HAWAII ETHANOL FROM MOLASSES PROJECT

The Research Corporation of the University of Hawaii
Contract with the U.S. Department of Energy
(No. DE-AC03-79ET23141)

AC03-79ET23141

REPORT ON PLANT INSPECTIONS

by

Project Manager: Mr. Warren O. Gibson
Consulting Engineer, Hawaiian Sugar Planters' Association

Investigators: Mr. Ken I. Mashima, Associate Engineer
Dr. Robert R. Roberts, Assistant Microbiologist
Hawaiian Sugar Planters' Association

Principal Investigator: Dr. Charles S. Chen, Director,
Center for Engineering Research
University of Hawaii

September 18, 1979

DISCLAIMER

SUMMARY

The Research Corporation of the University of Hawaii (RCUH), under a contract with the U.S. Department of Energy (DOE) (Contract No. DE-AC03-79ET23141), has subcontracted portions of the tasks to the Hawaiian Sugar Planters' Association (HSPA). The contract with DOE is for Phase I of the Hawaii Ethanol from Molasses Project (EFMP). Task 2 of Phase I is titled "Plant Inspections and Design" and states in part: "The contractor will determine by personal inspections of operating plants the best commercial processes presently in operation, prepare a conceptual design of a large plant incorporating these processes, describe the processes, and list best estimates of yields, energy requirements, capital costs and operating costs." Task 4 is titled "Industry Process Developments" and states in part: "The contractor will obtain from fermentation plant manufacturers and alcohol producers information, not held as proprietary, concerning their company-sponsored process improvement and new process developments."

HSPA personnel inspected plants in Europe and the U.S. for the purposes stated above. The HSPA group consisted of:

Mr. Warren O. Gibson, Consulting Engineer
Mr. Ken I. Mashima, Associate Engineer
Mr. Robert R. Roberts, Assistant Microbiologist

They left Hawaii August 2 destined for Europe and returned to the U.S. August 15 and returned to Hawaii August 18, 23, and 28. Appendix A presents the complete itinerary. The following plants were visited in Europe.

August 7	A. Ahlstrom Oy (Karhula, Finland) Pilot incineration
August 7	Oy Kaukas Ab (Lappeenranta, Finland) Commercial incineration
August 9	Zuid-Nederlandse Spiritusfabriek (Bergen op Zoom, Netherlands) Continuous fermentation
August 10	Zuid-Nederlandse Spiritusfabriek (Delfzijl, Netherlands) Batch fermentation
August 13	Mautner Markhof (Vienna, Austria) Baker's yeast and ethanol
August 14	Vereinigte Edelstahl Werk (Ternitz, Austria) Equipment manufacturing

Two plants were visited in the U.S. as follows:

August 20	Dehydro-Tech Corp. (East Hanover, New Jersey) Carver-Greenfield Process
August 22	Georgia-Pacific Corp. (Bellingham, Washington) Ether dehydration

In addition to plant visits, the group met with ALFA-LAVAL representatives in Sweden, August 6, and Dr. Roberts met August 17 with the plant manager of Archer-Daniels-Midland (ADM), Alcohol Division. ADM policy prevented observing plant operations.

Arrangements for visiting the Finland plants were made by Mr. Pauli Kujala, ALFA-LAVAL, Food Technology Division, S-147 00 Tumba, Sweden. Mr. Kujala accompanied the group on these visits. Mr. Jukka Sainiemi, AHLSTROM, P.O. Box 239, SF-00101 Helsinki 10, was in charge of the Finland visits. The commercial plant incinerating waste sulfite liquor was shown by Mr. Pertti Simola, the Operating Manager. The pilot incineration plant was shown by Dr. Seppo Ruottu, Research Engineer, AHLSTROM.

