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Economic Feasibility Study of an Acid Hydrolysis-Based Ethanol Plant

A Subcontract Report

Badger Engineers, Inc.
Cambridge, MA

April 1987

SERI Technical Monitor:
J. D. Wright

Prepared under Subcontract No. ZX-3-03096-2

Solar Energy Research Institute
A Division of Midwest Research Institute

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Prepared for the
U.S. Department of Energy
Contract No. DE-AC02-83CH10093

Table of Contents

Appendixes

Yeast Hydrolyzate Toxicity Trial

Report on work carried out under unsolicited proposal change order number 1 modification to Subcontract number ZX-3-03096-2.

A critical area of uncertainty in the acid based wood to ethanol technology is the fermentability of the hydrolyzate. Wood acid hydrolyzates have in the past been fermented to alcohol in high yield (Reference 5). Hydrolyzate from the Dartmouth reactor has been shown to be fermentable in yields of 97% using common yeast strains adapted to the hydrolyzate (Reference 26). Adaptation of the yeast is of course only possible providing the hydrolyzate contains no extraneous organics acutely toxic to the yeast. It has been found by Dartmouth researchers and others that over-neutralization of the acid hydrolyzate to pH 10 with lime and reacidification to a "near neutral pH (say 5) while boiling at a temperature of 212°F precipitated out toxic extraneous organics and resulted in a hydrolyzate mixture to which the yeast could be acclimatized. It was the intent of this work to show that the acid hydrolyzate preparation scheme proposed in the process removed the acutely toxic organics from the raw hydrolyzate and to show that the yeast strains used by the Japanese designers of the fermentation system could survive exposure to the prepared hydrolyzate. It was also intended to show that the yeast entrapment polymer suffered no corrosion or degredation in the hydrolyzate. The scope of work was therefore:

(1) To produce 20 liters of raw hydrolyzate from the Darmouth reactor.

(2) To prepare this by neutralization to pH 10 and reacidification to pH 5 while boiling.

(3) To separate out the lignin/tar residual solids by centrifugation.

(4) To concentrate the hydrolyzate stream to 6.5 percent by weight fermentable sugars by boiling off excess water. (This step was also intended to replace the steam stripping step used in the process.)

(5) To package one liter of the hydrolyzate and transport it to Japan. The hydrolyzate was acidified to pH 2 to preserve it during shipment. It was neutralized before toxicity trials were carried out.

(6) To test the exposure of yeast and the entrapping polymer to the hydrolyzate at the JGC/Kansai Paint laboratories in Japan.

Results

(1) 22 liters of Dartmouth hydrolyzate were produced in a single operating campaign at 240°F, 1.2% acidity and 8.24 seconds residence time. The fermentable sugar yield was 50% of theoretical the furfural yield was 84.5% of theoretical on pentose sugar.

(2) Hydrolyzate was pH adjusted while boiling. The procedure took 1½ hours.

(3) The hydrolyzate was then concentrated by boiling of excess water. Vapors were condensed and collected for analysis. The sugar concentration was monitored during evaporation by carrying out DNS reducing sugar analysis. The procedure took 3 hours.

(4) The final sugar concentration was found by glucose oxidase and by liquid chromatograph (HPLC) to be zero (even though the DNS test indicated a level of 6.5%).

(5) On confirmation of zero sugar by a second HPLC analysis it was concluded that the reducing sugars had degraded on prolonged boiling in the presence of extraneous organics.

(6) It was decided to add glucose to the hydrolyzate and transmit the "spiked" samples to Japan to complete the trial. It was felt that this would still be a useful and conservative test since the hydrolyzate now contained not only extraneous organics from the original hydrolysis but also extraneous organics produced on degredation of the reducing sugars. Reducing sugar content of the "spiked" hydrolyzate was confirmed twice by HPLC at MIT and Dartmouth (by Professor Grethlein); and by glucose oxidose test.

(7) Results of the Japanese tests showed that the yeast survived exposure to the reneutralized hydrolyzate at pH 5.2 and that the polymer beads suffered no damage on exposure to the hydrolyzate. No fermentation activity was observed as would be expected on first exposure of the yeast.

Attachments

(1) Analysis of raw Dartmouth hydrolyzate for fermentability trial.

(2) Analysis of concentrated hydrolyzate sent to Japan.

(3) Telex from Japan stating results of test.

Summary Table of Acid Hydrolysis Runs on Mixed Harwood

(90% Birch 10% Maple)

Reactor Temp.* °C	Acid wt.%	Time Seconds	Reactor Feed Solids mg/ml	Steam Effluent Dilution ml In/ ml Out	Reactor Factor Solids mg/ml	Potential Sugars Glucose mg/ml	Potential Sugars Xylose mg/ml	Hydrolyzate Sugars Glucos mg/ml	Hydrolyzate Sugars Xylose mg/ml	% Yield GLU	% Yield XYL
230	1.05	8.11	90.4	.638	25.2	25.1	12.9	8.65	9.52	34.5	73.8
230	1.57	8.23	90.4	.638	22.8	25.1	12.9	11.85	6.78	47.2	52.6
239	1.05	8.20	90.4	.622	20.2	24.5	12.6	13.22	5.85	54.0	46.4
239	1.51	8.03	90.4	.622	14.4	24.5	12.6	13.61	4.53	55.5	35.9
247	.86	7.66	90.4	.609	10.8	23.9	12.3	12.18	3.12	51.0	25.4
247	1.37	7.97	90.4	.609	9.47	23.9	12.3	11.83	2.61	49.5	21.2
Analysis of 22L Batch											
240*	1.23	8.24	102.3	.621	--	27.7	14.2	13.99	6.99	50.5	49.2

Actual reactor temperature is 2°C greater than wall temperature.

This is the condition for 22 liter sample for Badger:

Potential Glucose 43.55 mg/100 mg dry wood.
Potential Xylose 22.4 mg/100 mg dry wood.

Summary Table of Hydrolyzate Analysis on HPLC

Sugar Concentration in mg/ml

Sample		Cellobiose	Glucose	Xylose	Galactose	Arabinose	Mannose	HMF	Furfural
230°	1.05%	0.12	8.65	9.52	Trace	.70	1.33	.66	2.29
230°	1.57%	0.13	11.85	6.78	Trace	.38	1.04	1.19	3.72
239°	1.05%	0.12	13.22	5.85	Trace	.41	.98	1.32	3.93
239°	1.51%	0.12	13.61	4.53	Trace	.34	.89	2.01	5.02
247°	.86%	0.06	12.18	3.12	Trace	.36	.81	2.75	5.70
247°	1.37%	0.06	11.83	2.62	Trace	.34	.73	2.77	6.81
240°*	1.23	0.19	13.99	6.99	Trace	.44	1.07	1.53	3.94

*22L Sample Analysis

Dilution Factor F = Ml Feed/ml Reactor Effluent

$$F = 1.0355 - 1.713 \times 10^{3} T$$

where T = Reactor temperature in °C and is equal to reactor wall temperature measured on thermocouple +2° correction factor to get reactor temperature.

Wall Temperature °C		
230	T = 232	F = .638
239	241	.622
247	249	.609
240	242	.621

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*174174BADGER CAM

JGC CORP TOKYO APR 13 1984

BADGER CAMBRIDGE

FOR MR HV KERSHAW
RE: YOUR APR 12 TELEX (FERMENTABILITY TRIAL)
WE SHOW BELOW THE RESULTS OF OUR FERMENTABILITY TEST
ON THE WOOD HYDROLYSATE SUPPLIED FROM YOU.
STRAIN USED: YEAST SUITABLE FOR MOLASSES FERMENTATION,
POSSESSED BY JGC.
TEST CONDITIONS AND RESULTS:
(1) WOOD HYDROLYSATE (PH 1.7) WITH NO PH
ADJUSTMENTS: ALL YEAST PERISHED.
(2) WOOD HYDROLYSATE WITH PH ADJUSTED TO 5.2 (WITH
CAUSTIC SODA) AND ADDITION OF AMMONIUM SULFATE
AND YEAST EXTRACT: YEAST REMWINED ALIVE BUT
NO PROLIFERATION OR FERMENTATION OCCURRED.
THUS, OUR SIMPLE TEST INDICATES THAT OUR YEAST DEVELOPED
FOR MOLASSES FERMENTATION DOES NOT ALLOW ALCOHOL
FERMENTABILITY FOR THE WOOD HYDROLYSATE. WE SUSPECT
THE INFLUENCE OF BY-PRODUCTS CONTAINED IN RAW MATERIALS.
WE SEE A NEED TO STUDY PREPARATORY CONDITIONS OF MEDIUM
AS WELL AS TO LOOK FOR ANOTHER STRAIN SUITABLE
FOR WOOD HYDROLYSATE.
HAVE YOU OBTAINED ANY KNOWLEDGE ABOUT STRAINS FOR
WOOD HYDROLYSATE FERMENTATION? WE WOULD LIKE TO
HEAR YOUR COMMENTS ON OUR TEST RESULTS BEFORE STUDYING
FURTHER ACTIONS.
REGARDS
SHOGO NOJIMA

...

*174174BADGER CAM

0455 04/13
VIA TRT

THEY DISC.

ELAPSED TIME 00:03:33

PRINTED AT 0458 EST 04/13/84

Dartmouth Reactor Extended Operation Trial

Introduction

Seventy gallons of hydrolyzate were required to carry out hydroclone and centrifuge testing under Change Order No. 2 to subcontract ZX-3-03096-2. It was decided to produce as much as possible of this in one continuous campaign and to take the opportunity to investigate the stability of the Dartmouth reactor over an extended period of operation. This would also provide the opportunity to confirm that consistently high yields of fermentable sugars were possible over an extended operating campaign. Three attempts to operate the reactor in such a manner were made. The first two were unsuccessful due to blockage problems. (See attached report from R.D. Sexton who witnessed the May 24 and June 15 trials on behalf of Badger.) The third attempt was reasonably successful resulting in two consecutive campaigns each of 2 hours in duration. The first two campaigns were terminated due to severe blockage of the exit orifice and condenser. The third, with a cyclone vapor separator on the reactor outlet, gave good stability over the 2 hours of operation but exhibited increasing tar deposition at the separator liquid outlet. 90 gallons of hydrolyzate were produced: approximately 45 from the first and second campaigns, and 45 from the third. These were stored and shipped in drums A and B respectively. Fermentable sugar yields were 53.4% and 58.5% respectively. Furfural yield obtained from the first campaign was 50% on xylose or 78.8% of theoretical. A report of the two campaigns is given in the attached communication from Professor H.E. Grethlein, Dartmouth College.

Attachments

(1) Report on first hydrolyzate production trial by R.D. Sexton.

(2) Report on second campaign by R.D. Sexton.

(3) Report on second and third campaign trials by Professor H.E. Grethlein, Dartmouth College.

cc: H.S. Klein

BADGER ENGINEERS, INC.

MEMORANDUM

July 3, 1984

TO: S.W. Fitzpatrick

FROM R.D. Sexton

SUBJECT: Badger Job No. E-0461, SERI
Hydrolyzate Production For Hydroclone Trials
Trip Report For 24 & 25 May 1984 - Visit To Dartmouth

Introduction

The purpose of the visit was to witness the production of hydrolyzate for Badger's subsequent use in vendor testing of hydroclones. Prof. Alvin Converse of Dartmouth's Thayer School of Engineering had overall responsibility for the project but delegated to lab technician Hermann Ertl the immediate responsibility for setting up, running and controlling the production runs because of his prior experience with building and running the equipment. During this visit, no material of sufficient quality was produced but much was learned about the operating methods used for the Dartmouth process and their effects on long term (i.e, more than 10 minutes) operation.

Day 1-24 May

8:30 a.m.-Ran the system with steam and water only and tightened all leaking fittings except for possible leak hidden under insulation of steam line. This could, however, just be wet insulation steaming off as it is heated up.
9:00 a.m.-At desired flow rates (still just water and steam) could not get average reactor temperature above 250°C (range was 247 to 252, cycling back and forth). Steam safety valve on boiler was lifting at 800 psi, a deviation from previous experience. Valve had been set to lift at 800 psi but was lifting at 850 in actual operation until now. Valve had been removed, cleaned, and reinstalled just prior to my visit and now works much better.
9:15 a.m.-Another orifice assembly (see Appendix I) was installed but pressure drop was too high and it restricted the steam flow so that reactor wall temperature was only 245°C at 720 psi.
10:30 a.m.- Changed leaking drainvalve and installed another orifice-same result; tried adjusting orifice-temperature still at 245°C.
11:00 a.m.- Tried a less efficient orifice, got steady 251°C wall temperature but reactor pressure was 600 psi and therefore the steam was not condensing in the reactor.
11:30 a.m.- Tried another orifice assembly, got 250°C outside wall temperature. (therefore about 252°C inside according to Ertl) at 660 psi. This was satisfactory to start slurry feed.
11:35 a.m.- Started slurry feed. Residence time was 7 seconds, acid concentration was 1 percent, reactor O.D. was 13.mm. Slurry was 10. weight percent Wilner 170 hardwood mixed with water with a Charles Ross & Son mixer in 10 liter batches (i.e., 10. liters of water with one kilogram of wood). Wilner 170 (Wilner Wood Products, Norway, ME 04268) was used instead of Wilner 060 as had been used in

the past because there wasn't enough 060 on hand to make the desired 100. gallons of hydrolyzate. The only difference between the two Wilner products is particle size distribution, with 170 being coarser. This particular wood flour had been stored at Dartmouth for one year and had an assumed moisture content of 7 wt. percent per Ertl. After mixing 7 to 10 minutes and allowing to stand for three minutes the settled proportions (by volume) were 30 percent foam in a layer at the top, 30 percent liquid containing some suspended solids in the middle layer, and 40 percent solids settled at the bottom.
11:37 a.m.- Reactor temperature flucutating between 250 and 253°C, pressure between 670 and 680 psig. Collected sample No. 1 to test settleability-settled at same rate as hydrolyzate sample that I had brought with me. This hydrolyzate sample had been made by Dartmouth for Badger earlier this year.
11:40 a.m.- RXR temp. 246-248°C. According to Ertl this cooler wall temperature is because of coking on the inside wall.
11:46 a.m.- RXR tem. 243-245°C, RXR press. 700 psig. Collected sample No. 2-contained much more solid material than sample No. 1 and most of the solids floated.
11:48 a.m.- 238°C 710 psi-plugging evident so shutdown. I saved, intact, a portion of the material plugging the reactor. It contained some unreacted wood because the acid was shutoff before the flow of slurry was stopped.
3:30 p.m.- Reassembled and started up on water and steam. Temperature 240-250°C, fluctuating. Shutdown and disassembled steam mixer. Took out small amount of crud and turned mixer around when reinstalled. Mixer is symmetrical so this is ok to do.
4:00 p.m.- 251-255°C, 700 psi on water and steam, so started very dilute slurry feed.
4:15 p.m.- Temperature fell to 213-240°C, 700 psi; stopped slurry and went back to water feed only. Stayed steady at 228-230°C but steam valve is now wide open so this is the highest achievable temperature. Ertl noticed a raspy vibration in the steam injector that had never happened before.
4:30 p.m.- Shutdown. Ertl will clean steam injector overnight in a heated cleaning solution. I scraped and kept samples of tar from orifice assembly.

Day 2-25 May

Also present today was Michael Karpuk of SERI

Ertl reinstalled the steam injector and ran the system on steam and water. There was still the problem of temperature cycling: 240-2[illegible]°C, 230-240°C, but [illegible]-203°C. Ertl said raspy vibration noise from injector is much different than when it was new. The injector is made of solid zirconium, machined at Dartmouth but welded at Teledyne/WAH. It cannot be opened for inspection. Zirconium is corrosion resistant but is not erosion resistant. If the mixer is eroded it may no longer be condensing the steam properly. See Appendix II for zirconium steam injector construction details.

Erosion caused the old style steam injector to fail also. This was the multi-hole assembly made of 316SS. I borrowed this old assembly to take back to Badger for inspection and it will be returned to Dartmouth.

The steam control valve was on pressure control. The cycling time for the reactor temperature was 15 seconds. We noted that the boiler's control cycle was also 15 seconds with the boiler pressure operating in a range from 780 to [illegible] psig. We attempted to retune the pressure controller to make the reactor temperature steady. After retuning we still had cycling: [illegible]-253°C at 660 psi; [illegible]-210° at 350 psi; 164-166°C at 170 psi.

