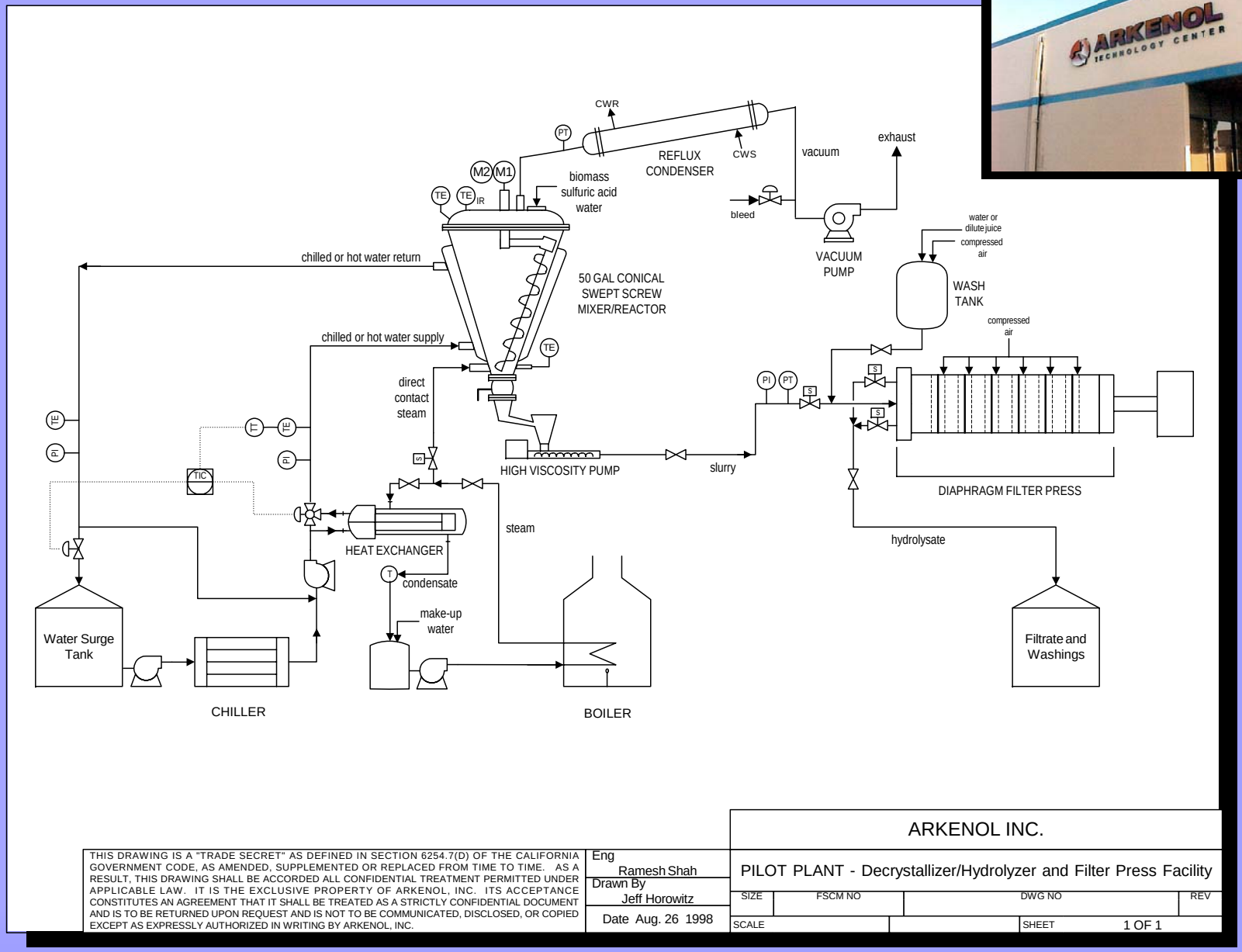
Preliminary Investigations at TVA and Univ. of Mississippi *reveal NO commercial technology!*

Completion of Base Technology Development - U.S. Patents Applied
Over 10 patents allowed!

Izumi Bio

Izumi Biorefinery Start-up

Arkenol Pilot Plant Schematic



THIS DRAWING IS A "TRADE SECRET" AS DEFINED IN SECTION 6254.7(D) OF THE CALIFORNIA GOVERNMENT CODE, AS AMENDED, SUPPLEMENTED OR REPLACED FROM TIME TO TIME. AS A RESULT, THIS DRAWING SHALL BE ACCORDED ALL CONFIDENTIAL TREATMENT PERMITTED UNDER APPLICABLE LAW. IT IS THE EXCLUSIVE PROPERTY OF ARKENOL, INC. ITS ACCEPTANCE CONSTITUTES AN AGREEMENT THAT IT SHALL BE TREATED AS A STRICTLY CONFIDENTIAL DOCUMENT AND IS TO BE RETURNED UPON REQUEST AND IS NOT TO BE COMMUNICATED, DISCLOSED, OR COPIED EXCEPT AS EXPRESSLY AUTHORIZED IN WRITING BY ARKENOL, INC.