The two fermentation plants are under the direction of Mr. P. Melman, Wittoucksingel 52, Bergen Op Zoom, Netherlands. Mr. Melman showed the Bergen Op Zoom plant and Mr. P. L. Kwant, Engineer, showed the Delfzijl plant. Arrangements for visiting these plants and the Austria plants were made by Mr. Gunter-Bernd Brodl, Technology, VOGELBUSCH, Vogelbusch Gesellschaft mbH, A-1110 Wien, Mautner-Markhof-Gasse 40, Austria. Mr. Johann Gurnhofer, Project Leader, VOGELBUSCH, same address as above, accompanied the group in Austria. Mr. Stefan Mayerhofer, Plant Manager, showed the Vereinigte Edelstahl Werk plant.

Only Mr. Mashima visited the Dehydro-Tech Corp. pilot plant for dewatering stillage. Arrangements were made by Mr. Charles Greenfield, President, Dehydro-Tech Corp., 6 Great Meadow Lane, East Hanover, New Jersey 07936.

Messrs. Gibson and Mashima visited the Georgia-Pacific plant with headquarters at 300 W. Laurel Street, Bellingham, Washington 98225. Mr. Ed Dahlgren, Manager of Engineering Services, Bellingham Division, arranged for the visit and showed the plant. Accompanying was Mr. Tom Spink, Technical Director.

Highlights of the trip were:

Observed commercial incineration of waste sulfite liquors. Observed the pilot plant (not in operation) to incinerate various waste liquors resulting from fermentation of different feedstocks.

Observed commercial continuous and batch fermentation of beet molasses for the production of ethanol and stillage evaporation to 70% dissolved solids for animal feed. Both plants (continuous and batch) are managed by the same person, Mr. P. Melman.

Observed pilot plant operation of a new process (Carver-Greenfield Process) for handling stillage. With this process, stillage is evaporated to a thick sludge and then oil is added. The mixture is then sent to a settling tank where the solids are separated. Centrifuging or pressing is the final step in producing a dry product.

Observed anhydrous ethanol production from fermentation of sulfite waste liquor using ethyl ether as the dehydrating agent and observed the safety precautions taken when using this hazardous material.

PLANT VISITS AND MEETINGS

DATE: August 6, 1979

COMPANY: ALFA-LAVAL
LOCATION: Tumba, Sweden
CONTACTS: Mr. Pauli Kujala, Sales Engineer, Food Technology Division; Dr. Carl Yhland, General Manager, Bioventure; Dr. Roger Cook, Manager, Process Engineering, Bioventure; Mr. Hans Axelsson, Manager, Food Technology Division

Fermentation and stillage handling processes were discussed extensively. In fermentation, they recommended that it should utilize molasses purification and sterilization, the shortest possible fermentation time with maximum ethanol yields, and yeast recycling. The possibility of recycling stillage waste waters back to molasses dilution was also mentioned. If feasible, it would reduce energy consumption during distillation-rectification and stillage evaporation, and it would reduce process water requirements.

From the standpoint of economics and energy, they felt that distilleries should be designed as a total processing complex in which stillage treatment is an integral part. Evaporated stillage at 60% D.S. can be incinerated to produce sufficient steam to cover the evaporation needs in a multiple-effect evaporator. However, the economics of this system require potassium (ash) recovery. This has traditionally created a problem of recovering a non-fused ash product from high temperature incineration. Alfa-Laval has worked with A. Ahlstrom Oy (in Finland) to develop a stillage-fired boiler with the capabilities of high combustion temperatures and ash recovery with a minimum of fusion. Pilot plant facilities were built in Sunila, Finland where tests are underway using molasses alcohol stillage.

DATE: August 7, 1979

COMPANY: A. Ahlstrom Osakeyhtio
LOCATION: Karhula, Finland
CONTACTS: Mr. Jukka Sainiemi, Engineer, Engineering and Sales;
Dr. Seppo Ruottu, Research Engineer, Engineering Works Division

A. Ahlstrom Osakeyhtio has considerable experience in engineering and manufacturing steam boilers fueled by wood waste. In order to test the incineration of various waste liquors, they have constructed a 2.5 MW pilot plant next to a pulp and paper factory. A cross section of the pilot plant is shown in Fig. 1. Since it is not equipped with evaporators nor turbine-generators, the fuel liquor must be pre-evaporated and the steam produced is used in the paper factory.