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Ertl noted that when the boiler operated at a higher pressure the steam condensed better and the system was more stable. With Prof. Converse's permission we removed the safety valve from the boiler at 1:00 p.m. The boiler had recently been hydrotested to 2700 psig and test-operated at 1500 psig in preparation for obtaining a higher boiler pressure rating. A new safety valve will take 12 to 16 weeks to be delivered.

1:25 p.m.-Started system again on water and steam with a smaller orifice assembly. RXR temperature was 247.8-250.0°C at 750 psig.
1:30 p.m.-Started dilute surry feed at RXR temperature 245-253°C at 700 psig.
1:35 p.m.-850 psig; collected sample No.-1
1:39 p.m.-248°C, 900. psig
1:40 p.m.-940 psig
1:46 p.m.-238°C, 1100 psig; switched to water only feed; by increasing pump rpm, ran up system pressure to 1800 psig and blew out the plug so that with water only system was at 250°C, 680 psig; started dilute slurry again.
1:50 p.m.-Pressure rising again; shutdown. Decided to replace orifice assembly. Ertl cannot recall ever before running above 240°C for more than a few minutes. I reminded him of Dartmouth's producing about 5 gallons of hydrolyzate at 250-258°C earlier this year, 1 gallon of which is still stored in Dartmouth's refrigerator. Ertl and Converse couldn't recall which of them did that particular production run or if there were any operating difficulties associated with it.
2:25 p.m.-Restarted with two back-to-back zirconium orifice plates with 1mm orifice diameter; system at 250°C at 580 psig.
2:30 p.m.-251.5°C, 590 psig-dilute slurry feed-collected sample No. 1; solids floated and saw much unreacted material. Checked and found that pressure was below the saturation pressure so that steam was passing through the reactor and the residence time was shorter than the calculated 7. seconds.
2:40 p.m.-Started again with labyrinthe orifice and dilute slurry; 261°C, 710 psig; collected sample No. 2.
2:43 p.m.-270°C, 820 psig; collected sample No. 3.
2:55 p.m.-265°C, 750 psig; collected sample No. 4.

After one hour, samples 2, 3, and 4 had not even begun to settle; much colloidal material remained suspended.

Continued to run on dilute slurry until 3:30 p.m.-no pressure rise observed but product still poor.

The hydrolyzate samples were divided as follows:

Date	Sample No.	Disposition
5-24	1 (control)	Dartmouth to analyze and keep as control
5-24	2	Badger kept
5-25	-1	Badger kept
5-25	1	Badger kept
5-25	2	Dartmouth to analyze
5-25	3	Dartmouth to analyze
5-25	4	Split-Badger kept one, Dartmouth to analyze the other.

I left written instructions for Converse and Ertl to follow next week:

1.) Analyze Samples left (4 total, 1 marked control)
2.) After analysis on all 4 is complete, report results to S.W. Fitzpatrick of Badger and agree upon production run parameters and method of operation.

3.) A. Produce 100 gallons of hydrolyzate with same settling characteristics as sample marked control.

B. Check contents of product collection bucket by sampling and settling during collection time and transfer bucket contents to storage drum only if settleability is satisfactory.

I agreed to send a copy of the analyses to M. Karpuk of SERI. They will be transmitted through H.V. Kershaw, Project Manager for Badger.

In addition to the samples mentioned earlier, I also brought back:

- Bag of Wilner 170 wood flour
- Bottle of 15. weight percent slurry (Wilner 170)
- Bottle of 20. weight percent slurry (Wilner 170)
- Bag of wood grinds (needle-like) made by SERI.

R.D. Sexton

RDS:lcf

attachments

APPENDIX I

LABYRINTHE ORIFICE ASSEMBLY (see also illustrations)

The assembly is a stack of orifice plates of two types and of varying thicknesses held within a housing which can be coupled to the end of the reactor. The orifice plates are of zirconium and are kept in alignment with a pin that passes through a guidehole near the edge of each plate. Type I orifice is a single hole, 1.2 mm diameter slightly offset from the center. Type II orifice has a hole near the edge of the plate with channels engraved on both sides of the plate. One side has a channel of square cross section 1.2 mm x 1.2mm. The other side has an involute-shape large area channel 1.2 mm deep. Both channels are oriented so that if a Type II orifice plate is sandwiched by two Type I plates, the flow will be guided through the first Type I orifice through the channel across the surface of the Type II orifice, through the Type II orifice, back through the channel across the other surface of the Type II orifice, and finally through the second Type I orifice. Any number of combinations of Type I & II orifices that will fit within the housing may be used. The stack is compressed (no gaskets) within the housing to minimize bypass flow between the outside of the stack of plates and the housing. There is a 2 mm annular space between the inside wall of the housing and the plates.

Different overall pressure drops can be achieved by varying the number of each type orifice used and by orienting the Type II plates so that the involute channels face one way or the other.

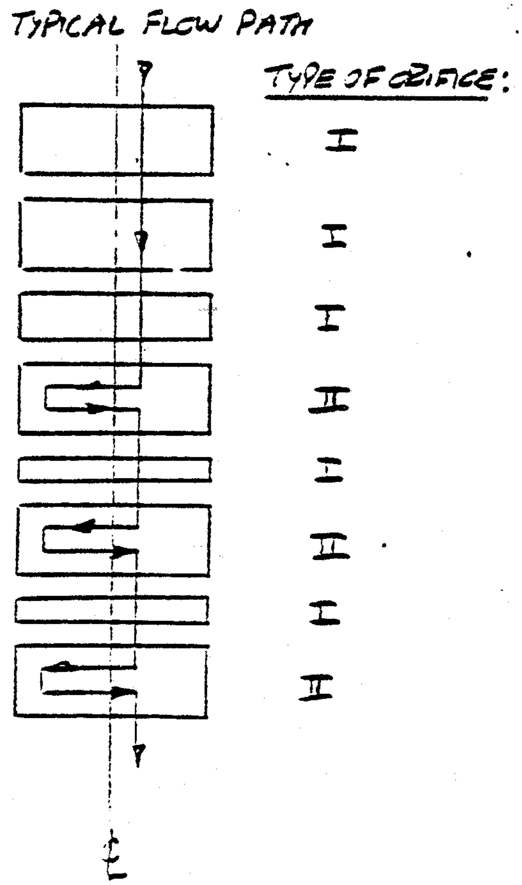
APPENDIX I

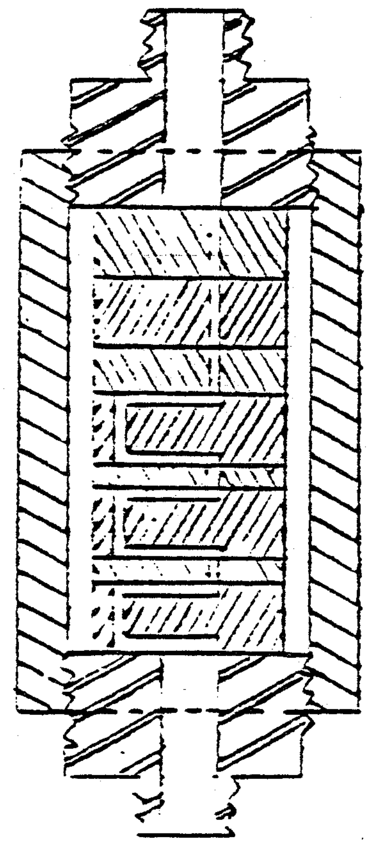
LABYRINTHE ORIFICE ASSEMBLY

SERI E-CA61

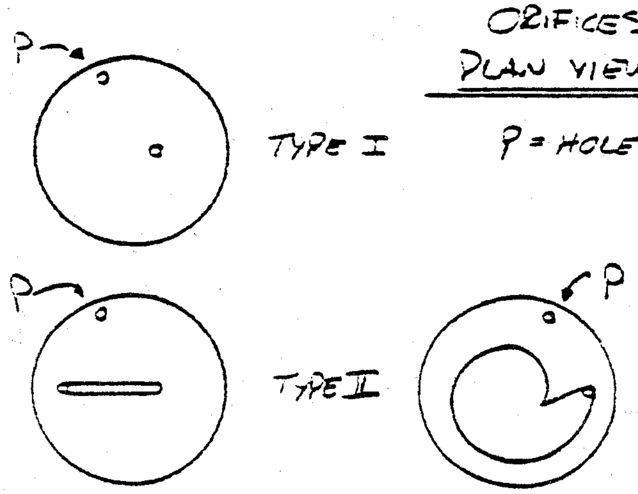
ORIFICE PLATES
EXPLODED VIEW

ASSEMBLY
SECTIONAL VIEW





ORIFICES
PLAN VIEWS



P = HOLE FOR RETAINING PIN

OBVERSE

REVERSE

DRAWINGS NOT TO SCALE

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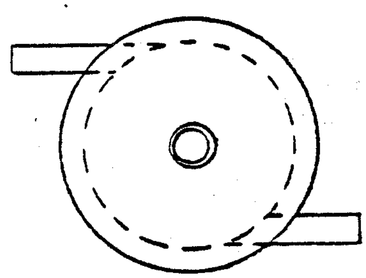
[illegible]

SERI
E-0461

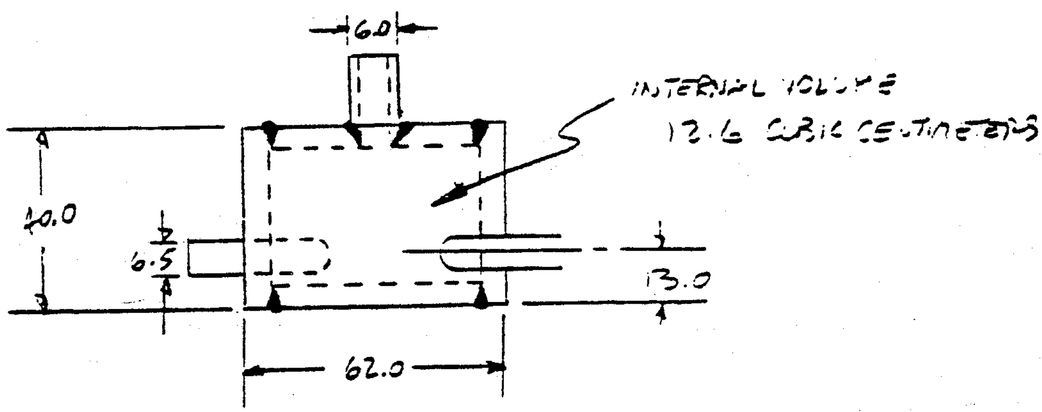
APPENDIX II

DARTMOUTH STEAM INJECTOR

PLAN VIEW



ELEVATION



DRAWING NOT TO SCALE
DIMENSIONS IN MILLIMETERS

[illegible]
[illegible]

cc: H.S. Klein

BADGER ENGINEERS, INC.

MEMORANDUM

June 29, 1984

TO: S. W. Fitzpatrick

FROM: R. D. Sexton

SUBJECT: Badger Job No. E-0461, SERI
Hydrolyzate Production for Hydroclone Trials
Trip Report for 15 June 1984 Visit to Dartmouth

The purpose of the trip was to witness the production of wood hydrolyzate by Dartmouth's acid hydrolysis process and to verify the suitability of the product for subsequent testing by hydroclone vendors.

The process was directly supervised by Prof. Alvin Converse and operated by the Thayer School lab technician, Hermann Ertl, with the assistance of graduate students John Ward and Bill Grous. About 1600 gallons of hydrolyzate produced two days ago had been collected in a drum and grab samples of the same material taken during production had been set aside. The material had been produced at 250°C (wall temp.), 7 seconds residence time, 1% acid and the wood slurry contained the acid prior to being pumped. Depending on the temperature, the product samples showed both floating and sinking solids. The higher the temperature the fewer floating solids; at lower temperatures (say 245°C and less) there were more floating solids and more solid material overall. Of the sinking solids there were two kinds distinguished by their light or dark color. None of the solids had dissolved when allowed to stand in kerosene for 24 hours. When spun in a centrifuge for 60 seconds all solids sank and the dark-colored solids were collected separately at the bottom. Dark solids amounted to about 10 percent of total solids. The product drum contained much foam. Samples were withdrawn from the drum in long glass double open-ended tubes in an effort to determine how much settling had occurred. No clear liquid could be found at any level. The drum contained only those batches of production which, when centrifugally spun, showed few solids indicating good conversion.

At 10:30 AM a production run was begun, using feed made up as follows: 12 L water, 1 kg Wilner 170, 205 g sulfuric acid 97%. A single zirconium orifice plate with 1 mm diameter orifice was installed.

Time	Wall Temp., C		Press., PSIG RXR	Press., PSIG Boiler
10:30 AM	249.8-250.8,	4 sec cycling	560	770-800, 30 sec cycling

Because of the low RXR pressure, steam was not condensing, residence time and conversions were low, and product contained much solid material, all floating. Product was rejected. No vibration from steam injector.

Time	Wall Temp., C		Press., PSIG RXR	Press., PSIG Boiler
10:30 AM	254.4-254.6,	no cycling	630	

Product contained both floating and sinking solids. Small solids fraction when spun down. Two kinds (colors) of solids. Product kept and added to drum. No vibration from steam injector.

Time	Wall Temp., C		Press., PSIG RXR	Press., PSIG Boiler
11:10 AM	250.8-251.6		700	

All solids floating again. Large fraction of solids when spun. Product rejected. Steam pressure control valve wide open. System is plugging up.

11:15 AM Shutdown

After disassembly, reactor showed plugging at both ends but not in the middle. The outlet (top) plug was tight material, extending halfway down the reactor, with a 1.5 mm ø channel in the center. The inlet (lower) plug was fluffy material and extended up into the reactor about 3 inches.

Plugging is a common feature of this process. Converse recalled that 5 years ago Dartmouth made 20 gallons of hydrolyzate for and could only make 6 or 7 gallons at a time before shutdown was necessary due to plugging. Dartmouth is unsure of the effect of presently using Wilner 170 feedstock instead of Wilner 060 that had been used in the past. They could run longer if the boiler was run at a higher pressure but this is presently not allowed by Dartmouth's Insurance Company.

Dartmouth asked if they would be paid in full if they put in the time and materials but could only make 30 gallons. I gave no answer.

In a telephone conversation with R. Sandel it was agreed that:

1. Dartmouth should make 30 gallons now for immediate shipment to Dorr-Oliver and later make 60 gallons for shipment to Bauer in July.

2. Badger would like to get whatever analyses have been made by Dartmouth for each run or day's operation, including material balances, solids content, liquid composition (HPLC analyses) in order to help understand reproducibility.

3. Badger would like to get samples of the tar.

4. We should agree on a "standard test" so we can consistently compare settling. We should compare settling of fresh material with the same material at the time Dorr-Oliver starts their test and after D-O has processed it so that the effects of time and processing on settlability can be judged. Dartmouth should retain 1 gallon of hydrolysate from the material it will ship to D-O.

Converse and I agreed on the following settling test procedure:

1. Using 12 ml tubes, spin for 60 seconds to de-aerate and pack solids. Measure high, low and average height of solid-liquid interface.

2. Resuspend by careful stirring so as not to re-aerate. Measure interface height after 1, 2, 24 and 48 hours.

I left written instructions with Converse as follows:

"Please provide the following information on each run (if it is available) that went into making up the bulk sample:

- Run parameters (RXR temp., RXR press., residence time, percent acid, percent solids, and whatever else you normally record).
- Product analyses ("standard" settling test, solids content, liquid composition.) Please retain 1 gallon sample for retesting at later times. This will help us to understand reproducibility of results."

Converse said they would report percent glucose, xylose, HMF, and furfural and percent glucose yield.

At 3 p.m. another production run was begun, using the labyrinthe orifice assembly.

Time	Wall Temp., C	RXR Press., psig	Spin Test
3:00 p.m.	254.6-255.2	730	Very Good-Few Solids
	252.2		
	250.2-253.4, 20 sec. cycling		Good-Few Solids
3:08	249.2		
3:09	248.6		
	246.2		
	244.8		
3:12	243.6	730(constant)	Poor-Increased Solids
3:12	Shutdown		

Dartmouth will continue next week going back to using the single zirconium plate orifice and making 6 to 8 gallons at a time, following my written instructions. They will continue to try to get the the insurance company to agree to increasing the boiler pressure rating.