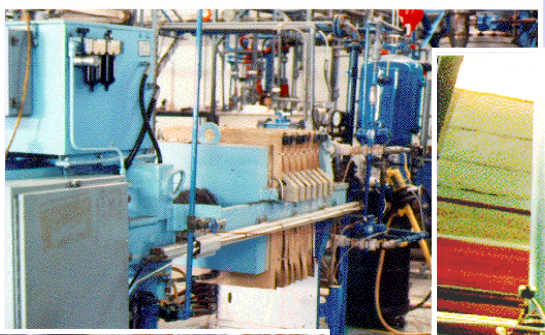
Eng	Ramesh Shah
Drawn By	Jeff Horowitz
Date	Aug. 26 1998

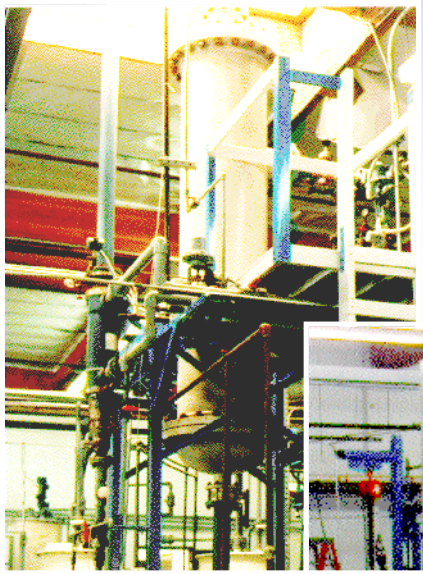
ARKENOL INC.

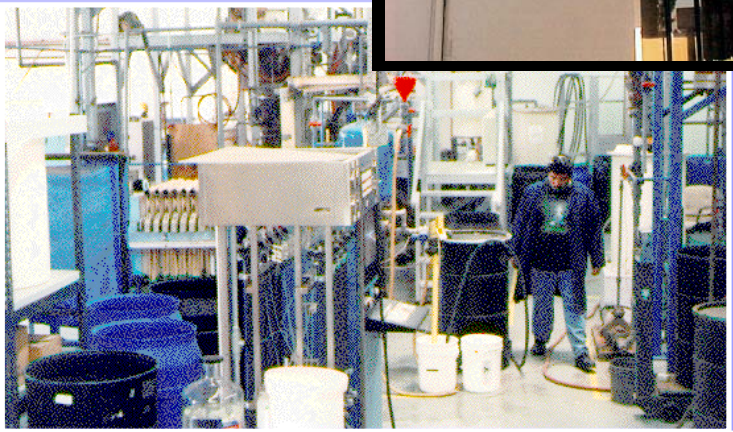
PILOT PLANT - Decrystallizer/Hydrolyzer and Filter Press Facility

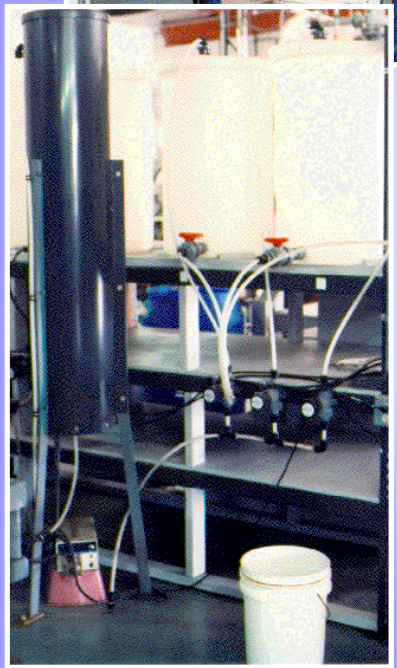
SIZE	FSCM NO	DWG NO	REV
SCALE		SHEET 1 OF 1	

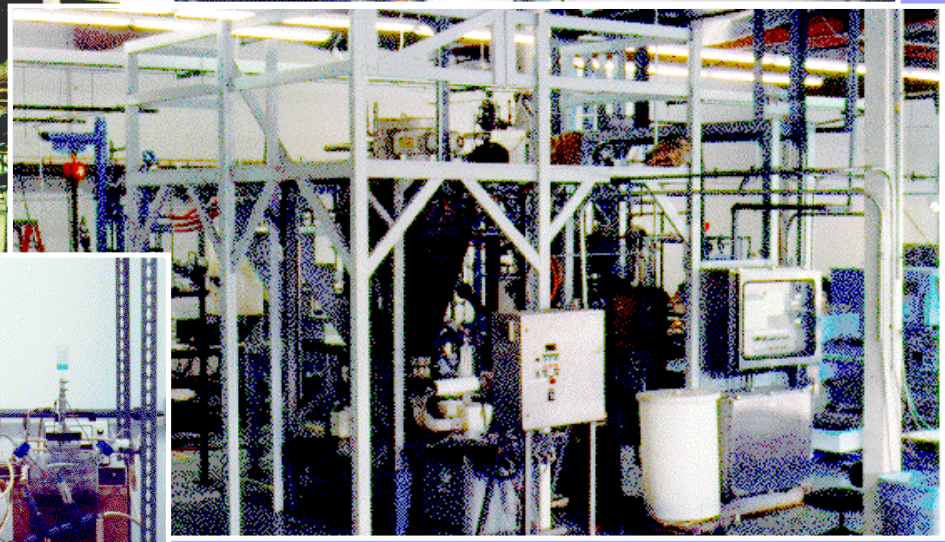
Arkenol Process Pilot Facility

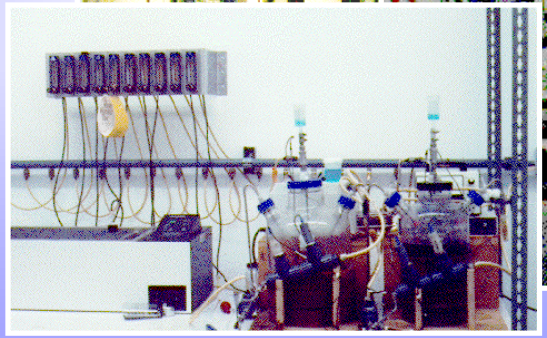












Continuous operation for 5 years!