At the time of our visit the pilot plant was not in operation (holiday season), however, the incineration of molasses alcohol stillage (MAS) was described to us from previous tests. Pre-evaporated MAS at 62% D.S. is introduced into the combustion chamber through a specially designed nozzle and atomized with steam before ignition. Prehated air enters tangentially to the fuel creating a vortex in the octagonal combustion chamber and complete combustion occurs at high temperatures ($\sim$1100°C). The flue gases flow downward past the water tube impactor where some of the potassium ashes fall out, and the gases continue upward past the convection bank and air preheater where more ash is recovered. Most of the remaining ash is then removed in a hopper below the stack. Since flue gas exit temperatures range from 530° to 550°C, the gases are expected to be used for partial evaporation of the MAS in a commercial incineration plant.

Although MAS incineration problems are solved, Ahlstrom expects to continue tests to maximize potassium recovery.

DATE: August 7, 1979

COMPANY: Oy Kaukas Ab
LOCATION: Lappeenranta, Finland
CONTACTS: Mr. Pertti Simola, Engineer, Power Division

Oy Kaukas Ab manufacturers pulp, paper and various other wood products. Electricity and process steam for this factory are provided by five high-pressure boilers through co-generation. Two of these boilers are fired by waste sulfite liquor while the others are fired by coal, fuel oil, and bark. The HSPA personnel were permitted to inspect one of the recovery boilers manufactured by A. Ahlstrom Oy.

Fuel in the form of dilute sulfite liquor is concentrated in a 6-effect evaporator to 60-62% D.S., preheated, then incinerated in the recovery boiler through atomizing burners. The boiler produces superheated steam at 84 bars, 480°C which passes through a 10.5 MW