I received a sample of the tar drilled out from the upper end of the reactor.

R.D. Sexton

RDS:lw

Summary Report on Preparation of Large Samples of Hydrolyzate for Badger

Hans E. Grethlein

A large quantity of hydrolyzate for Badger was prepared. Two 45 gallon Drums labeled A and B were shipped to Dorr-Oliver, Inc. in Stanford, Connecticut. The history of Drums A and B is given below.

The specifications were to produce a sample that has high glucose yield and good settling characteristics as was observed in the sample of 20ℓ we prepared for Badger in November 1983.

It was difficult to operate the reactor for more than 4 to 5 gallons of product hydrolyzate before the reactor or heat exchanger after the orifice blocked. During the period of time from May 22 to June 22, we tried many runs and finally evolved a procedure that is reasonable to produce large samples.

There are two failure modes of the reactor: 1) the solids plug inside the reactor usually by building up a wall layer in the reactor until the flow path is just a narrow channel at the center of the tube and 2) there is a blockage of solids at the cold end of the heat exchanger after they have passed through the let down orifice. The heat exchanger blockage can occur after a relatively short time of operation. The wall build up in the reactor is indicated by wide temperature variation between the top and bottom of the reactor. Normally, these agree to within a degree centigrade.

The use of various orifice sizes and types did not overcome the plugging problem. Two mesh sizes of Wilner mixed hardwood (grade 140 and 170) were used with similar results with regard to plugging the reactor.

During the period while these changes were made the hydrolyzate that had reasonable yield was accumulated in Drum A to about 45 gallons. The summary of results is given in Table 1. Drum A is the accumulation of runs from June 13 to June 18 with a yield generally above 50%. This incremental approach was too labor intensive, so a procedure was developed that allowed a larger sample to be prepared before the reactor plugged as discussed below.

The solids content for selected samples is given in Table 2. The settling characteristics vary and are sensitive to reactor conditions. The settling volumes are given in Table 3 and photos of the freshly mixed slurry after 24 hours of settling are given in Figure 1.

The normal flow rate is about 800 mL/min, which gives an average velocity of 0.46 ft/sec or a Reynolds number of 1700. This low velocity was considered part of the problem in allowing the solids to stick to the reactor wall. So the reactor length was increased from 87.5 cm to 132.5 cm. on June 18 with a corresponding pump RPM increase to keep the same residence time while increasing the velocity to .70 ft/sec. After a short time the system failed in the heat exchanger because tars when cooled can form a plug. Consequently, we removed the heat exchanger and flashed the reactor effluent through a cyclone separator. The steam was vented to the atmosphere and the liquid collected at 100°C.

One could see the dramatic appearance of tar in the hot flashed liquid slurry as the reactor temperature passed a critical point corresponding to about 50% yield. in fact, the tars even plugged the exit of the cyclone separator because the cyclone does not have net pressure with the vent open to the atmosphere.

The final procedure on June 22 involved a frequent reaming of the exit cone of the cyclone to keep the tar from building up. Now about 25 to 30 gallons were made in one afternoon instead of 2 to 4 gallons per run. The final failure under the new procedure is the wall build up of solids in the reactor, but the rate of buildup is slower than before due to the modest increase in velocity. Since the Badger design will use about 10 ft/sec, the wall build up may not occur, but some pilot plant work is needed here. The material in Drum B is obtained with the cyclone.

One important change in the settling characteristics is noticed when using the cyclone - the solids all settle to the bottom. The foamy solids that are obtained with the heat exchanger are due to the mixing of non-condensables with the slurry in the heat exchanger. The hydrolyzate foams easily and so a fairly stable phase of floating solids can form. The cyclone clearly disengages the slurry from the gas phase.

The effects of the cyclone is noticed in Table 1 for sample for June 20 and later. The sugar concentrations increased due to the steam flashed from the cyclone and the furfural concentration in the hydrolyzate is lower than before due to the partial flashing with the steam. The yield calculation is an estimate based on the effective steam dilution factor (0.873) for the combined steam injection and flashing in the cyclone. During the run on June 22, when about 25 gallons was made, the run was prolonged by decreasing the pump RPM as the reactor pressure increased due to wall build up to keep about a constant glucose concentration in the reactor effluent, as measured on-line with a glucose analyzer.

For the record, the HPLC analysis of samples taken during the various runs as well as the Drums A and B are given in the Appendix. The HPLC sample numbers are defined in Table 1.

TABLE 2: Solids of Badger Samples

Sample ID	[g/kg]
Drum A	11.2
Drum B	18.5
6/13 - 2	11.3
6/14 - 3	11.5
6/15 - 5	8.7
Run # 11/6	13.4
6/18 - 1	10.8
6/18 - 2	8.7
6/21 - 2	14.9
6/22 - 2	16.4
Feed 6/21	65.3

TABLE 3: Settling of Badger Samples

50 ml Samples. Settled Level in Graduated Cylinder

HPLC No.	Sample ID	1 hour	2 hours	24 hours
1	Drum A	46 - 30*	46 - 26	47 - 22
2	Drum B	48	46.5	33
3	6/13 - 1	38	31	17
4	6/13 - 2	45 - 33	45 - 28	45 - 20
5	6/14 - 3	43 - 22	43 - 26	45 - 20
6	6/15 - 4	8 - 4	13 - 5	26 - 11
7	6/15 - 5	20	15.5	11
8	6/15 - 6#11	18 - 0	20 - 0	22 - 0
9	6/18 - 1	44 - 29	44 - 24	45 - 18
10	6/18 - 2	14	12	9
14	6/21 - 1	48	45.5	31
15	6/21 - 2	49	47	30
16	6/21 - 3	48	46	34.5
17	6/22 - 1	49	47	40
18	6/22 - 2	49	47.5	38
19	6/22 - 3	49	38	38
20	6/22 - 4	49	49	44.5

*NOTE: Two numbers give the upper and lower boundary of clear liquid where there are two solid phases, one on top and one settled.

TABLE 1: HPLC Analysis of Glucose Yield and Reactor Conditions for Badger Samples

HPLC No.	Sample ID	Glucose g/L	Xylose g/L	HMF g/L	Furfural g/L	D.F.*	Glucose Yield %	Reactor Conditions: Wall Temp. °C	Reactor Length cm	Orifice	Pressure psi	Comments
1	Drum A	9.15	3.50	1.55	3.38	0.625	53.4					Substrate Mixed Hardwood Flour from
2	Drum B	14.01	7.92	1.18	0.80	0.873	58.5					Wilner Wood Products. Grade 170 in
3	6/13 - 1	10.01	2.84	1.72	3.60	0.635	57.5	240	87.5	two, 1 mm		all runs except as noted.
4	6/13 - 2	10.16	3.54	1.29	3.23	0.635	58.3	250	87.5	two, 1 mm		
5	6/14 - 3	9.10	3.08	1.50	3.43	0.635	52.3	240/250	87.5	two, 1 mm		All runs made from feed slurry con-
6	6/15 - 4	9.20	4.15	1.08	2.48	0.625	53.7	250	87.5	one, 1 mm		sisting of 12 ℓ water, 1 kg wood
7	6/15 - 5	9.24	2.83	1.51	3.22	0.615	54.8	255	87.5	one, 1 mm		flour, and 205 g, 97% H_2SO_4.
8	6/15 - 6#11	8.51	4.91	0.73	2.26	0.615	48.3	255	87.5	Vortex		
9	6/18 - 1	9.71	3.75	1.69	3.95	0.625	56.6	250	132.5	two, 1 mm	590 to 740	Drum A contains material from 6/13
10	6/18 -2	7.97	2.22	1.87	4.51	0.625	46.5	250	132.5	two, 1 mm	590 to 740	to 6/18. Drum B contains material
11	6/20 - 240	12.43	6.48	0.97	0.91	}	51.9	240	132.5	two, 1 mm	510	from 6/20 to 622.
12	6/20 - 245	13.23	5.61	1.30	0.85	}	55.2	245	132.5	two, 1 mm		
13	6/20 - 250	14.25	3.77	2.00	1.04	}	59.5	250	132.5	two, 1 mm		Wilner Grade 060 used for 11 to 13.
14	6/21 - 1	13.26	5.08	1.52	0.87	}	55.4	245	132.5	two, 1.2 mm	520	Cyclone separator for 11 to 20.
15	6/21 - 2	13.48	4.60	1.60	0.84	} 0.873	56.3	to	132.5	two, 1.2 mm	to	
16	6/21 - 3	12.16	5.47	1.20	0.82	}	50.8	242	132.5	two, 1.2 mm	740	
17	6/22 - 1	14.68	8.06	1.11	0.64	}	61.3	245	132.5	one, 1.2 mm	520	
18	6/22 - 2	15.48	7.22	1.30	0.79	}	64.7	250	132.5	one, 1.2 mm	570	
19	6/22 - 3	15.69	7.87	1.21	0.78	}	65.5	250	132.5	one, 1.2 mm	700	
20	6/22 - 4	13.48	9.67	0.79	0.58	}	56.3	245	132.5	one, 1.2 mm	720	

Yields are based on 42% potential glucose and 65.3 g solids/kg

* dilution factor due to life steam injection

\# calculated dilution factor for flash to atmosphere.

Figure 1: Photos of Freshly Stirred Hydrolyzate After 24 hours of Settling on June 27, 1984. Sample Identification is the HPLC No.

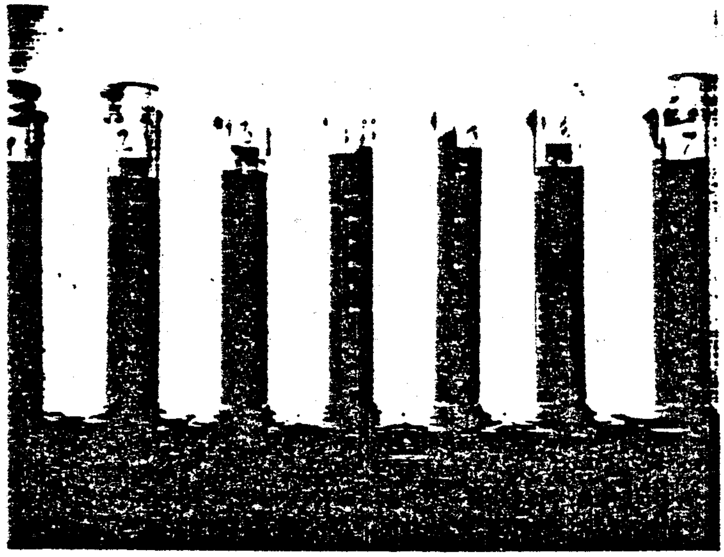


Photo a) Samples 1, 2, 3, 4, 5, 6, and 7

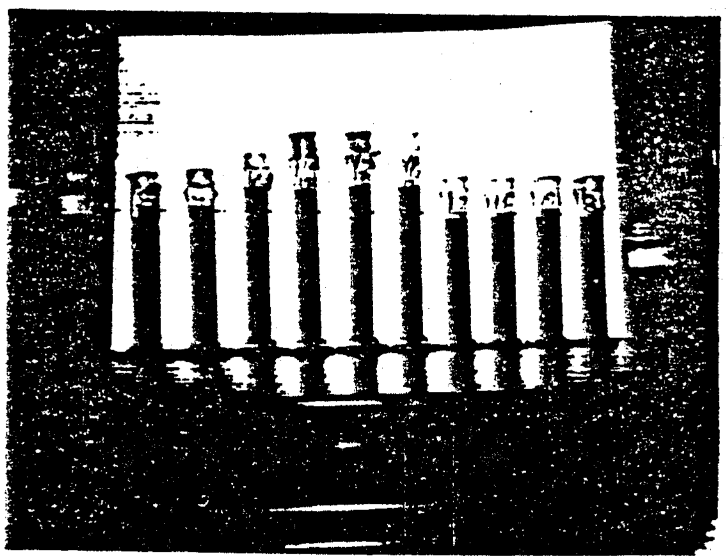


Photo b) Samples 8, 9, 10, 14, 15, 16, 17, 18, 19 and 20

Lignin/Tar Separation Trials

Report on Change Order Number 2 to
Subcontract Number ZX-3-03096-2

Acid hydrolysis of lignocellulosic material using the Dartmouth plug flow reactor results in a hydrolyzate stream comprising lignin and tar solids in an aqueous acidic sugar stream. Separation and washing of the solids represents an important processing step. The key requirement is to remove the solids while minimizing losses of fermentable sugar in the cake liquors. Wash water must be minimized in the process since this dilutes the hydrolyzate stream going to fermentation and leads to excessive energy requirements for either distillation of a dilute alcohol beer or concentration of the fermentation feed. Further requirements for the separation were to maximize the solids recovery since they form a major fraction of the fuel for the boilers and to minimize the water content of the solids cake since this water must be removed by drying in order to give efficient combustion in the boiler.

Preliminary Testing

Various unit operations for separation and washing were examined in a preliminary study. These were filtration, froth flotation, hydroclones, and centrifugation.

In a preliminary exercise the above methods were assessed by test at vendors or at Badger's Weymouth Laboratory. The conclusion of this preliminary work was that two methods looked promising: hydroclones and centrifugation. The other two options were eliminated for the following reasons:

Filtration

Samples of hydrolyzate produced at Dartmouth were used in filtration tests in Badger's Weymouth Laboratory. Tests were carried out in a 4" Buchner funnel with a variety of filter cloths. The hydrolyzate was found to be extremely slow filtering due to blinding of the cloth even after addition of a flocculating agent. The apparent specific cake resistance was measured at 2.1×10^{-14} m^{-1}. Filter tests performed at Bird Machine Company, Inc. on a sample of the hydrolyzate resulted in the same qualitative conclusions (report attached).

Froth Flotation

Dartmouth hydrolyzate sample were sent to three manufacturers of flotation equipment. Krofta Engineering Corporation, Linatex Corporation of America, and Komline-Sanderson, Inc. Tests at all three laboratories showed that froth flotation was a suitable primary method of solids separation. Approximate capital costs were generated for a system using froth flotation as the primary means of separation followed by centrifuges for washing and dewatering. Consideration of the capital costs involved revealed that this was not a cost-effective means of separation.

From preliminary consideration, centrifuges and hydroclones were found to be the most suitable separation methods.

Centrifuges

Merco washing centrifuges appeared to be a suitable means of separation and washing. These machines built by Dorr Oliver, Inc. are capable of handling large feed volumes for over 600 gpm while carrying out a high efficiency pseudo-displacement wash on the separated solids. Calculations suggested that with the high efficiency wash three stages of centrifuges would be required to give a 99% recovery of sugars using a wash water addition rate of 20% of the feed hydrolyzate flow.

Preliminary tests at vendors' laboratories (Bird Machine, MA; Sharples, NY; and Dorr Oliver) indicated that the use of centrifuges for separation was promising (see attached vendors reports).

A further witnessed trial at one of the vendor's laboratories using Dartmouth hydrolyzate was planned.

Hydroclones

On initial consideration hydroclones appeared to be the most attractive option allowing a number of counter-current stages of washing and separation for relatively low capital cost. Calculations indicated that with ten stages of hydroclones, 99.6% recovery of sugars was possible with a wash water addition rate of only 20% of the feed hydrolyzate flow. Samples of Dartmouth hydrolyzate were sent to two manufacturers of hydroclones, C.E. Bauer and Dorr Oliver for preliminary testing. On preliminary inspection of the samples both vendors indicated that hydrolyzate separation looked feasible. It was planned to carry out large scale witnessed trials to determine hydroclone separation performance in continuous operation.

Hydroclone and Centrifuge Trials at Dorr Oliver

An additional unsolicited proposal for Change Order No. 2 was made to SERI to test the two separation methods which had been identified in the preliminary testing exercise. It was planned to produce 70 gallons of hydrolyzate for two continuous hydroclone tests. A report on the hydrolyzate production campaign is given in Appendix III.

The hydrolyzate was planned to be shipped to one manufacturer, and if the hydroclone tests were successful to the second manufacturer for a confirmatory trial. It was planned to use a portion of the hydrolyzate for centrifuge trials. It was decided to carry out the first trials at Dorr Oliver since this would provide an early opportunity to witness the test for the Merco centrifuge as well.

To determine whether the settling characteristics of the hydrolyzate slurry changes over time gravity settling tests were carried out during production of the hydrolyzate at Dartmouth and again at the vendors' laboratories.