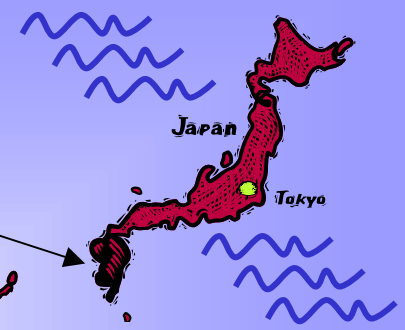
With Funding from NEDO, JGC developed a 5 year program to commercialize the Arkenol Technology for Japan accomplishing several goals:

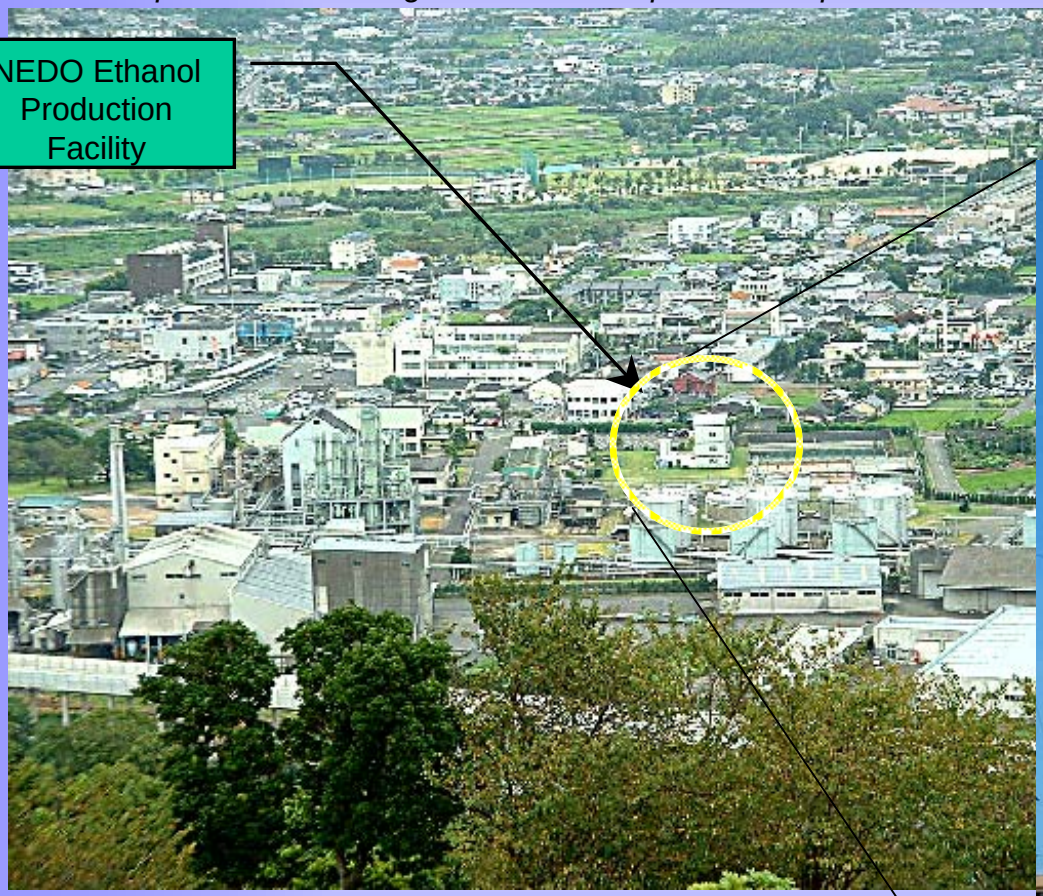
- **Produce fermentable sugars from wood waste.**
- **Ferment resulting sugars to ethanol.**

3rd party validation of Arkenol's process !

- **Reduce energy requirements of ethanol production by introducing novel technologies like flash fermentation and membrane distillation and purification.**
- **Provide consistent source of biomass-derived sugars for use in developing new recombinant microbes for improved ethanol production.**
- **Produce consistent supply of biomass-derived ethanol for use in engine driveability programs.**

Izumi is a small industrial town of 50,000 with an agricultural component, on the southern tip of Japan, several hours travel SW of Tokyo where warm, hard-working people are found. The facility is sited next to a 35-year old NEDO ethanol purification facility. Having started up in September 2002, the facility is under contract to NEDO through 2007 to produce sugar for ethanol production. JGC will use this plant as the platform from which to scale the technology to various capacities, marketing to its client companies in Japan and SE Asia.