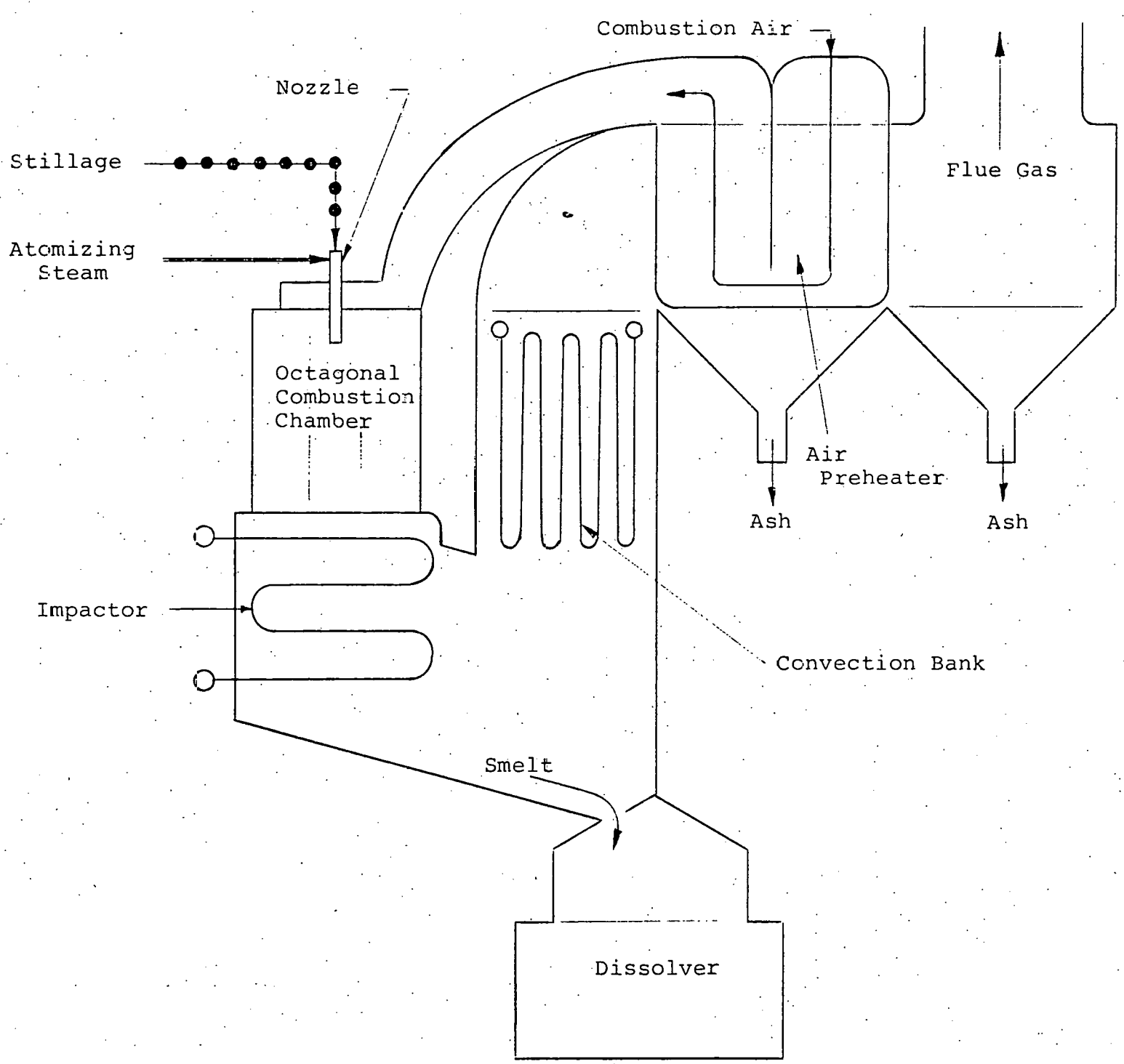

Fig. 1. Schematic diagram of Ahlstrom's pilot incineration plant.

turbine-generator unit. Ashes in the flue gas are recovered at various locations (hoppers) downstream from the boiler tank with final removal achieved through electrostatic precipitators. The recovered ashes (sodium sulfate) are used in the paper manufacturing process.

DATE: August 9, 1979

COMPANY: Zuid-Nederlandse Spiritusfabriek (ZNSF)
LOCATION: Bergen op Zoom, The Netherlands
CONTACTS: Mr. Th. P. Melman, Director

The ZNSF distillery was designed, supervised, and started up by Vogelbusch, GmbH. The distillery is operating a multistage fermentation process (continuous fermentation) with a continuous feed of sugarbeet molasses. The fermentation plant has two rows of seven, $70m^3$ stainless steel fermentors with each row operating independently. The fermentation time is eight hours, and the ethanol concentration in the mash is 10.5% (v/v). At the completion of the fermentation, the mash is centrifuged, and a portion of the recovered yeast is returned to the first fermentor while the excess yeast is dried, packaged, and sold. The liquid from the centrifuge is distilled, rectified, and dehydrated (using cyclohexane) to produce anhydrous ethanol and fusel oils. The remaining liquid stillage is dehydrated to 70% dry substance and sold as a cattle feed supplement. Although the yield from the distillery varies slightly depending on the market for ethanol, the distillery produces approximately 170,000 liters of anhydrous ethanol and 11,000 kg of fodder yeast per day as well as a small quantity of fusel oils.

DATE: August 10, 1979

COMPANY: Zuid-Nederlandse Spiritusfabriek (ZNSF)
LOCATION: Delfzijl, The Netherlands
CONTACTS: Mr. P. L. Kwant, Engineer, Alchol Fabriek Delfzijl;
Mr. Th. P. Melman, Director

This distillery (designed by Vogelbusch, GmbH) is fermenting sugarbeet molasses using a short fermentation time batch process with recycled yeast. Six fermentors are used, each displacing $80m^3$. The fermentation time is approximately eight hours, and the batch turn around time is 12 hours yielding a mash contain- 10% (v/v) ethanol. At the completion of the fermentation, the mash is centrifuged, and a portion of the recovered yeast is used in a subsequent fermentation. The surplus yeast is washed, dried, packaged, and sold. The liquid from the centrifuge is distilled and rectified to produce ethanol (96%) and fusel oils. The remaining liquid stillage is dehydrated to 70% dry substance and sold as a cattle feed supplement. The distillery capacity is 42,000 liters of 96% potable ethanol and approximately 1500 kg of surplus yeast per day.