Results

The results of both the hydroclone trial and centrifuge tests are contained in the attached report from Dorr Oliver. The results can be summarized as follows:

(1) A significant increase in the gravity settling rate was observed over the period between production and testing at Dorr Oliver. This is thought to be due to disengagement of air from the solids during standing and shipment. This conclusion was reinforced by the observation that when samples were remixed with air at the vendor's laboratory the slower settling was again observed. Air entrainment was observed to have no effect on centrifuge settling rate (centrifugal force causes extremely rapid disengagement of air).

(2) Hydroclones do not separate the lignin/tar solids from the hydrolyzate. The failure of this trial in the light of preliminary favorable indications is thought to be due to floc disintegration in the high shear regime created in the hydroclones. Although in the earlier preliminary tests, flocs appeared to settle well under gravity the extremely fine particles created on floc disintegration do not. Some separation was observed with the hydroclone evidenced by the darker color of the underflow. This was due to separation of gritty tarry material.

(3) Centrifuge spin tests worked well on the hydrolyzate indicating that this is an ideal application for centrifuges. On the basis of this test, a separation system using Merco centrifuges for separation and a solid bowl centrifuge for dewatering has been specified by Dorr Oliver. This system gives complete removal of the lignin/tar solids and 99% recovery of sugars using a wash water flow of only 20% of the hydrolyzate feed stream.

Attachments

(1) Filtration and centrifugation test report from Bird Machine Company, Inc.

(2) Centrifugal separation test reports from Sharples.

(3) Dorr Oliver test report on the hydroclone and the centrifuge test.

BIRD MACHINE COMPANY, INC.

CUSTOMER: Badger

REPORT NO. 10552

SPIN TUBE TEST
As received, 10 ml, 240^{o}F

	sec	cc Cake	% Vol Cake	Cake Cond	Eff Cond
1000 x G	10	1.5	15	0	sl. cldy.
	30	1.2	12	0	clear
	60	1.05	10.5	0	"
	120	0.9	9	0.05	"
	180	0.8	8	0.05	"
	300	0.7	7	0.05	"
	480	0.67	6.7	0.05	"
2000 x G	60	1.0	10	0.05	clear
	120	0.9	9	0.05	"
	180	0.8	8	0.1	"
	300	0.6	6	0.1	"

The solids settle out readily in a reasonable time but the solids have little bulk even with extended spin time.

A sample of this material spun for 2000 x G for 3 minutes produced a cake containing 25.3% TS by weight.

CUSTOMER: Badger

REPORT NO. 10552

SPIN TUBE TEST
10 ml, 1000 x G, 240°F

	Time	% Solids in Supernate SUSPENDED	% Solids in Settled Cake T.S.
1	3	0.9	8.7
2	10	0.5	9.0
3	20	0.4	10.2
5	40	0.2	18.0

	Time	% Recovery (Comparison of Supernate to Feed)
1	3	25.0
2	10	58.3
3	20	66.7
4	30	75.0
5	40	83.3

Only a trace amount of cake is collected on the Bird Young leaf (rotary drum filter leaf) and spitback is a problem. The filtrate is dirty with a K-15 cloth and only a few mls are collected.

The filtration time is long on the Bird Pannevis leaf (belt filter) with a thin cake collected.

Since this material is not typical in particle size, the filtration characteristics will be markedly different with the typical production slurry. The filtration rate is influenced by particle size distribution.

The sample as received is a poor application for vacuum filtration.

MAM:cg
Typed 3/28/84

BIRD PANNEVIS LEAF DATA

Customer: Badger

Feed Material: Lignin

Feed Specific Gravity: 0.99

Mother Liquor, Specific Gravity: 1.00

Mother Liquor, % Dissolved Solids: 3.4

Wash Composition:

☐ Countercurrent ☐ Direct

Leaf Area: 80 cm^2

	FEED					PRI. FILT.		WASH #1			CAKE					
RUN NO.	Volume mls	Temp oC	Vacuum "Hg	Surface Dry sec	% Susp. Solids	Volume mls	% Susp. Sol.	Volume mls	Temp oC	Time sec	Thickness cm	Dry Time sec	Vacuum "Hg	Gms Wet Cake	Gms Dry Cake	% Sol T
A	24	116	17	225	1.2	19.4	0.03				0.05	30		1.5	0.5	33.3

Cloth: PEK-15

BADGER ENGINEERS, INC.
SUBSIDIARY OF THE BADGER COMPANY, INC.
ONE BROADWAY, CAMBRIDGE, MASSACHUSETTS 02142
Tel. (617) 494-7000
Telex 92-1442

February 28, 1984

Mr. J. Gould
Pennwalt Corporation
955 Mearns Road
Warminster, Pennsylvania 18974

Dear Mr. Gould:

I was recently discussing a possible application of Sharples centrifuges with your Mr. Edward Trump. The application involves separation and washing of lignin residue from the outflow stream of a high temperature wood hydrolysis reactor as part of a U.S. D.O.E. feasibility study on chemicals production from wood. Mr. Trump suggested that I forward a sample of the reactor product to your laboratory for a preliminary assessment.

Enclosed herewith is a 250 ml sample of hydrolysate marked "BADGER SAMPLE 250°C" along with a questionnaire form.

Due to experimental limitations, the solids concentration in the sample is approximately 2% by weight. The commercial scale reactor will produce a slurry effluent containing approximately 5% by weight.

Yours sincerely,

BADGER ENGINEERS, INC.

S. W. Fitzpatrick

SWF:sh
Enclosure

FORM 1025 PENNWALT CORPORATION

SUBJECT Badger Engineers
Cambridge, Massachusetts

DATE March 20, 1984

TO C. E. Trump

FROM Jerry Gould CDL #1642

IN RE Clarification of Hydrolysate (Fuel Alcohol)

COPIES TO R. Moll, D. S. Hammond, A. Letki, J. Sacks, file

Dear Ted:

Refer to the attached letter and flow schematics from S. W. Fitzpatrick of Badger Engineers for process details.

The maximum temperature of feed to the centrifuge will be 225°F (108°C).

The submitted sample was evaluated with a bottle centrifuge; details are attached.

If the samples returned to the client are acceptable then, ignoring metallurgy, a Super-D-Canter could be recommended at a fairly high effective rate, e.g. P-800 at 3-4 gpm.

Very truly yours,

Jerry Gould

JG:sw
Attach.

CLIENT BADGER ENGINEERS, INC

DATE 3-6-84

BOTTLE CENTRIFUGE EVALUATION
(RCF X G = 2000) 190°F

SPIN TIME MINS.		1.0						
SLURRY AR ① ✓								
LIQUID APPEAR ②		A/B (orange)						
SEDIMENT ~~CC~~								
%		5	✓ soft					
SLURRY WF ①								
LIQUID APPEAR ②								
SEDIMENT CC								
%								

① AS RECEIVED pH 7.0
WITH FLOCCULANT

② A CLEAR
B SL CLOUDY
C CLOUDY
D ≈FEED

✓ sample returned to client

DORR-OLIVER
DORR-OLIVER INCORPORATED

274 RIVERSIDE AVENUE
WESTPORT, CONNECTICUT 06880
TEL. 203 358-3800

August 16, 1984

Badger Engineers, Inc.
One Broadway
Cambridge, MA 02142

Attention: Mr. S. W. Fitzpatrick

Reference: Countercurrent Washing of Lignin

Dear Mr. Fitzpatrick:

Please find enclosed three (3) copies of Lab. Order 84041 describing the results of the 10mm DorrClone testwork that you witnessed at our laboratory. Although the tests showed that 10mm DorrClones could not make the separation desired, spindown tests showed that a Merco Disc-Nozzle Centrifuge appears to be a promising alternative. The Merco Centrifuge would also give an effective washing capability. The samples collected during the DorrClone tests have been sent to you under separate cover.

For your expected flowrates of 705102 #/hr of lignin slurry and 131964 #/hr of wash water, we would recommend a 3 stage countercurrent wash with our Model H-36 Merco Centrifuge. Two (2) H-36 centrifuges would be required for each stage. Budget pricing for these centrifuges would be $1,650,000. Two (2) Model 25L MercoBowl Centrifuges would be required to thicken the Merco underflow from 25% solids to a 50% cake. Budget pricing for two (2) Model 25L MercoBowl Centrifuges would be $400,000.

For the one-fifth scale plant, the equipment would be correspondingly smaller. Three (3) stages of Merco Model H-30 centrifuges would be required. Budget pricing for three (3) H-30 centrifuges would be $550,000. One (1) Model 22L MercoBowl Centrifuge would be required for dewatering of the Merco underflow. Budget pricing for this unit would be $150,000.

DORR-OLIVER

Badger Engineers, Inc.
Mr. S. W. Fitzpatrick
August 16, 1984

The one-twenty fifth scale demonstration plant would require three (3) stages of the Model H-20 Merco Centrifuge. Budget pricing for these units would be $350,000. In addition, one (1) Model 12L MercoBowl would be required for dewatering the merco underflow. Budget pricing for this unit would be $65,000.

As we discussed, small scale laboratory equipment is available on a rental basis for further process sizing requirements. I enclose bulletins MB-1 and 2612 describing the Merco and MercoBowl Centrifuges and their features in detail. I look forward to working with you in the next stage of pilot development and thank you for your interest in Dorr-Oliver process equipment.

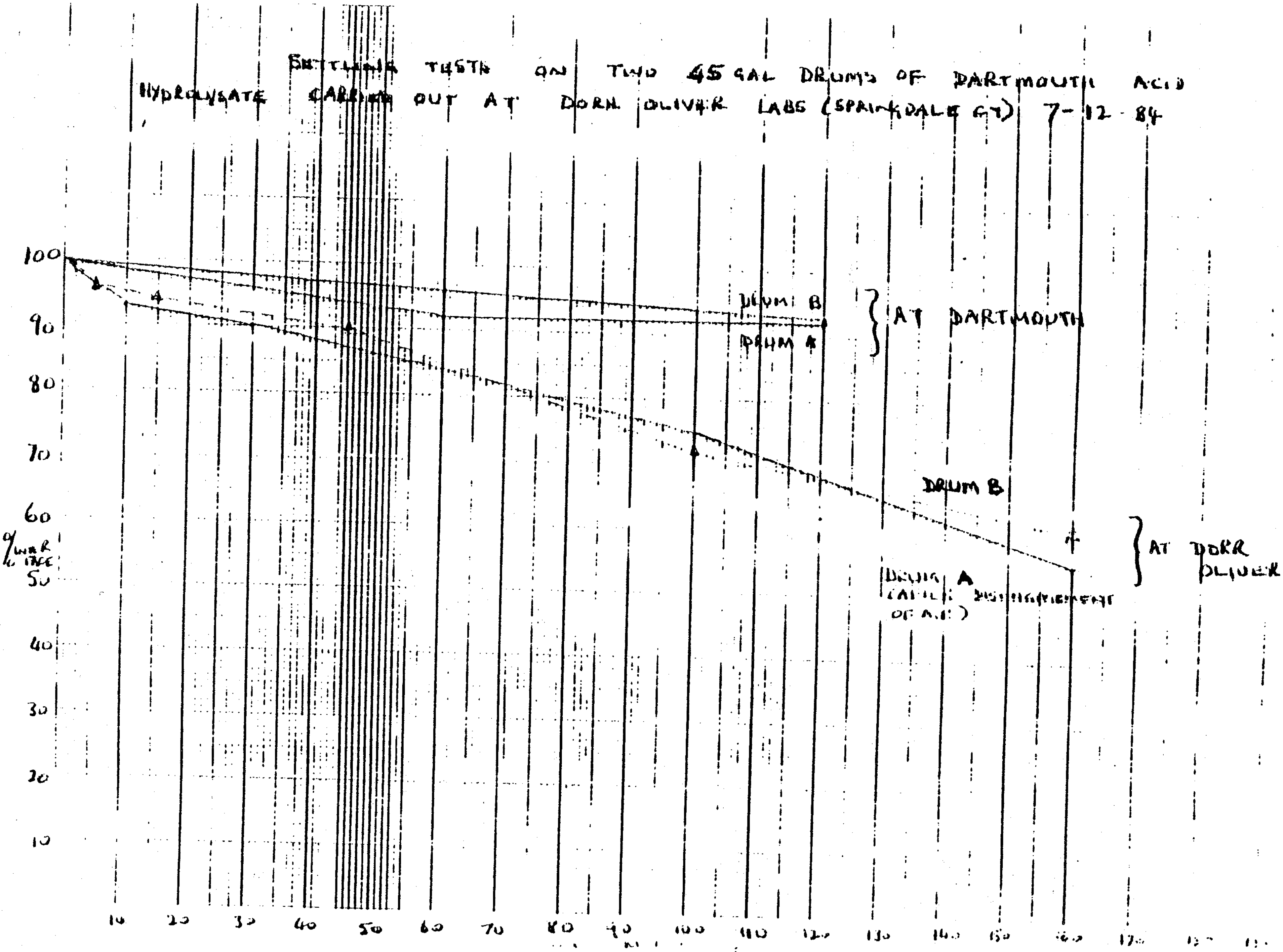
Very truly yours,

Michael J. Smith,
Resident Manager
Eastern Region

MJS:pk

Enclosures

SETTLING TESTS ON TWO 45 GAL DRUMS OF DARTMOUTH ACID HYDROLYSATE CARRIED OUT AT DORR OLIVER LABS (SPRINGDALE CT) 7-12-84



LO 84041 July 1984

DISTRIBUTION

M. Smith (4+1)	Westport
T.H. Bier	Stamford
P. Nyrop	"
J. Peeters (2)	"

Material File (2)

Abstract (14)

RECOVERY OF LIGNIN WITH A 10mm DORRCLONE

DORR-OLIVER

prepared by DORR-OLIVER LABORATORIES for

Badger Engineers, Inc.
Cambridge, MA 02142

order number: LO 84041 July 23, 1984

RECOVERY OF LIGNIN WITH A 10mm DORRCLONE

A laboratory trial was conducted for Badger Engineers, Incorporated to determine the feasibility of using a 10 millimeter DorrClone to recover lignin from an acidic slurry.

Due to excessive foaming of the slurry, and the tendency of the lignin to absorb gas and float, the 10 millimeter DorrClone was not an effective means of concentration.

A laboratory centrifugal spin test was performed on the samples giving promising results for the use of a Merco disc-nozzle centrifuge or Merco Bowl solid-bowl centrifuge.

I. CLIENT

Badger Engineers, Incorporated
One Broadway
Cambridge, MA 02142

II. SAMPLE

Two 30-gallon drums of slurry (labeled Drum A and Drum B) were received at the Springdale Development Center from Dartmouth College. The samples are the product from a reactor utilizing wood chips and acid. Each of the samples contain lignin (solid) in an acidic solution (pH of approximately 1.0).

III. OBJECTIVE

To determine the feasibility of using a 10 mm DorrClone to recover lignin from an acidic slurry.

IV. SUMMARY AND RECOMMENDATIONS

1. Due to the foaming of the slurry and the tendency of the lignin to absorb gas and float, the 10 mm DorrClone is not a suitable means to recover the lignin.

2. Total solids analysis were done on samples from Drum A and B. The results were 2.98% TS (Drum A) and 4.38% TS (Drum B).

3. A laboratory spin test was performed on both samples using a clinical centrifuge. The results indicate the use of a Merco disc-nozzle centrifuge to be very promising. A pilot test is recommended.

V. DETAILS

A. INTRODUCTION

The test slurry was used as is from each drum. The slurry was then fed to a Doxie 5 unit in an effort to remove the lignin. The overflow and underflow were mixed in the feed tank, reconstructing the feed and thus allowing continuous operation. (Figure 1).

B. PROCEDURE

1. Gently mix Drum A slurry with wooden paddle.

2. Add approximately 10 gallons of sample from Drum A to tank.

3. Start pump with by-pass valve open and feed valve open.

4. Increase feed pressure to approximately 40 psi by closing the by-pass valve.

5. Restrict underflow with a needle valve to give approximately an 80/20 flow split and results in a higher underflow concentration.

6. Sample feed, overflow, and underflow.

7. Measure overflow and underflow capacity with stop watch and calibrated bucket and record results (Figure 2).

8. Adjust the underflow needle valve to obtain another flowsplit and repeat Steps 6 and 7.

9. Return slurry to Drum A.

10. Repeat Steps 1 through 9 for Drum B.

VI. DISCUSSION

The primary negative factor encountered in the trial runs was foaming of the slurry which resulted in flotation of the solids rather than settling. The foaming is due to the tendency of the lignin to absorb gas when the slurry is very slightly agitated. As a result, the 10mm DorrClone was not effective in recovering the solids.