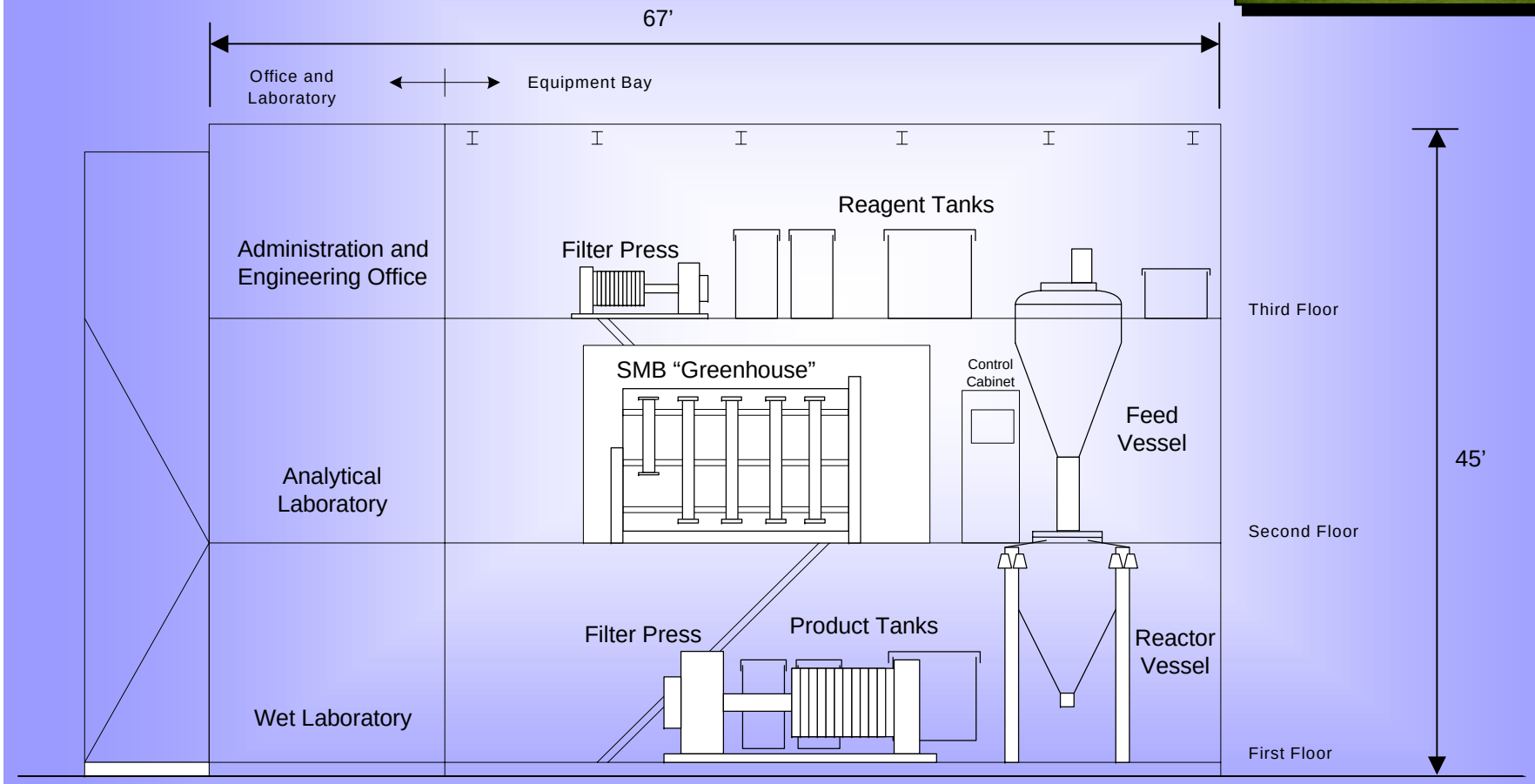




The facility is housed in a three-story shell, with a footprint of approximately 30' x 72'. The first floor houses a wet chemistry bay where hydrolysis at bench-scale may be studied. The second floor houses the analytical laboratory. The third floor provides office space.