DATE: August 13, 1979

COMPANY: Mautner Markhof
LOCATION: Vienna, Austria
CONTACTS: Mr. Johann Gurnhofer, Engineer, Vogelbusch, GmbH;
Mr. Gunter-Bernd Brodl, Technologist, Vogelbusch, GmbH

Mautner Markhof operates a plant producing baker's yeast and ethanol as a by-product. This plant was reconstructed under the supervision of Vogelbusch, GmbH, and they continue to provide technical consulting services.

The plant uses sugarbeet molasses as feedstock. The molasses is heated to 90°-100°C then cooled by expansion to 65°-70°C and then further cooled to 30°C. The solids in the molasses are separated by filtration through diatomaceous earth. In the fermentor, the treated and diluted molasses is pumped at a high velocity past an orifice through which air is drawn. Yeast is grown rapidly in this manner, separated from the mash and drum-dried. The remaining liquid is distilled to remove beverage grade ethanol and the stillage is disposed in the sewage system.

DATE: August 17, 1979

COMPANY: Archer-Daniels-Midland
LOCATION: Decatur, Illinois
CONTACTS: Ray Strasma, Manager

Archer-Daniels-Midland (ADM) is enlarging its plant to a capacity of 500,000 gallons (1,900,000 liters) ethanol per day. However, the plant will be operated initially at 150,000 gallons (570,000 liters) of ethanol per day. The fermentors will have a volume of 100,000 gallons ($378m^3$). Their method of operation in the new facilities will either be a 16-hour batch fermentation or a continuous fermentation. They will recycle their yeast in the new plant.

ADM is using a dextrose syrup derived from the hydrolysis of corn starch as a feedstock for the fermentation. The same dextrose syrup could be routed to an enzyme treatment for the production of high-fructose corn syrup depending on end-product profitability.

In the old plant they were using 100,000 gallons ($378m^3$) fermentors inoculated with 350 pounds (160 kg) of dry yeast, which were grown in the plant. A small amount of protein was added to the fermentors since the feedstock was protein deficient. The initial mash density was approximately 20° Brix and pH was 6.0; the final pH was about 4.0. After a 40-hour fermentation, the mash contained 10% to 11% (v/v) ethanol. The stillage was concentrated in four stages to 40% dry substance and used as an animal feed supplement. For dehydration (on a small scale) benzene was being used, and the benzene consumption was 100 ppm. Other methods for the dehydration of ethanol are being investigated. Mechanical recompression of steam is being done to conserve energy.

DATE: August 20, 1979

COMPANY: Dehydro-Tech Corporation
LOCATION: East Hanover, New Jersey
CONTACTS: Mr. Charles Greenfield, President; Mr. Eric P. Steiner, Foster Wheeler Energy Corporation

The Dehydro-Tech Corporation has developed a low energy, environmentally clean system for dewatering various forms of sludges and slops. The system, called the Carver-Greenfield Process, produces a dry product which, depending upon the type of product, may be incinerated, used for fertilizer or animal feed, or disposed of as is. This Process is currently marketed by the Foster Wheeler Energy Corporation.

Pilot plant facilities for the Carver-Greenfield Process are located in East Hanover (approximately 8 kilometers from the Foster Wheeler offices) where dewatering tests are conducted on various sludge-type materials. Preliminary on-site tests are also possible with their mobile pilot plant.

In the Carver-Greenfield Process, water is removed from the sludge (slops) by evaporation using multiple-effect evaporators. Thickened sludge, which is difficult to pump and causes scaling during evaporation, is mixed with oil. The oil acts as a transport medium during evaporation leaving an oil and solids mixture after all of the water has been vaporized. The mixture is then sent to a settling tank which separates the oil from the solids. Any remaining oil in the solids is removed in a centrifuge or screw-type press, leaving a final product which is fine, dry, and powdery.