Samples from Drum A and B were put in two 15cc graduated test tubes and spun in a clinical centrifuge at 50G force for 30 seconds. The settled volume and centrate clarity were noted (Figure 3). This procedure was repeated for a 1 minute spin. The assessment of centrifugal capability was made using the centrate quality (Figure 4). From the results obtained, a Merco disc-nozzle centrifuge or a Merco Bowl solid-bowl centrifuge has good possibilities. A pilot test is in order at this point to establish separation performance, maximum throughput capacity, and full scale requirements.

DORR-OLIVER LABORATORIES

John F. Peeters

John F. Peeters

Checked and Approved:

Per Nyrop

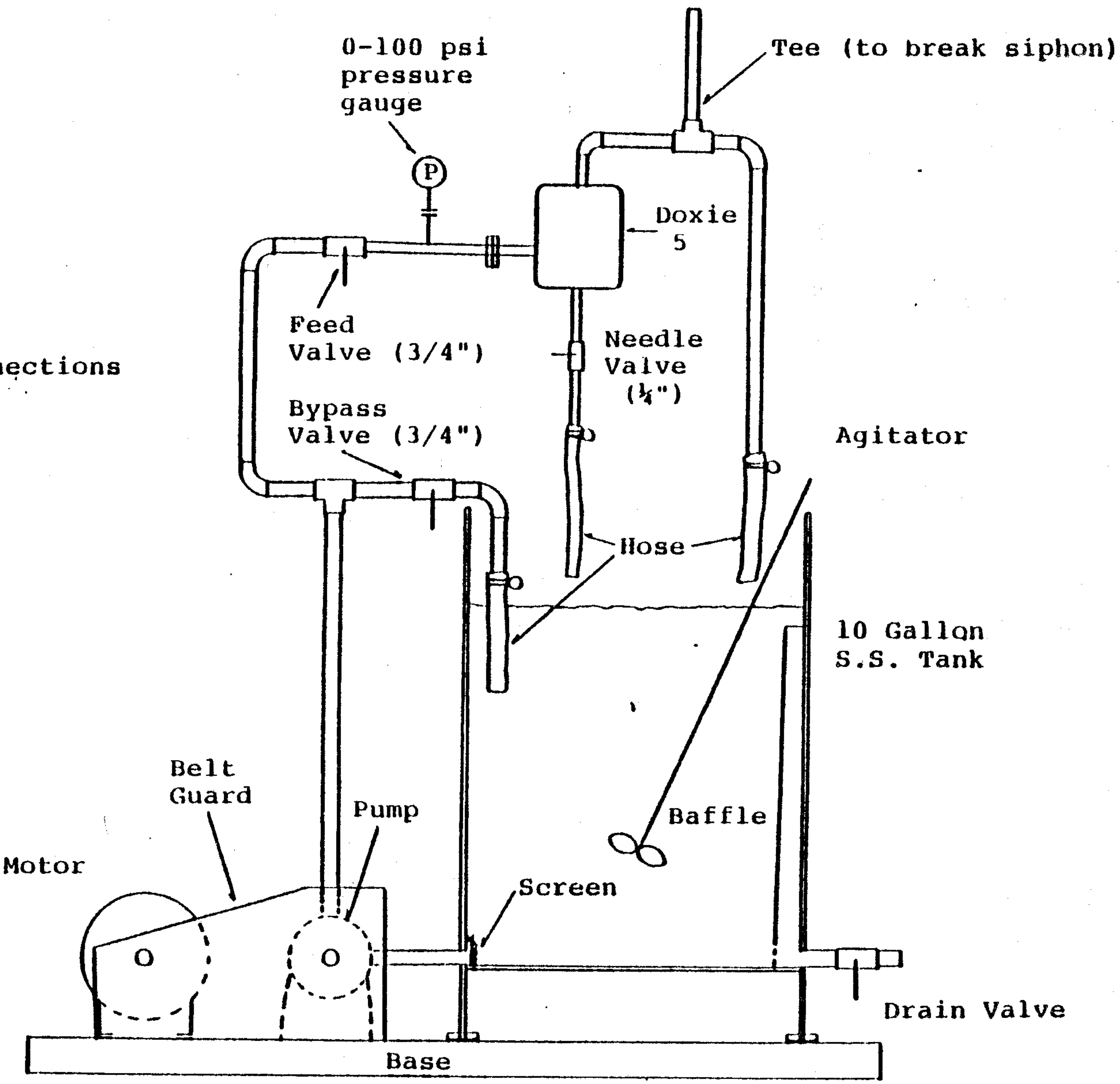
Per Nyrop

Figure 1

DOXIE 5 TEST STAND

Note:

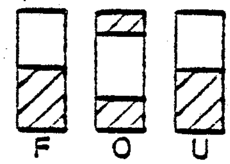
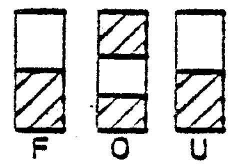
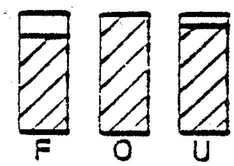
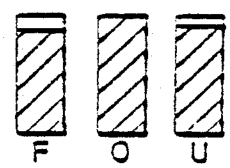
All Doxie 5 Connections
are ½" npt.



J.F.P.
7/24/84

Figure 2

Doxie Test Data

Run	Drum	ΔP(3) (psi)	O'Flow (gpm)	U'Flow (gpm)	Split (OF/UF)	Temp (°C)	Sample Jars (4)
1	A	37	5.6	0.2	97/3	23	
2	A	31	3.0	1.1	73/27	-	
3	B	33	2.25	1.1	67/33	-	
4	B	33	2.6	0.75	78/22	29	

Notes:

(1) Solids are floc-like.

(2) Slurry in tank remained unagitated for 1 hour between run 3 and 4 to let the foam dissipate.

(3) The pressure drop is the highest that could be obtained with the present pump on the test stand.

(4) The samples collected were observed one hour later.

Figure 3

Spin Test Data

	Drum A	Drum B
30 Second Spin	2.5 ml Solids in 15 ml Total	5.2 ml Solids in 16 ml Total
1 Minute Spin	2.2 ml Solids in 15.5 ml Total	4.4 ml Solids in 15 ml Total

Notes:

(1) Approximately 0.5 to 1 ml of solids are a darker brown.

(2) Very loosely packed solids.

(3) Centrate is clear in all spins.

Figure 4

Centrifugal Separation Capability

Time to get clear centrate (Minutes)	Centrifugal Separation Capability
0.5	Good
1.0	Marginal (borderline)
3.0	Poor

Calculation for Assessment of Technical Risk from Point of View of Cost Growth and Performance Shortfall

Based on Methodology from Rand Report R-2569-DOE
September 1981

(1) Present Estimate

Estimate the Rand cost growth factor based on present level of research and development and commercial plant cost estimate as defined by Badger report of September 1984.

Percent New

- Variable Definition: "Percent of capital cost in technology proven in commercial use." Range: 0-100
- Assume Hydrolysis unit is only unit unproven in commercial use.
- From Cost Estimate: 21.74/103.4 x 100 = 21

<u>Impurities</u>

- Variable Definition: "Assessment by industry process engineers of difficulties with process impurities encountered during development." Range: 0 = None, 5 = Major

- Variable includes impurities build up as it relates to catalyst deactivation and corrosion.

- Plant has two major liquid recycle loops (from stillate evaporation and from furfural recovery).

- Recycle loops present catalyst (yeast) deactivation and equipment sizing/capacity problems. Prediction of hydrolyzate fermentability is an area of technical uncertainty affected by impurity build up.

- Corrosion is not expected to be a problem since plant definition includes reasonable use of stainless steel.

- Judged Value: Medium-high because of understanding of yeast inhibition.

- Use 3.

Complexity

- Variable Definition: "Simply a count of the number of continuously linked process steps or block units in the plant."
- Block Units Include: Feedstock handling, hydrolysis, fermentation, ethanol purification, furfural recovery, offsite tankage, waste treatment, utilities.
- Use 8.

Inclusiveness

- Variable Definition: "Percentage of three items included in the scope of an estimate." Range: 0-100
- All items were addressed in Badger estimate as items of cost to be estimated, and were included in from our number. Could argue value is 100.
- Use 90.

Project Definition

- Variable Definition: "Levels of engineering and site-specific information included in estimate." Range: 2 = Most, 8 = Least

- Study not site-specific, however, environmental impact minimized by design.

- Use 6.

Process Development Stage

- Variable Definition: "Selection of stage of process development from four categories." Range: 0 if proven at commercial or precommercial, 1 if at R&D stage.

- Choose stage "(2) Development: A coordinated R&D program is underway."

- Use 1.

<u>Cost Growth</u>

o Intercept	1.12196
o (Percent New = 21) x -0.00297	-0.06237
o (Impurities = 3) x 0.02125	-0.06375
o (Complexity = 8) x -0.01137	-0.09096
o (Inclusiveness = 90) x +0.00111	+0.0999
o (Project Definition = 6) x (Process Development Stage = 1) x -0.06361	-0.38166
o Cost Growth	0.62312

(2) With Demonstration Unit

(This is an integrated demonstration plant encompassing all the major process units.)

What can be expected in reduction in cost growth ratio from building and operating the demonstration unit.

Cost Growth

o Intercept	1.12196
o Percent New - Unchanged at 32	-0.06237
o Impurities - Assume that demono will increase understanding of effect of recycle on fermentability. Therefore decrease value to 1 (1) x -0.02125	-0.02125
o Complexity - Unchanged at 8	-0.09096
o Inclusiveness - Unchanged at 90	+0.0999
o Project Definition - Slightly increased site-specific information available say reduce to 5.	
o Process Development Stage - Increase stage of development to (3). Precommercialization: "Pilot work of demonstration type and there are sufficient data to start design on a commercial unit." (5)(-0.04011)	-0.20055
o Cost Growth	0.84673

(3) With Site-Specific Study

(A description of a typical site-specific study is given on page 14 of this Appendix.)

What can be expected in reduction of cost growth ratio from completing a site-specific study.

Cost Growth

o Intercept	1.12196
o Percent New - Unchanged at 21	-0.06237
o Impurities - Unchanged at 3	-0.06375
o Complexity - Unchanged at 8	-0.09096
o Inclusiveness - Increased to 100 (100) x +0.00111	+0.111
o Project Definition - Reduced to 4 Level of Engineering: (2) Study design (Moderate Basis). Quality of Information: (2) Preliminary or limited work.	
o Process Development Stage - Unchanged at R&D Stage (2)	-0.2544
(4) x -0.06361	0.805

(4) With Both

What can be expected in reduction of cost growth from both the building and operating of the demonstration unit and completing the site-specific study.

Cost Growth

o Intercept	1.12196
o Percent New - Unchanged at 32	-0.06237
o Impurities - Reduce to 1 (Demo)	-0.02125
o Complexity - Unchanged at 8	-0.09096
o Inclusiveness - Increase to 100 (Study)	+0.111
o Project Definition - Reduce to 4 (Study)	
o Process Development Stage - Increase to (3) precommercialization, (Demo) (4) x -0.04011	-0.1604
o Cost Growth	0.898

Calculation of Technical Risk from Point of View of View of Performance Shortfall

Based on the Rand Methodology from Rand Report R-2569-DOE
September 1981

(1) Present Estimate

Estimate the most likely plant performance in months 7-12 after startup as a percentage of design assumed in Badger study.

New Steps

- Variable Definition: Number of process units that incorporate technology unproven in commercial use.
- Assume uncertainty lies in hydrolysis unit. Since hydrolysis unit covers many steps treat as two units.
- Assume 2.

Balance Equations

- Variable Definition: Percentage of heat and material balance equations based on actual data from prior plants.
- Data obtained from Darmouth reactor performance.
- Fermentation, ethanol purification, furfural recovery and feedstock handling data based on previously tested technology but with many differences.
- Use 40% for this.

Waste

- Variable Definition: Assessment by industry process engineers of difficulties with waste handling encountered during development.
- Plant designed to limit waste to solid landfill and vents. However, actual magnitude of waste problem or of local constraints unknown in practice.
- Allow 2.5.

Solids

- Variable Definition: Designates that a plant processes primarily solid feedstocks.
- Wood chips in solid feedstock.
- Use 1.

Performance Shortfall

o Intercept	85.77
o New Steps 2 x -9.69	-19.38
o Balance Equations 40 x .33	+13.2
o Waste 2.5 x 4.12	-10.3
o Solids 1 x -17.91	-17.91
	51.4

(2) With Demonstration Unit

What can be gained in the increase in expected performance as a percent of design from building and operating the demonstration unit.

Performance Shortfall

o	Intercept	85.77
o	New Steps - Demonstration plant increases understanding of all steps in hydrolysis - reduce to zero.	Zero
o	Balance Equations - Assume most heat and material balances can be confirmed during demonstration phase - increase to 90%.	+29.7
o	Waste - Demonstration plant allows confirmation of assumptions about wastes generated. However, not site-specific - reduce to 1.0.	- 4.12
o	Solids - Remains at 1	-17.19
		93.44

(3) With Site-Specific Study

What can be gained in the increase in expected performance as a percentage of design from carrying out a site-specific study.

Performance Shortfall

o Intercept	85.77
o New Steps - Remains at 2	-19.38
o Balance Equations - Remains at 40%	+13.2
o Waste - Allows site-specific environmental factors to be defined - reduce to 2.	- 8.24
o Solids - Remains at 1	-17.91
	53.44

(4) With Both

What can be gained in the increase in expected performance as a percent of design from both building and operating of a demonstration unit and completing the site-specific study.

Performance Shortfall

o Intercept	85.77
o New Steps - Zero	Zero
o Balance Equations 90%	29.7
o Waste - Zero	Zero
o Solids 1	17.91
	97.56

Description of Typical Site-Specific Study

A typical site-specific study would define four major items not included in the present conceptual design study:

(1) Identify all major technical and project execution issues requiring resolution before initiation of or during the design.

(2) Define all the necessary facilities (verify technical feasibility).

(3) Present an execution plan including schedule for engineering, procurement, and especially fabrication and construction.

(3) Present a realistic investment cost and project cash flow (verify commercial feasibility, allowing negotiation of realistic value for feedstock).

Some of the issues that would be addressed in a site-specific Phase 0 study of the first commercial plant for the hydrolysis technology would be:

(1) Engineering

- o basic design data and design codes for site
- o modifications for specific feedstocks, definitions of feedstock delivery, and product shipment systems
- o environmental and safety requirements

Details of Economic Analysis Calculations

The following pages explain the detailed economic calculations used in the Badger and SERI economic analysis. Footnotes follow the computer calculations to explain the method and assumptions used.

The pages of calculations are as follows:

Summary Sheet for Raw Data
Analysis of Revenues
Analysis of Costs of Sales
Investment Summary
Proforma Income Statement
Cash Flow Analysis
Plant Operating Cost Data
Cost Data During Construction

Finally, examples of the sensitivity analysis printout is given for the Badger and SERI based calculations.

Where major differences between the SERI and Badger parameters exist these are highlighted in the footnotes.