Simplified Arrangement of Izumi Facility

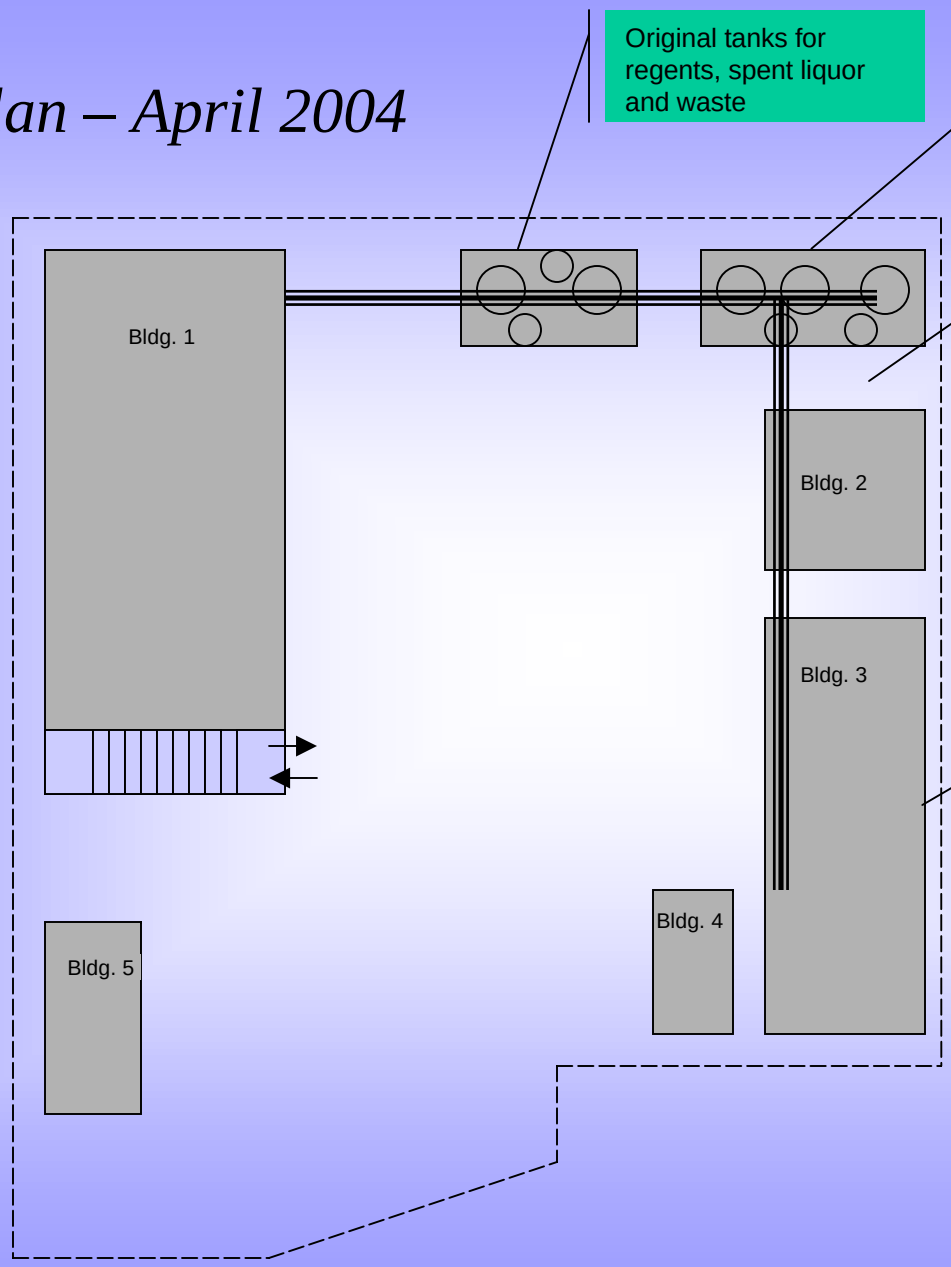
- initial (year 2002) operating configuration



Note: Does not include 2003/2004 modifications

Drawing Not to Scale

Current
Izumi Site Plan – April 2004



Legend

- Bldg.1 – Original process building
- Bldg. 2 – Feedstock dryer building with heaters, ID fan, and baghouse
- Bldg. 3 – BNRI membrane separation unit
- Bldg. 4 – Misc. storage (original feedstock storage unit)
- Bldg. 5 – Lockers and misc. storage

Feedstock Management 2002

Chips arrive in sacks just as they are produced and are sized on-site to a nomimal 10 mm, with high fines fraction.

*Waste wood chips, comprised of a mix of **cedar, pine,** and **hemlock**, are supplied by the local furniture and paper industry, and are used as target feedstock.*

Feedstock Management 2004

- *Feedstock dryer and storage building provides capability to dry wood chips to specified conditions independent of weather conditions.*
- *Unit is heated by natural gas, direct-fired heaters.*

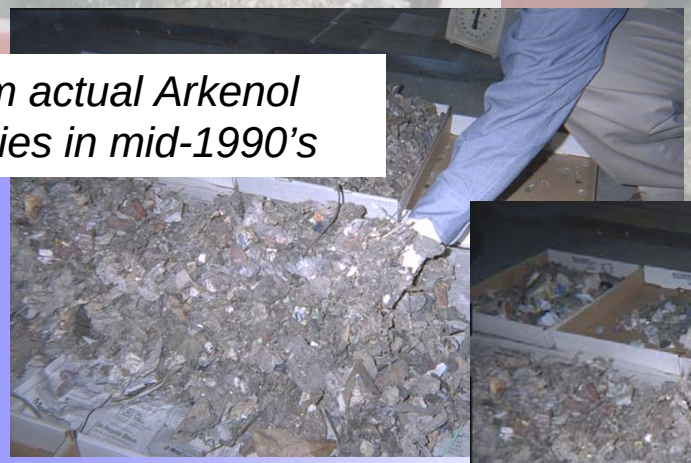
Baghouse Filter

Heaters

- *Feedstock is processed on a campaign basis, then bagged for future use.*

Post-sorted MSW as a feedstock

From actual Arkenol studies in mid-1990's



By weight…post-sorted MSW is more than <u>70% cellulose</u>!

From Holland…
to Minneapolis….
to Los Angeles!