Foster Wheeler and Dehydro-Tech indicated that the Carver-Greenfield Process could be applied to yeast drying and stillage drying. In fact, an ethanol plant in Italy (outside of Milan) has recently installed the Carver-Greenfield Process for stillage drying. They are incinerating the dry stillage and will look into the possibility of potassium recovery.

DATE: August 22, 1979

COMPANY: Georgia-Pacific Corporation
LOCATION: Bellingham, Washington
CONTACTS: Mr. Ed Dahlgren, Manager of Engineering Services, Bellingham Division; Mr. Tom Spink, Technical Director, Bellingham Division

One of the many production processes at this Georgia-Pacific plant involves anhydrous ethanol production from the fermentation of sulfite waste liquor using ethyl ether as the dehydrating agent.

The fermented sulfite waste liquor containing 1.8% to 2.0% ethanol is distilled and rectified to obtain 190° proof alcohol. The still "bottoms" are processed to recover all by-products,

and fusel oils and aldehydes are disposed of in the steam generator. The alcohol from the rectifying column is then fed to a dehydrating column where the remaining water in alcohol is removed using ethyl ether. The daily production of anhydrous ethanol is approximately 22,700ℓ.

For the dehydration process, the steam requirement is about 0.6 kg/ℓ of 100% ethanol, and the consumption of ethyl ether amounts to 0.003 ℓ/ℓ of 100% ethanol. Precautionary steps are taken in working with ethyl ether. We noted that supplies are kept cool under a constant water spray and nitrogen is used as a blanket during injection.

APPENDIX A

ITINERARY

Group: W. Gibson, K. Mashima and R. Roberts

LV	Honolulu	Th	8/2	
AR	Los Angeles	Th	8/2	
LV	Los Angeles	F	8/3	
AR	Copenhagen	Sat	8/4	
LV	Copenhagen	Sat	8/4	
AR	Stockholm	Sat	8/4	
		M	8/6	Meeting with Alfa-Laval representatives
LV	Stockholm	M	8/6	
AR	Helsinki	M	8/6	
		Tu	8/7	Visit pilot incineration plant, visit commercial incineration plant
LV	Helsinki	W	8/8	
AR	Stockholm	W	8/8	
LV	Stockholm	W	8/8	
AR	Amsterdam	W	8/8	
		Th	8/9	Visit continuous fermentation plant
		F	8/10	Visit batch fermentation plant
LV	Amsterdam	Sun	8/12	
AR	Vienna, Austria	Sun	8/12	
		M	8/13	Visit plant producing yeast and ethanol
		Tu	8/14	Visit manufacturing plant
LV	Vienna, Austria	W	8/15	
AR	New York	W	8/15	
		Th	8/16	Meeting with Technical Enterprises

W. Gibson Only

LV	New York	F	8/17	
AR	Portland, Oregon	F	8/17	
LV	Portland, Oregon	Tu	8/21	
AR	Bellingham, Wash.	Tu	8/21	Meet with Ed Dahlgren, Georgia-Pacific
		W	8/22	Visit Georgia-Pacific plant
LV	Bellingham, Wash.	Th	8/23	
AR	Honolulu, Hawaii	Th	8/23	

K. Mashima Only

		F	8/17	Meeting with Dehydro-Tech Corp.
LV	New York	M	8/20	
AR	New Jersey	M	8/20	Visit pilot plant for dewatering stillage
LV	New Jersey	M	8/20	
AR	Portland	M	8/20	
LV	Portland	Tu	8/21	
AR	Bellingham, Wash.	Tu	8/21	Meet with Ed Dahlgren, Georgia-Pacific
		W	8/22	Visit Georgia-Pacific plant
LV	Bellingham, Wash.	Th	8/23	
AR	Honolulu, Hawaii	Tu	8/28	

R. Roberts Only

LV	New York	Th	8/16	
AR	Decatur, Illinois	Th	8/16	
		F	8/17	Meet with ADM Manager
LV	Decatur, Illinois	S	8/18	
AR	Honolulu, Hawaii	S	8/18	