SERI E-0461 BADGER Date: 20-Sep-84

CONSTRUCTION RELATED DATA: Jan 84	Unit	Amount
Base year for Constant Dollars	date	Jan 84
Construction schedule	months	30
Starting date	date	Jan 85
Estimated capital costs	$MM	139.70
Land cost	$MM	1.00
Interest during construction	%	13.0
Investment tax credit	%	10.0
Other tax credits		
- Business Energy	%	10.0
	%	0.0
	%	0.0
Percent equity	%	100.0
Percent debt	%	0.0
Inflation rate	%	0.0
Escalation on capital	%	0.0
Monthly Compounding	%	1.0000

OPERATING RELATED COSTS:	Unit	Amount
Inflation rate	%	0.0
Escalation on operating costs	%	0.0
Interest during plant operation	%	13.0
Working capital	$MM	8.50
Tax rate	%	45.0
Salvage % at end of operation period	%	10.0

Product sales	MM$/Yr:	77.43
Raw materials	MM$/Yr:	28.35
Operating expenses	MM$/Yr:	15.44
Gross Income, 1984 basis		33.64

		Unit	Capacity Units /Year	Unit price $/Unit	Yearly costs MM$/yr
Products	ethanol	MMGals	27.50	1.80	49.50
	furfural	MMlbs	130.20	0.15	19.53
	electricity	MWHrs	176000	50.00	8.80
	landfill	metr tons	63333	-5.00	-0.32
Raw materials	wood chips	metr tons	590400	42.00	24.80
	sulfuric acid	metr tons	18155	65.00	1.18
	lime	metr tons	18383	35.00	0.64
	other cats & chems	$/yr	609800		0.61
	diesel oil	Gals	10000	1.00	0.01
	gasoline	MMGals	1.31	0.85	1.11
Operating costs	labor	MM$/yr	1.40		1.40
	supervision	MM$/yr	0.06		0.06
	direct overhead	%	40	labr+supvn	0.62
	maintenance	%	4	capital	5.59
				subtotal	7.75
	selling G & A	%	60	subtotal	4.65
	insur & taxes	%	2	capital	2.80
	royalty	$/yr	250000		0.25

Summary Sheet for Raw Data

Economic Assessment Data

Notes:

(1) Base Year - Inflation and escalation if included in the analysis begin in the base year.

(2) Starting Date - Depreciation calculations use the starting date as the basis.

(3) Estimated Capital Costs - This represents the total depreciable investment required. The method of estimating is given in Appendix VII and capital cost components are given in Section 5.0 of the main report.

(4) Land Cost - Land cost is nondepreciable and is included in the economic calculations as a separate item.

(5) Interest During Construction - Interest during construction including past years is capitalized and included as total depreciable investment.

(6) Tax Credits - Total tax credits amount to 20% of depreciable capital investment. 10% from investment tax credit, 10% from business energy tax credit. SERI based calculations do not take the 10% business energy credit.

(7) Percent Equity - Badger calculations have been carried out on the basis of 100% equity. SERI based calculations use 70% equity, 30% debt.

(8) Inflation Rate - Badger calculations have used zero inflation rate. SERI based calculations use a 7% inflation rate.

(9) Escalation Rate on Capital - SERI have requested that an escalation rate of 1% on capital be used in the calculations. The Badger based calculation does not include escalation.

(10) Interest During Construction - Interest due during construction is compounded monthly (SERI calculation).

(11) Escalation Rate on Operations - SERI have requested that an escalation rate of 1.5% on operations be used in the calculations. The Badger based calculation does not include escalation.

(12) Working Capital - Working capital is computed using the following formula:

30 Days Accounts Receivable
+Cash (10% Accounts Payable)
+15 Days Inventories
+30 Days Maintenance and Spares
-30 Days Wages
-30 Days Raw Materials
-30 Days Maintenance and Labor
-90 Days Taxes

(13) Tax Rate - The tax rate used in calculations is given by SERI.

(14) Salvage - A 10% salvage value at the end of the project is taken in the Badger calculation. The SERI calculation assumes zero salvage value.

(15) Product Costs - These costs are FOB plant.

(16) Product Volumes - The ethanol production volume at 100% design is 26.2 million gallons per year (nominal capacity is 25 million gallons). The figure given here of 27.5 million gallons includes 5% gasoline (purchased as 87% octane gasoline) blended as denaturant.

Analysis of Revenues

Notes:

(1) Year Start and Number - Plant construction begins in year zero and is complete mid-way through year two. The correspondence with calendar years is indicated.

(2) Plant Availability - Plant availability is defined as that portion of a year that plant is available for operation. Since project duration is assumed to be 15 years plant is available for only half of year 17.

(3) Stream Factor - Stream factor is defined as that percentage of design capacity at which the plant operates during operating year. This actual production will be stream factor times plant availability times design capacity. The SERI based calculation uses a constant stream factor of 100% from startup. The Badger analysis uses a gradual increase over three years: 50%, 80%, 100%, etc. The figures shown above reflect the average stream factor for the year, e.g., (50%+80%) — 2 = 65%.

(4) Inflation and Escalation - This analysis is prepared for constant dollar DCF accordingly for the Badger calculation zero inflation assumed. Inflation index is expressed relative to year -1.

(5) Product Volumes - Actual production is design capacity modified by plant availability and stream factor.

(6) Selling Prices - Constant dollar analysis for determining DCF 1984 dollars. Land fill is indicated as a negative value because charges will be incurred for collection and disposal by outside contractor.

(7) Total Revenue - Total revenue line is carried over to Proforma Income Statement.

SERI E-0461

BADGER

Date: 20-Sep-84

ANALYSIS OF REVENUES

Year Start:		Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93
Year No. :		-1	0	1	2	3	4	5	6	7	8
Plant availability		0%	0%	0%	50%	100%	100%	100%	100%	100%	100%
Stream factor		0%	0%	0%	50%	65%	90%	100%	100%	100%	100%
Inflation + Escalation, effect on operating costs:		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PRODUCT VOLUMES	Unit										
Ethanol	MMGals	0.00	0.00	0.00	6.88	17.88	24.75	27.50	27.50	27.50	27.50
Furfural	MMLbs	0.00	0.00	0.00	32.55	84.63	117.18	130.20	130.20	130.20	130.20
Electricity	MWhrs	0	0	0	44000	114400	158400	176000	176000	176000	176000
Landfill	metr Tons	0	0	0	15833	41166	57000	63333	63333	63333	63333
SELLING PRICES	$/....										
Ethanol	MMGals	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Furfural	MMLbs	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Electricity	MWhrs	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Landfill	metr Tons	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
REVENUES	MM$										
Ethanol		0.0	0.0	0.0	12.4	32.2	44.6	49.5	49.5	49.5	49.5
Furfural		0.0	0.0	0.0	4.9	12.7	17.6	19.5	19.5	19.5	19.5
Electricity		0.0	0.0	0.0	2.2	5.7	7.9	8.8	8.8	8.8	8.8
Landfill		0.0	0.0	0.0	-0.1	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3
	TOTALS	0.0	0.0	0.0	19.4	50.4	69.7	77.5	77.5	77.5	77.5

Year Start:		Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year No. :		9	10	11	12	13	14	15	16	17
Plant availability		100%	100%	100%	100%	100%	100%	100%	100%	50%
Stream factor		100%	100%	100%	100%	100%	100%	100%	100%	100%
Inflation + Escalation, effect on operating costs:		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PRODUCT VOLUMES	Unit									
Ethanol	MMGals	27.50	27.50	27.50	27.50	27.50	27.50	27.50	27.50	13.75
Furfural	MMLbs	130.20	130.20	130.20	130.20	130.20	130.20	130.20	130.20	65.10
Electricity	MWhrs	176000	176000	176000	176000	176000	176000	176000	176000	88000
Landfill	metr Tons	63333	63333	63333	63333	63333	63333	63333	63333	31667
SELLING PRICES	$/....									
Ethanol	MMGals	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Furfural	MMLbs	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Electricity	MWhrs	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Landfill	metr Tons	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
REVENUES	MM$									
Ethanol		49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	24.8
Furfural		19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	9.8
Electricity		8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	4.4
Landfill		-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2
	TOTALS	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	38.7

Analysis of Cost of Sales

Notes:

(1) Cost of Sales - These are divided into costs that behave as variable and costs that behave as fixed for ease in calculating cost of sales at reduced plant operating rates.

(2) Raw Material Quantities - These are discussed in text and prorated with fractions of reduced operating years.

(3) Unit Costs - These are discussed in the text and are in 1984 constant dollars.

(4) Fixed Costs - Fixed costs include direct labor and other items which might be considered variable. To be conservative it is assumed that these costs are fixed during all years at levels corresponding to 100% production.

(5) Total Cost of Sales - This is carried over to proforma income statement. This item includes straight line depreciation of depreciable assets for book purposes. This is adjusted to a tax basis for DCF calculations.

SERI E-0461

B A D G E R

Date: 20-Aug-84

ANALYSIS OF COSTS OF SALES

Year Start:			Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year No. :			-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plant availability			0%	0%	0%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%
Stream factor			0%	0%	0%	50%	65%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Inflation + Escalation, effect on operating costs:			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RAW MATERIALS QUANTITIES																					
wood chips	metr Tons		0	0	0	147600	383760	531360	590400	590400	590400	590400	590400	590400	590400	590400	590400	590400	590400	590400	295200
sulfuric acid	metr Tons		0	0	0	4539	11801	16340	18155	18155	18155	18155	18155	18155	18155	18155	18155	18155	18155	18155	9078
lime	metr Tons		0	0	0	4596	11949	16545	18383	18383	18383	18383	18383	18383	18383	18383	18383	18383	18383	18383	9192
other cats & chems			0.00	0.00	0.00	0.25	0.65	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50
diesel oil	Gals		0	0	0	2500	6500	9000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	5000
gasoline	MMGals		0.00	0.00	0.00	0.33	0.85	1.18	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	0.66
UNIT COSTS	$/....																				
wood chips	metr Tons		42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00
sulfuric acid	metr Tons		65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
lime	metr Tons		35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
other cats & chems	/Yr		609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800	609800
diesel oil	Gallon		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
gasoline	Gallon		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
TOTALS	MM$																				
wood chips			0.0	0.0	0.0	6.2	16.1	22.3	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	12.4
sulfuric acid			0.0	0.0	0.0	0.3	0.8	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.6
lime			0.0	0.0	0.0	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.3
other cats & chems			0.0	0.0	0.0	0.2	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.3
diesel oil			0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
gasoline			0.0	0.0	0.0	0.3	0.7	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.6
TOTAL VARIABLE COSTS			0.0	0.0	0.0	7.1	18.4	25.5	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	14.2
FIXED COSTS	Units, unit rates		MM$																		
labor	MM$/yr	1.48	0.00	0.00	0.00	0.74	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	0.74
supervision	MM$/yr	0.06	0.00	0.00	0.00	0.03	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.03
		subt I	0.00	0.00	0.00	0.77	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	0.77
direct overhead	% subt I	40	0.00	0.00	0.00	0.31	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.31
maintenance	% capital	4	0.00	0.00	0.00	2.80	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	2.80
insur & taxes	% capital	2	0.00	0.00	0.00	1.40	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	1.40
royalty	$/yr	250000	0.00	0.00	0.00	0.13	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.13
depreciation, (book)			0.00	0.00	0.00	4.51	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	4.51
TOTAL FIXED COSTS			0.00	0.00	0.00	9.91	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	9.91
TOTAL COSTS OF SALES			0.00	0.00	0.00	16.99	38.24	45.33	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	24.08

Investment Summary

Notes:

(1) Investment Summary - Contains a summary of all investment figures contained in other schedules.

(2) Gross Investment - Gross investment in plant and equipment corresponds to construction schedule of 30 months.

(3) Average Gross Investment - This is defined as the average of gross investment at the beginning and end of the operating year. It is used for the purpose of calculating a yearly ROI (simple) based on book (proforma) income.

(4) Depreciation Summary - Reflects accelerated depreciation for plant, equipment, buildings.

(5) Book Depreciation - This is 15 year straight line.

(6) Average Net Investment - This is defined as the average value of net investment at the beginning and end of the year (tax depreciated investment). It is used for calculating a notional interest charged to the proforma income statement. It is netted out for DCF calculation.

(7) Interest - Interest is charged to proforma income statement calculated at 13% of average net investment (tax basis).

SERI E-0461

BADGER

Date: 20-Sep-84

INVESTMENT SUMMARY

Year Start:	Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year No. :	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plant availability	0%	0%	0%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%
GROSS INVESTMENT																			
Plant and Equipment	0.00	55.91	111.82	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78	139.78
Land	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Buildings and other	Included with Plant and Equipment																		
Working capital	0.00	0.00	0.00	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	0.00
Total gross investment	0.00	56.91	112.82	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	140.78
AVERAGE GROSS INVESTMENT	[illegible]	28.45	84.87	131.05	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	145.03
DEPRECIATION SUMMARY																			
TAX: Plant and Equipment (1)	0.00	0.00	0.00	26.97	30.75	29.35	29.35	29.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buildings and other (2)	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl
Investment tax credit	0.00	0.00	0.00	27.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	48.92	30.75	29.35	29.35	29.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AVERAGE TAX DEPRECIATION	0.00	0.00	0.00	24.46	39.84	30.05	29.35	29.35	14.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUMULATED AVG. TAX DEPRECIATION	0.00	0.00	0.00	24.46	64.30	94.35	123.71	153.06	167.74	167.74	167.74	167.74	167.74	167.74	167.74	167.74	167.74	167.74	167.74
BOOK DEPRECIATION																			
Plant and Equipment	0.00	0.00	0.00	4.51	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	4.51
Buildings and other	0.00	0.00	0.00	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl
Total	0.00	0.00	0.00	4.51	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	4.51
Average Net Investment (Tax basis)	0.00	28.46	84.87	106.59	84.98	54.93	25.57	0.00	0.00	0.00	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest for Income statement interest rate: 13 %	0.00	0.00	0.00	13.86	11.05	7.14	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTES: (1) Assumed depreciation basis is five years, at resp. 15, 22, 21, 21, and 21 %
(2) Included with Plant and Equipment

Proforma Income Statement

Notes: (1) Proforma Income Statement - This is produced to indicate the incremental impact of this project on the income statement of an existing company. This statement contains two major departures from DCF analysis: interest charged at a rate of 13% of the average net investment (tax basis) during operating year; and income tax is based on an income reflecting national interest. Tax is allowed to be negative because it assumes that the company operating the facility will be capable of employing tax losses.

(2) Revenues and Cost of Sales - This is taken directly from supporting schedule.

(3) Distribution - It is uncommon for a venture of this kind to simply produce product FOB plant. Generally, it will have distribution expenses and investment associated with distribution equipment. Since this is site-specific and dependent on specific customer bases it is not included in the present calculation. Selling price is thus FOB plant.

(4) Selling G and A - This is the general and administrative overhead costs of production.

SERI E-0461

B A D G E R

Date: 20-Sep-84

PRO-FORMA INCOME STATEMENT

	Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year Start:																			
Year No. :	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Revenues	0.00	0.00	0.00	19.37	50.36	69.73	77.48	77.48	77.48	77.48	77.48	77.48	77.48	77.48	77.48	77.48	77.48	77.48	38.74
Cost of sales	0.00	0.00	0.00	16.99	38.24	45.33	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	48.16	24.08
Gross profit	0.00	0.00	0.00	2.38	12.12	24.40	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	14.66
Distribution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct profit	0.00	0.00	0.00	2.38	12.12	24.40	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	29.32	14.66
Selling, G & A	0.00	0.00	0.00	2.32	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	2.32
Profit before Interest and Tax	0.00	0.00	0.00	0.05	7.47	19.76	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	12.33
Interest, on avg net investment	0.00	0.00	0.00	13.86	11.05	7.14	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net profit before tax	0.00	0.00	0.00	-13.80	-3.57	12.62	21.34	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	12.33
Pro-forma Tax at 45%	0.00	0.00	0.00	-6.21	-1.61	5.68	9.60	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	5.55
Net Income, MM$	0.00	0.00	0.00	-7.59	-1.97	6.94	11.74	13.57	13.57	13.57	13.57	13.57	13.57	13.57	13.57	13.57	13.57	13.57	6.78
GROSS AVG. INVESTMENT.	0.00	28.46	84.57	121.35	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	149.28	145.03
ROI (Net Income/Gross Investment) %	0.0%	0.0%	0.0%	-6.5%	-1.3%	4.6%	7.9%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	4.7%

<u>Cash Flow Analysis</u>

Notes:

(1) Sources and Uses Statement - This is used to calculate IRR discounted cash flow internal rate of return). This analysis assumes 100% equity, that is, the IRR reflects a rate of return for total capital consumed.

(2) Net Profit Before Taxes - This is taken directly from the proforma income statement. Accordingly, NPBT have notional interest and book depreciation subtracted from it, which are noncash expenses; these are added back in within the statement.

(3) Accelerated Tax Depreciation - This is employed as discussed in the text. It is assumed in the Badger analysis that the tax benefit of accelerated depreciation can be utilized by the venture owning the facility. (Otherwise, there would be a tax loss carry forward, as used in the SERI based analysis.)