<u>Typical Components:</u>

- Paper
- Plastic
- Glass
- Ferrous
- Non-ferrous

Component breakdown into carbohydrates

i.e., NOT paper or plastic

Analysis of Athens T-3 Residual Stream

Based on 250 lbs sorted material 5/10/99, 5/11/99 supplied by Clements Environmental

		Feed		Moisture	Moisture	Feed, dry	Feed, dry	Cellulosics	Cellulosics	
		lbs	%	%	lbs	lbs	%	%	lbs	
Paper		201.0	81.74%	0.10	20.1	180.9	73.57%	95.00%	171.86	
Plastics		14.5	5.90%	0.00	0	14.5	5.90%	0.00%	-	
Mixed residue		30.4	12.36%	0.40	12.16	18.2	7.42%	67.00%	12.22	
	Totals	245.9	100%		32.26	213.64			184.08	
						213.6			29.56	

		Composition (est)		Composition (est)						
		Glucans	Xylans	Glucans	Xylans	Lignin	Lignin	Ash/Inerts	Ash/Inerts	Totals
Paper		%	%	lbs	lbs	%	lbs	%	lbs	
Plastics		95%	5%	163.3	8.6	2.00%	3.62	3.00%	5.4	100.00%
Mixed residue		0%	0%	0.0	0.0	0.00%	0.00	100.00%	14.5	100.00%
	Totals	80%	20%	9.8	2.4	12.00%	2.19	21.00%	3.8	100.00%
				173.04	11.04		5.81		23.8	
							29.5642			

Composite Feed Analysis

	%	%
Glucan	81.00%	71.60%
Xylan	5.17%	4.57%
Lignin	2.72%	2.40%
Ash/Inerts	11.12%	9.83%
Total, dry	100.00%	
Moisture	13.12%	11.60%
Total (wet)	113.12%	100.00%

New Tank/Piping for Ethanol and Sugar Storage

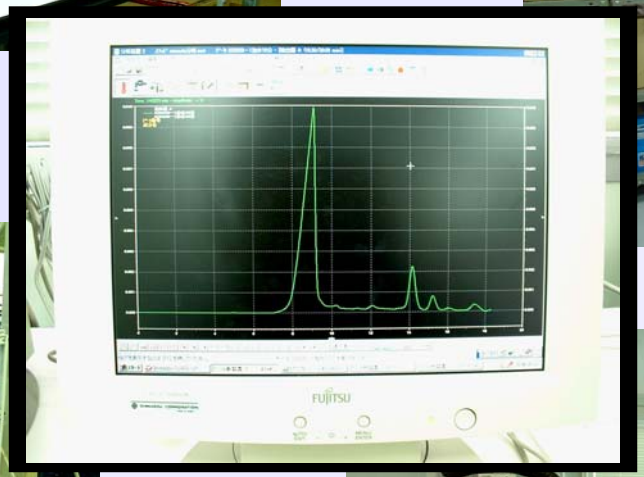
Feedstock Dryer

Membrane Distillation and Purification Building – *Installed by BNRI, division of Mitsui*

First Floor – Wet Chemistry

The second floor analytical laboratory is well-stocked with two (2) Shimadzu HPLC columns, IR Spectrograph, ovens, hoods, an autoclave unit, and storage for glassware and reagents.

Second Floor - Analytical



The HPLC provides timely feedback as to the completion of the hydrolysis run

The third floor office serves as a work area for engineers, scientists, and a secretary. Each morning, a staff meeting is held to reviews plans for the day's activities and prior day's results.

Third Floor - Office

A computer network enables fast exchange of data, email, and print jobs for color printers.