(4) Adjusted Profit Before Taxes - This is calculated to determine the actual taxes due before investment and business energy tax credits. It should be noted that interest s not deducted for determination of taxes. It is assumed that the hurdle rate for the IRR will reflect an overall cost of capital for an existing operating company (i.e., capital structure, debt, equity, and interest for the existing entity are reflected in a cost of capital). The recovery of $13.98 mm in salvage value is a taxable event in year 17.

(5) Tax Credits - An investment tax credit of 10% of plant investment is assumed. In the Badger analysis an additional 10% business energy credit is also taken during the first operating year. It is assumed that this venture would qualify due to its nature. The DCF is given credit for the tax credits during the first operating year (see note 2).

(6) Uses of Funds - This is derived from "Investment Summary" schedule. Working capital of $8.5 million is required in the first operating year and is recovered in the last operating year. Land is treated similarly.

(7) Net Cash Flow - This reflects total capital flowing in and out of the venture. It reflects a total return on capital (see note 1).

(8) Cumulative Cash Flow - Cumulative cash flow is used to calculate simply payback period, again assuming that the owning company can utilize all tax losses incurred (Badger basis).

SERI E-0441

BADGER

Date: 20-Sep-84

CASH FLOW ANALYSIS

Year Start:		Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92
Year No. :		-1	0	1	2	3	4	5	6	7
SOURCES OF FUNDS										
Net Profit before Taxes		0.00	0.00	0.00	-13.80	-3.57	12.62	21.34	24.67	24.67
Add: Gain/Loss on Salvage (1)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Add: Interest expense		0.00	0.00	0.00	13.86	11.05	7.14	3.32	0.00	0.00
Add: Book depreciation		0.00	0.00	0.00	4.51	9.02	9.02	9.02	9.02	9.02
Deduct: Tax depreciation		0.00	0.00	0.00	-20.97	-30.75	-29.35	-29.35	-29.35	0.00
Adjusted Profit before Taxes		0.00	0.00	0.00	-16.41	-14.25	-0.56	4.33	4.33	33.69
Deduct: Income Taxes at	45%	0.00	0.00	0.00	-7.38	-6.42	-0.25	1.95	1.95	15.16
Adjusted net income		0.00	0.00	0.00	-9.02	-7.84	-0.32	2.38	2.38	18.53
Add: Tax depreciation		0.00	0.00	0.00	20.97	30.75	29.35	29.35	29.35	0.00
Add: Investment tax credit		0.00	0.00	0.00	27.96	0.00	0.00	0.00	0.00	0.00
TOTAL SOURCES	MM$	0.00	0.00	0.00	39.90	22.91	29.03	31.74	31.74	18.53
USES OF FUNDS										
Plant and Equipment		0.00	55.91	55.91	27.96	0.00	0.00	0.00	0.00	0.00
Land		0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buildings and other		incl	incl	incl	incl	incl	incl	incl	incl	incl
Working capital		0.00	0.00	0.00	8.50	0.00	0.00	0.00	0.00	0.00
TOTAL USES	MM$	0.00	56.91	55.91	36.46	0.00	0.00	0.00	0.00	0.00
NET CASH FLOW	MM$	0.00	-56.91	-55.91	3.44	22.91	29.03	31.74	31.74	18.53
CUMULATIVE CASH FLOW	MM$	0.00	-56.91	-112.82	-109.38	-86.47	-57.44	-25.70	6.04	24.57

Year Start:	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year No. :	8	9	10	11	12	13	14	15	16	17
SOURCES OF FUNDS										
Net Profit before Taxes	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	12.33
Add: Gain/Loss on Salvage (1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.98
Add: Interest expense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Add: Book depreciation	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02	4.51
Deduct: Tax depreciation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjusted Profit before Taxes	33.69	33.69	33.69	33.69	33.69	33.69	33.69	33.69	33.69	30.82
Deduct: Income Taxes at 45%	15.16	15.16	15.16	15.16	15.16	15.16	15.16	15.16	15.16	13.87
Adjusted net income	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	16.95
Add: Tax depreciation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Add: Investment tax credit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SOURCES (MM$)	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	16.95
USES OF FUNDS										
Plant and Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00
Buildings and other	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl
Working capital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-8.50
TOTAL USES (MM$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-9.50
NET CASH FLOW (MM$)	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	26.45
CUMULATIVE CASH FLOW (MM$)	43.09	61.62	80.15	98.68	117.20	135.73	154.26	172.79	191.32	217.77

IRR 15.15%

NOTES: (1) Assumes a salvage value of
10% of current plant costs,
minus tax of 45%
Also includes gain or loss
from the sale of land.

Plant Operating Cost Date

Notes:

(1) Plant Operating Cost Data - This is a schedule which calculates IRR in direct manner. This analysis ties completely with the IRR calculation in previous schedules but simply eliminates interim or redundant calculations.

(2) Overall cash Flow (Single) - This is the cash flow of the venture under the assumption that the project is a single venture and use of tax losses and tax credits must therefore be deferred until the single venture itself consumes them. This basis is used in the SERI based economic analysis.

(3) Overall cash Flow (Multiple) - This is identical to the cash flow determined in earlier schedules. It assumes that the plant is operated by an existing company with other profitable projects against which losses and tax credits can be written off as soon as they occur.

SERI .E-0461

B A D G E R

Date: 20-Sep-84

PLANT OPERATING COST DATA

	Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year Starts / Year No. :	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plant availibility	0%	0%	0%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%
Stream factor	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Inflation + Escalation, effect on operating costs	1.00	1.09	1.16	1.26	1.39	1.50	1.63	1.77	1.92	2.08	2.26	2.45	2.66	2.89	3.13	3.40	3.69	4.00	4.34
Product sales	0.00	0.00	0.00	39.47	65.56	92.93	100.34	109.41	118.71	128.83	129.74	151.62	164.51	176.49	193.67	210.13	227.99	247.37	134.20
Raw materials costs	0.00	0.00	0.00	18.11	19.20	42.63	45.76	50.19	54.46	59.06	54.11	69.56	75.47	81.86	88.84	96.39	104.59	113.48	61.56
Gross margin	0.00	0.00	0.00	21.36	46.36	50.30	54.58	59.22	64.25	69.71	75.64	82.07	89.04	96.61	104.82	113.73	123.40	133.89	72.63
Operating costs	0.00	0.00	0.00	9.86	21.40	23.22	25.19	27.33	29.66	32.18	34.91	37.88	41.10	44.59	48.38	52.50	56.96	61.80	33.53
Gross income	0.00	0.00	0.00	11.50	24.96	27.08	29.39	31.88	34.59	37.53	40.72	44.19	47.94	52.02	56.44	61.24	66.44	72.09	39.11
Depreciation %/yr	0	0	0	15	22	21	21	21	0	0	0	0	0	0	0	0	0	0	0
Depreciation $/yr	0.00	0.00	0.00	26.12	38.31	36.57	36.57	36.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Principal paid	0.00	0.00	0.00	1.88	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76
Outstanding debt	0.00	0.00	0.00	56.41	52.67	48.90	45.14	41.38	37.62	33.86	30.09	26.33	22.57	18.81	15.05	11.29	7.52	3.76	.00
Interest paid during plant operation	0.00	0.00	0.00	3.67	6.65	6.36	5.87	5.38	4.89	4.40	3.91	3.42	2.93	2.45	1.96	1.47	0.98	0.49	.00
Net taxable income	0.00	0.00	0.00	-18.28	-20.19	-15.84	-13.05	-10.06	29.70	33.13	36.61	40.76	45.01	49.57	54.48	59.77	65.46	71.60	39.11
Cumulative taxable income	0.00	0.00	0.00	-18.28	-38.48	-54.32	-67.37	-77.44	-47.73	-14.60	22.21	62.98	107.98	157.56	212.04	271.81	337.27	408.87	447.98
Tax basis	0.00	0.00	0.00	-18.28	-38.48	-54.32	-67.37	-77.44	-47.73	-14.60	22.21	40.76	45.01	49.57	54.48	59.77	65.46	71.60	39.11
Tax payable before credits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	18.34	20.25	22.31	24.52	26.90	29.46	32.22	17.60
Tax credit remaining	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax actually paid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.93	20.25	22.31	24.52	26.90	29.46	32.22	17.60
Construction cash flow		-44.55	-47.30	-25.05															
Operations cash flow	0.00	0.00	0.00	-2.55	14.35	16.96	19.76	22.74	25.94	29.37	[illegible]	26.08	20.99	23.50	26.20	29.11	32.24	35.62	50.50
OVERALL CASH FLOW (Single) IRR 15%	0.00	-44.55	47.30	-27.60	14.35	16.96	19.76	22.74	25.94	29.37	33.65	26.06	20.99	23.50	26.20	29.11	32.24	35.62	50.50

		Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Net taxable income		0.00	0.00	0.00	-18.28	-20.19	-15.84	-13.05	-10.06	29.70	33.13	36.61	40.76	45.01	49.57	54.48	59.77	65.46	71.60	39.11
Tax payable before credits	45%	0.00	0.00	0.00	-8.23	-9.09	-7.13	-5.87	-4.53	13.37	14.91	16.57	18.34	20.25	22.31	24.52	26.90	29.46	32.22	17.60
Tax credit		0.00	0.00	0.00	17.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax actually paid		0.00	0.00	0.00	-25.64	-9.09	-7.13	-5.87	-4.53	13.37	14.91	16.57	18.34	20.25	22.31	24.52	26.90	29.46	32.22	17.60
Construction cash flow		0.00	-44.55	-47.30	-25.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations cash flow		0.00	0.00	0.00	23.10	23.44	24.09	25.63	27.27	12.58	14.46	16.49	18.66	20.99	23.50	26.20	29.11	32.24	35.62	50.50
OVERALL CASH FLOW (Mult 3/1) IRR 16%		0.00	-44.55	-47.30	-1.96	23.44	24.09	25.63	27.27	12.58	14.46	16.49	18.66	20.99	23.50	26.20	29.11	32.24	35.62	[illegible]

Cost Data During Construction

Notes:

(1) Monthly Drawdown - Funds to cover construction, land, tax, and interest payments are paid in equal amounts each month throughout the construction phase.

(2) Tax Credits - Tax credits allowed are taken as 10% investment tax credit plus 10% business energy credit, the percentage being of the total depreciable investment.

(3) The Badger Analysis has been conducted using 100% equity.

(4) Cost Data During Construction - Covers all costs including interest on loans for construction and land purchase incurred during the construction phase which can be capitalized. If construction ends sometime during a year, the proportion of interest charges incurred in the fraction of the year representing the end of the construction phase can be capitalized.

(5) Costs of Plant - Covers depreciable investment in plant and equipment including capitalized interest on loans.

(6) Costs of Land - Land is nondepreciable.

SENT E-0461

BADGER

Date: 20-Sep-84

COST DATA DURING CONSTRUCTION

Overall by year

1985	1986	1987	Sum	
				COSTS OF PLANT
43.80	47.30	25.05	116.15	Drawdown on equity
18.77	20.27	10.74	49.78	Drawdown on loan
				Cumulative loan
1.31	3.85	2.94	8.10	Interest on loan
63.87	71.42	38.73	174.03	subtotal
				COSTS OF LAND
0.76	0.00	0.00	0.76	Land equity
0.32	0.00	0.00	0.32	Loan for land
0.04	0.04	0.02	0.11	Interest on land loan
1.12	0.04	0.02	1.19	subtotal
65.00	71.47	38.75	175.22	Total investment

Month Date:	Jan-84	Feb-84	Mar-84	Apr-84	May-84	Jun-84	Jul-84	Aug-84	Sep-84
Month No. :	-12	-11	-10	-9	-8	-7	-6	-5	-4
Inflation + Escalation	1.00	1.01	1.01	1.02	1.03	1.03	1.04	1.05	1.05
COSTS OF PLANT									
Drawdown on equity									
Drawdown on loan									
Cumulative loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Month Date:	Oct-84	Nov-84	Dec-84	Jan-85	Jan-85	Mar-85	Apr-85	May-85
Month No. :	-3	-2	-1	0	1	2	3	4
Inflation + Escalation	1.06	1.07	1.07	1.08	1.09	1.09	1.10	1.11
COSTS OF PLANT								
Drawdown on equity				3.52	3.55	3.57	3.59	3.61
Drawdown on loan				1.51	1.52	1.53	1.54	1.55
Cumulative loan	0.00	0.00	0.00	1.51	3.03	4.56	6.10	7.65
Interest on loan	0.00	0.00	0.00	0.02	0.03	0.05	0.07	0.08
COSTS OF LAND								
Land equity				0.76				
Loan for land				0.32				
Interest on land loan				.00	.00	.00	.00	.00
				0.02	0.04	0.05	0.07	0.09

Drawdown on equity		116.15
Drawdown on loan		49.78
Interest for plant		8.10
Interest for land		0.11
TOTAL DEPRECIABLE INVESTMENT	MM$:	174.14
Maximum TAX CREDIT at 10%	MM$:	17.41
Drawdown on loan		49.78
Interest on loan		8.10
Loan for land		0.32
Interest on land loan		0.11
TOTAL CONSTRUCTION DEBT		58.31

SERI E-0461

BADGER

Date: 20-Sep-84

Jun-85 5	Jul-85 6	Aug-85 7	Sep-85 8	Oct-85 9	Nov-85 10	Dec-85 11	Jan-86 12	Jan-86 13	Mar-86 14	Apr-86 15	May-86 16	Jun-86 17
1.12	1.12	1.13	1.14	1.14	1.15	1.16	1.17	1.17	1.18	1.19	1.20	1.20
3.64	3.66	3.68	3.71	3.73	3.76	3.78	3.80	3.83	3.85	3.88	3.90	3.93
1.56	1.57	1.58	1.59	1.60	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68
9.20	10.77	12.35	13.94	15.54	17.15	18.77	20.40	22.04	23.69	25.36	27.03	28.71
0.10	0.12	0.13	0.15	0.17	0.19	0.20	0.22	0.24	0.26	0.27	0.29	0.31
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0.10	0.12	0.14	0.15	0.17	0.19	0.21	0.22	0.24	0.26	0.28	0.30	0.31

Jul-86 18	Aug-86 19	Sep-86 20	Oct-86 21	Nov-86 22	Dec-86 23	Jan-87 24	Feb-87 25	Mar-87 26	Apr-87 27	May-87 28	Jun-87 29
1.21	1.22	1.23	1.24	1.24	1.25	1.26	1.27	1.28	1.28	1.29	1.30
3.95	3.98	4.00	4.03	4.06	4.08	4.11	4.14	4.16	4.19	4.22	4.24
1.69	1.71	1.72	1.73	1.74	1.75	1.76	1.77	1.78	1.80	1.81	1.82
30.41	32.11	33.83	35.55	37.29	39.04	40.80	42.58	44.36	46.15	47.96	49.78
0.33	0.35	0.37	0.39	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0.33	0.35	0.37	0.39	0.41	0.43	0.45	0.46	0.48	0.50	0.52	0.54

A summary of the SERI based economic calculations is given in the following pages.

SERI ECONOMIC PARAMETERS

Raw Data

Calculation Summary
and
Sensitivity Analyses
(Base Case)

SERI E-0?at P A D D L E R Date: 20-Sep-84

CONSTRUCTION RELATED DATA: Jan 84	Unit	amount
Base year for Constant Dollars	date	Jan 84
Construction schedule	months	[illegible]
Starting date	date	Jan 85
Estimated capital costs	$MM	139.70
Land cost	$MM	1.00
Interest during construction	%	13.0
Investment tax credit	%	10.0
Other tax credits		
- Business Energy	%	0.0
	%	0.0
	%	0.0
[illegible]	%	[illegible]
[illegible]		[illegible]
[illegible]	%	[illegible]
Escalation on capital	%	1.0
Monthly compounding	%	1.0024

OPERATING RELATED COSTS:	Unit	amount
Inflation rate	%	7.0
Escalation on operating costs	%	1.5
Interest during plant operation	%	13.0
Working capital	$MM	0.50
Tax rate	%	45.0
Salvage % at end of operation period	%	0.0

Product Sales	MM$/Yr:	[illegible]
Raw materials	MM$/Yr:	[illegible]
Operating expenses	MM$/Yr:	1?.44
Gross income, 1984 basis		[illegible]

		Unit	Capacity, Units /Year	Unit price $/Unit	Yearly costs MM$/yr
Product	ethanol	MMgal.	[illegible]	[illegible]	[illegible]
	furfural	MMlbs	[illegible]	0.15	19.5?
	electricity	MMkWh	[illegible]	[illegible]	[illegible]
	landfill	metr tons	[illegible]	[illegible]	0.35
Raw materials	wood chips	metr tons	5?? 000	4?.00	24.40
	sulfuric acid	metr tons	[illegible]	65.00	1.10
	lime	metr tons	[illegible]	35.00	0.64
	other cats & chems	$/yr	[illegible]		[illegible]
	diesel oil	[illegible]	[illegible]	1.00	[illegible]
	gasoline	MMgals	1.31	[illegible]	1.11
Operating costs	labor	MM$/yr	1.40		1.40
	supervision	MM$/yr	0.06		0.06
	direct overhead	%	40	lab+supvn	0.62
	maintenance	%	4	capital	5.59
				subtotal	7.75
	selling G & A	%	60	[illegible]	4.6?
	taxes & insur.	%	2	[illegible]	[illegible]
	royalty	$/yr	250000		0.25

INTERNAL RATE OF RETURN ON EQUITY, for the REFERENCE conditions as a % : 15% for a Single Venture business structure. 10% for a Multiple Venture business structure.