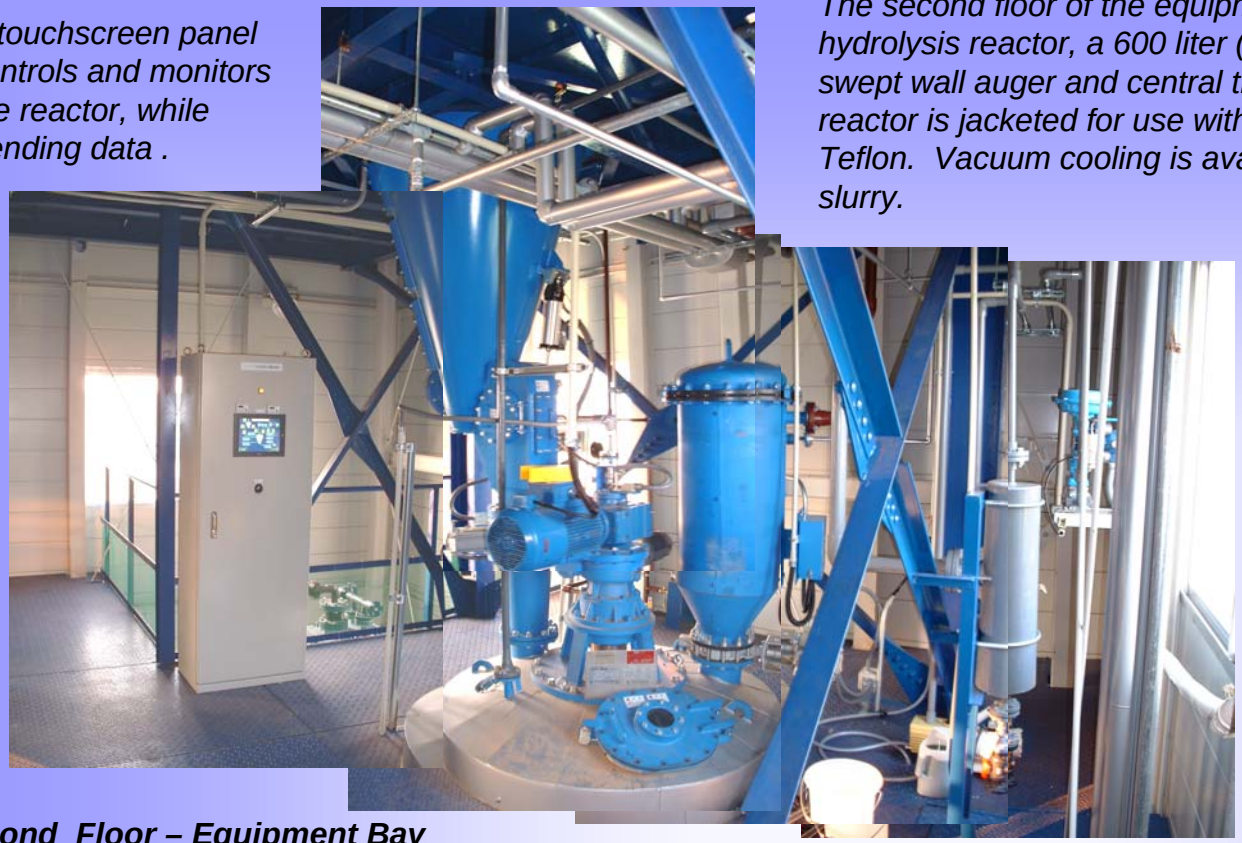
A full charge for the feed vessel is 260 kg. It is very convenient to fill the vessel with pre-weighed 10 kg. bags of feed to the desired level for a given run.

Third Floor – Equipment Bay

The third floor of the equipment bay is where feedstock is loaded in the feed vessel. Storage tanks, chillers and a gypsum filter press may be found on this floor.

Through the doorway (at right) is the engineering office and its meeting room.

A touchscreen panel controls and monitors the reactor, while trending data .

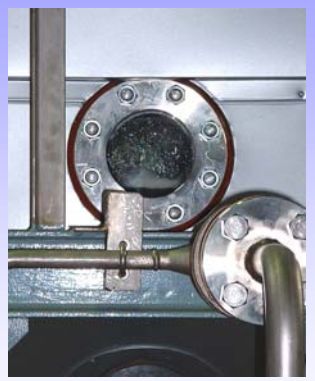


The second floor of the equipment bay provides access to the hydrolysis reactor, a 600 liter (working volume) conical reactor with swept wall auger and central thermoprobe. The stainless steel reactor is jacketed for use with steam and internally coated with Teflon. Vacuum cooling is available to speed the cooling of the slurry.

Second Floor – Equipment Bay

Feedstock is metered from the vessel on the third floor where it is mixed with acid at temperatures from 35-65ºC. During hydrolysis, the structure of the feed breaks down into a slurry.

The third floor houses the drain and pump for the main reactor vessel, the filter press, steam boiler, plant air, water treatment, liquid storage tanks, and the acid reconcentration system.



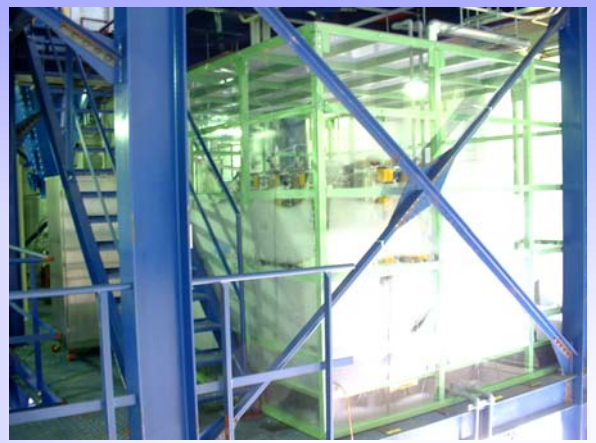
The acid reconcentrator receives the acid stream at about 18% sulfuric acid and efficiently removes enough water to reach 75% working strength.

The filter press is used to separate inert solids in the hydrolyzate slurry from the liquid that contains the soluble sugars.

First Floor – Equipment Bay

Update: Supplied by Mitsubishi, pressure filter is installed and operating since June 2004. Unit shown is as delivered and is identical to type specified for scale-up.

Update: A 4x expansion of the SMB was accomplished in February 2004, to allow for processing of <u>all</u> hydrolyzate. Start-up performance MATCHED that of the original!

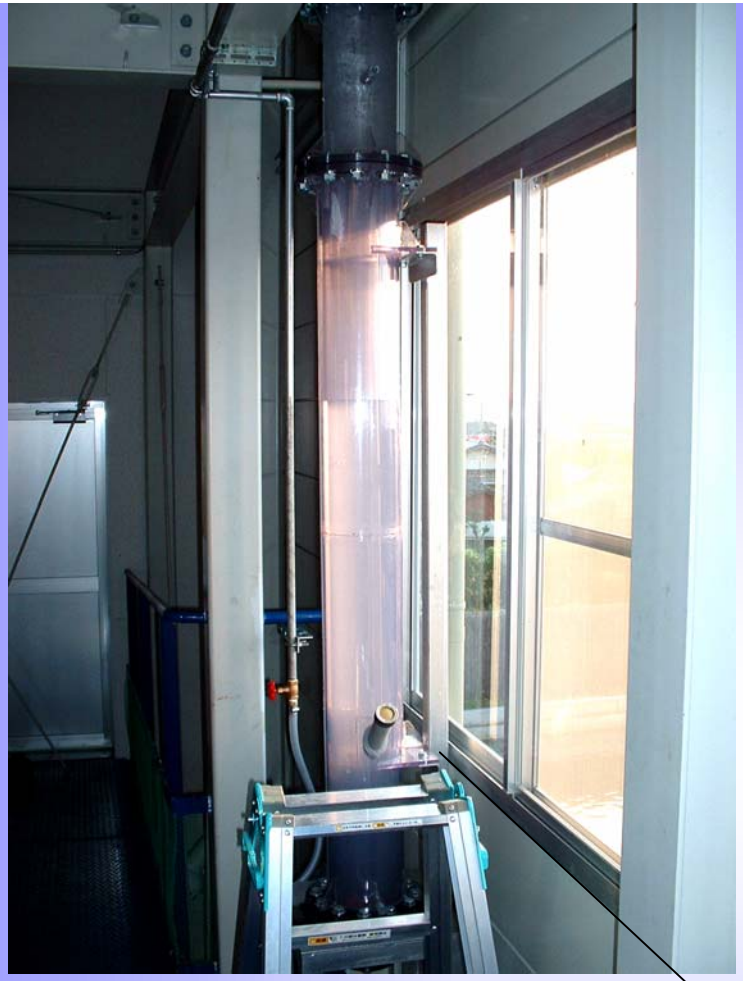


Second Floor – Equipment Bay

The simulated moving bed (or "SMB") chromatographic separations unit is the key to separating the acid fraction of the hydrolyzate from the sugar stream. Using small plastic beads made of either a cation or anionic resin, the SMB makes it possible to recover and recycle acid at high efficiency and with low energy expenditure.

SMB's may be found within the sugar industry and are used for glucose-fructose separation and for separating sugar from molasses.

For maximum efficiency, the unit is housed in a climate controlled "greenhouse" that maintains temperature at about 28ºC.



Third Floor – Equipment Bay

<u>Goals for Ethanol production</u>: (1) produce ethanol for Japan's fuel blend driveability program, and (2) introduce new technologies to reduce energy required for production.

Ethanol fermentation takes place in a fluidized reactor with immobilized media. Use of the immobilized media in this configuration greatly reduces the amount of cell biomass debris typically produced during fermentation, thus greatly reducing the BOD loading of effluent from any plant using this technology

During the operating life of the facility, six Japanese universities will use the facility as an operating platform to test new recombinant microbes for the production of ethanol. Included in this mix will be a variant of rec. Zymomonas mobilis supplied by the U.S. National Renewable Energy Laboratory in Golden, Colorado.

- **Model of "bubbling bed, fixed media, flash fermenter"**
- **Ethanol concentration < 4%(vol) to maintain optimal metabolic rates.**

Ethanol Fermentation And Flash Distillation

Installed and Operating
August 2003

At Vendor - Prior to Shipping To Izumi

Third Floor View

Second Floor View

Common distillation and beer well

First Floor View

- 2 Fermentation Trains
  - 1 x 35 liters
  - 1 x 350 liters
- Distillation Capacity 100 liters/day of 95.5% ethanol product

Continuous Hydrolysis Unit

- !st Generation -
Installed and Operating
May 2003

Continuous Hydrolysis Unit

- 2nd Generation-
August 2003

Capacity: 40kg/hr wood chips

Unit is a evaluation unit used by vendor to design purpose-built unit ready for installation in May 2004.

Continuous Hydrolysis Unit

- 3rd Generation-
June 2004

Capacity: 40kg/hr

Izumi Highlights

Arkenol/JGC/NEDO

2004

- Fully integrated, Arkenol concentrated acid-hydrolysis system using waste wood chips as feedstock, operational since 2002.
- Cellulose conversion efficiencies stable at 70%, with optimization to 80%.
- Sulfuric acid recovery at over 97% with reconcentration to 75% in continual use since 2002.
- Lignin combustion test (requiring 4 tons fuel lignin) completed successfully.
- JGC-developed flash fermentation offers significant operating cost savings.
- Uses NREL developed rec. *Z. mobilis* (under license) in fixed bed and *S. cereviscae* to produce ethanol at 95% and above for over one year.
- Capacity of continuous ethanol production raised from 100 liters/day to a total of 300 liters/day in March 2004.
- Uses first commercial membrane distillation and purification system supplied by Mitsui with significant operating cost savings over conventional (molecular sieve) technology.
- Ethanol used by Japanese Government program for engine driveability tests and materials coupon tests.
- JGC commits to providing Design Specification Package for U.S. and will consider equity participation in a California project.

Our trained and helpful staff of professionals….