SENSITIVITY ANALYSIS:

IRR	15%	Cost of wood chips in $/metric ton. (in U44) 35	40	42	44	47	52
Selling	0.70	4%	2%	5%	-9%	-16%	-37%
price	1.00	13%	10%	8%	7%	5%	1%
of	1.23	18%	16%	15%	14%	12%	9%
Ethanol	1.50	24%	22%	21%	20%	18%	16%
(in U37)	1.80	30%	28%	27%	[illegible]	[illegible]	[illegible]
$/US Gal	2.20	36%	35%	34%	33%	[illegible]	[illegible]

IRR	15%	Capital costs in MM$. (in N6) 100	120	140	150	170	200
Selling	0.70	6%	1%	5%	-8%	17%	35%
price	1.00	17%	12%	8%	7%	4%	2%
of	1.23	24%	19%	15%	13%	9%	5%
Ethanol	1.50	31%	25%	21%	19%	15%	11%
(in U37)	1.80	37%	32%	27%	25%	21%	17%
$/US Gal	2.20	44%	39%	34%	32%	28%	23%

Capital cost (in N6)	IRR
	15%
100.00	24%
120.00	19%
137.78	16%
150.00	13%
170.00	9%
200.00	5%

Furfural unit price (in D40)	IRR
	15%
0.10	8%
0.12	11%
0.15	15%
0.17	17%
0.20	20%
0.30	30%

Own money, % (in N14)	IRR
	15%
50	17%
60	16%
70	15%
80	14%
90	14%
100	13%

Working capital (in N20)	IRR
	15%
1.0	15%
8.5	15%
15.0	14%

Electricity, $/MWhr (in D41)	IRR
	15%
30.00	11%
50.00	15%
100.00	[illegible]

Inflation, % (in H17)	IRR
	15%
0	7%
7	15%
15	[illegible]

Sensitivity of IRR versus:	Unit	Cost/ Unit	Relative index	
Cost of wood chips	$/mton	42.00	(6.86)	! -------
Selling price of ethanol	$/MMGal	1.23	13.91	! *********
Capital costs	MM$	137.78	(11.23)	! *********
Equity	%	70.00	(1.67)	! -
Furfural unit price	$/MMlbs	0.15	7.00	! +++++++
Working capital	MM$	8.50	(0.21)	! -
Electricity	$/MWhr	50.00	3.33	! +++
Inflation	%/Yr	8.50	3.28	! +++

SERI E-0461 BADGER Date: 25-Sep-84

PLANT OPERATING COST DATA

Year Starts	Jan-84	Jan-85	Jan-86	Jan-87	Jan-88	Jan-89	Jan-90	Jan-91	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96	Jan-97	Jan-98	Jan-99	Jan-2000	Jan-2001	Jan-2002
Year No. :	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plant availability	0%	0%	0%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%
Stream factor	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Inflation + Escalation, effect on operating costs	1.00	1.09	1.18	1.28	1.39	1.50	1.63	1.77	1.92	2.08	2.26	2.45	2.66	2.89	3.13	3.40	3.69	4.00	4.34
Product sales	0.00	0.00	0.00	39.82	86.42	93.76	101.73	110.38	119.76	129.94	140.99	152.97	165.97	180.08	195.39	212.00	230.02	249.57	135.39
Raw material costs	0.00	0.00	0.00	18.11	39.29	42.63	46.26	50.19	54.46	59.08	64.11	69.56	75.47	81.88	88.84	96.39	104.59	113.48	61.56
Gross margin	0.00	0.00	0.00	21.72	47.12	51.13	55.47	60.19	65.31	70.86	76.88	83.42	90.51	98.20	106.55	115.60	125.43	136.09	73.83
Operating costs	0.00	0.00	0.00	9.86	21.40	23.22	25.19	27.33	29.66	32.18	34.91	37.88	41.10	44.59	48.38	52.50	56.96	61.80	33.53
Gross income	0.00	0.00	0.00	11.85	25.72	27.91	30.28	32.86	35.65	38.68	41.97	45.54	49.41	53.61	58.16	63.11	68.47	74.29	40.30
Depreciation %/yr	0	0	0	15	22	21	21	21	0	0	0	0	0	0	0	0	0	0	0
Depreciation $/yr	0.00	0.00	0.00	26.12	38.31	36.57	36.57	36.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Principal paid	0.00	0.00	0.00	1.88	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76
Outstanding debt	0.00	0.00	0.00	56.43	52.67	48.90	45.14	41.38	37.62	33.86	30.09	26.33	22.57	18.81	15.05	11.29	7.52	3.76	.00
Interest paid during plant operation	0.00	0.00	0.00	3.67	6.85	6.36	5.87	5.38	4.89	4.40	3.91	3.42	2.93	2.45	1.96	1.47	0.98	0.49	.00
Net taxable income	0.00	0.00	0.00	-17.93	-19.43	-15.01	-12.15	-9.09	30.76	34.28	38.06	42.11	46.47	51.16	56.21	61.64	67.49	73.80	40.30
Cumulative taxable income	0.00	0.00	0.00	-17.93	-37.37	-52.38	-64.53	-73.62	-42.86	-8.59	29.47	71.58	118.05	169.22	225.42	287.06	354.55	428.35	468.66
Tax basis	0.00	0.00	0.00	-17.93	-37.37	-52.38	-64.53	-73.62	-42.86	-8.59	29.47	42.11	46.47	51.16	56.21	61.64	67.49	73.80	40.30
Tax payable before credits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.26	18.95	20.91	23.02	25.29	27.74	30.37	33.21	18.14
Tax credit remaining	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	17.41	4.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax actually paid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.80	20.91	23.02	25.29	27.74	30.37	33.21	18.14
Construction cash flow		-44.55	-47.30	-25.05															
Operations cash flow	0.00	0.00	0.00	-2.19	15.12	17.79	20.65	23.72	27.00	30.52	34.29	23.55	21.80	24.38	27.15	30.14	33.36	36.83	51.15
OVERALL CASH FLOW (Single) IRR 15.10%	0.00	-44.55	-47.30	-27.25	15.12	17.79	20.65	23.72	27.00	30.52	34.29	23.55	21.80	24.38	27.15	30.14	33.36	36.83	51.15
Net taxable income	0.00	0.00	0.00	-17.93	-19.43	-15.01	-12.15	-9.09	30.76	34.28	38.06	42.11	46.47	51.16	56.21	61.64	67.49	73.80	40.30
Tax payable before credits 45%	0.00	0.00	0.00	-8.07	-8.74	-6.76	-5.47	-4.09	13.84	15.43	17.13	18.95	20.91	23.02	25.29	27.74	30.37	33.21	18.14
Tax credit	0.00	0.00	0.00	17.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax actually paid	0.00	0.00	0.00	-25.48	-8.74	-6.76	-5.47	-4.09	13.84	15.43	17.13	18.95	20.91	23.02	25.29	27.74	30.37	33.21	18.14
Construction cash flow	0.00	-44.55	-47.30	-25.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations cash flow	0.00	0.00	0.00	23.29	23.86	24.55	26.12	27.81	13.16	15.09	17.17	19.40	21.80	24.38	27.15	30.14	33.36	36.83	51.15
OVERALL CASH FLOW (Built JV) IRR 18.04%	0.00	-44.55	-47.30	-1.76	23.86	24.55	26.12	27.81	13.16	15.09	17.17	19.40	21.80	24.38	27.15	30.14	33.36	36.83	51.15

General Estimating Procedure

Basic Capital Cost Estimate

Working with equipment lists, plot plans and specifications, the Badger Estimating Department concluded a factor estimate for a 25 million gallon per year wood chips to ethanol plant. Separate estimates of direct costs were made for each defined area of the plant. The total project summary sheet combines all the direct costs by area, as well as the total direct costs, i.e., engineering and field indirect accounts. A typical worksheet is given in Appendix VII.

The basic factor estimate was accomplished in the following steps:

- Equipment material costs were developed for each piece of equipment using vendor quotation or in-house Badger data. Quotations were obtained for very expensive items and item unique to this type of plant, (example: grinders and chip cleaners).

- Each piece of equipment has been multiplied by an installation factor to arrive at a total direct installed cost of a U.S. Gulf Coast (USGC) basis. Installation factors were applied to the equipment costs to account for the costs of piping and valving, instrumentation and controls, structural steel, electrical, all civil work including foundations, insulation, painting and the like. These factors are determined by utilizing historical Badger data for similar projects.

- By utilizing historical project cost data, the total direct cost has been broken down into material cost, labor cost and labor manhours. Historical data has also been used to break down the total field manhours into direct hire and subcontract manhours.

- Field indirect costs have been established from historical Badger data and based on direct manhours.

- Engineering costs have been based mainly on number of equipment pieces and modified by equipment size, cost, repetition and the like.

Reduced Capacity Plant

An estimate has been made for a reduced capacity plant - 5 million gallon per year. Using equipment lists prepared for this capacity, estimating procedures followed were the same as those used for the base estimate - 25 million gallon per year. In many cases equipment costs were exponentially scaled from the base estimate, rather than based on a separate vendor quote.

Other Costs

In addition to the base estimate cost, allowances were made for the following items: (see Appendix V)

- Departmental Overhead
- General and Administrative Overhead
- Land (Included Separately in Economic Analysis)
- Taxes
- Spare Parts
- Startup Allowance
- Fee
- Plant Transfer from U.S. Gulf Coast to Mid-west
- Contingency (To Arrive at "Most Likely" Estimate Figure)

SERI: 25 Million Gallon Per Year Base Case
Major Items with Basis for Capital Cost

Area	Item Number	Description	Method of Estimating
100	GM-104 A/B/S	Front End Loader	Quote by Caterpillar
	GS-105	Magnetic Clip Cleaner	Quote by Dings Magnetic
	GM-106 A/B	Switch Engines	Quote by Plymouth Locomotive
200	MS-201	Slurry Vessel	Quote by Jayco/Vrieco
	MR-202	Hydrolysis Reactor	Quote by Teledyne/Chung Wah
	MS-203	High Pressure Flash Drum	Office Estimate
	MB-216	Chip Feed Bin	Office Estimate
	PD-201 A/B/S	Hydrolysis Feed Pump	Quote by Worthington
	GG-202 A/B/C	Grinder	Quote by Bauer
	GA-204 A/B	High Pressure Feeder	Quote by Ingersoll Rand
	GC-209	Primary Lignin Centrifuge	Quote by Dorr Oliver
	GC-214	Lignin Centrifuge	Quote by Dorr Oliver
	GC-215	Primary Gypsum Hydroclone	Quote by Bauer
	GF-220	Gypsum Filter	Quote by Bird Centrifuge
	GS-231	Wood Grinds Beet Feeder	Quote ty K-Tron
	GA-224	Lime Mix Tank Agitator	Quote by Lightnin
300	AS-301	Scrubber	Office Estimate
	MR-301 A/B	Fermenter	Office Estimate
	PB-309 A/S	Recycle Blower	Quote by Roots-Dresser
	GZ-312	Yeast Immobilizing Unit	Quote by JGC
400	AS-401	Beer Column	Office Estimate
	AS-402	Rectification Column	Office Estimate
	PC-402	Sugar Stripper Vapor Compressor	Office Estimate
	TT-403 A/B	Beer Column Reboilers	Office Estimate
	TT-413	Feed Preheater	Office Estimate
	GZ-401	Molecular Sieve	Quote by Kemp
500	AS-501	Azeo Column	Office Estimate
	MS-502	Solvent Decanter	Office Estimate
	TY-501	Azeo Column Preheater	Office Estimate

SERI: 25 Million Gallon Per Year Base Case
Major Items with Basis for Capital Cost

Area	Item Number	Description	Method of Estimating
600		Buildings	Office Estimate
		Railroad Spur	Office Estimate
		Roads	Office Estimate
		Fire Loop	Office Estimate
		Tank Dikes	Office Estimate
	MT-607	Fire Water Tank	Office Estimate
700	MT-707	Biotreater	Office Estimate
	PE-704	Evaporation Vacuum System	Office Estimate
	PB-712 A/S	Aeration Blowers	Office Estimate
	GV-708	Secondary Clarifier	Office Estimate
800	HB-801 A/B	Boiler	Quote from Zurn
	GZ-811	Turbogenerator	Quote From Turbodyne
	GT-812	Cooling Tower	Quote from Marley
	HC-803	Biofuel System	Quote from Flakt
	PP-808 A/S	High Pressure Boiler Feed Water Pump	Office Estimate
	PP-812 A-H	Cooling Tower Pumps	Office Estimate
	GV-806	Deaerator	Office Estimate

BADGER

ESTIMATE SUMMARY SHEET

CASE I

GRAND SUMMARY

CLIENT SERI

LOCATION US GULF COAST 2Q84

PLANT 1.0 MM GAL/YR WOOD TO ETHANOL

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	5			56,000		
M	DRUMS, TANKS & REACT.	36			531,300		
P	PUMPS, COMPR., ETC.	63			216,700		
T	HEAT EXCHANGERS	33			305,200		
G	SPECIAL EQUIPMENT	48			503,500		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	185			1,612,700		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS		74,300		3,045,000	1,633,000	4,678,000
	PORTABLE EQUIP/WREHSE SPARES						190,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						845,000
U	HOME OFFICE INCL G & A, OVHD			75,000			3,597,000
	GRAND TOTAL						9,310,000

For exclusions, see overall summary listing.

Excl. G&A, OVHD 8,000,000

E-0461
8/20/84

ESTIMATE SUMMARY SHEET INDEX

JOB NO.: E-0461
DATE: AUG. 20, 1984

SOLAR ENERGY RESEARCH INSTITUTE
PLANT DEFINITION STUDY
WOOD TO ETHANOL: 1.0, 5.0 & 25.0 MM GAL/YR.
COMPILATION OF APPROXIMATE TOTAL COST TO CLIENT

CATEGORY OF COST	CASE I 1.0 MM GPY $MM	CASE II 1.0 MM GPY $MM	BASE 5.0 MM GPY $MM	ALTERNATIVE 5.0 MM GPY $MM	BASE 25.0 MM GPY $MM	ALTERNATIVE 25.0 MM GPY $MM
1. Battery Limit Factor Estimate	8.00	19.83	49.00	40.20	103.40	99.30
2. Overhead @ 50% & G.A. @ 15%	1.31	2.35	4.06	4.02	5.82	5.94
3. Catalyst & Chemicals-incl. w/Item #15						
4. Land allowance, 5 acres	0.10	0.10	0.10	0.10	0.10	0.10
5. Taxes, allow 1½% of Plant Cost	0.17	0.41	0.84	0.66	1.77	1.70
6. Spare Parts 4% [A-B + 2/3(C-B)]	0.10	0.30	0.82	0.65	2.10	1.94
7. Escalation: Basis 10/85 start	1.15	2.80	7.21	5.59	14.57	14.00
8. Royalty w/IGC Fermentation	0.07	0.07	0.25	0.25	0.25	0.25
9. Start-up Allowance	0.35	0.50	0.70	0.70	1.00	1.00
10. Fee	Excl	Excl	Excl	Excl	Excl	Excl
11. Transfer Plant: USGC to Midwest +15%	1.70	3.75	8.43	6.60	17.69	17.00
12. Contingency, nominal +10% + first-of-a-kind +5%	1.50	3.50	8.43	6.60	17.69	17.00
13. Client Costs: 5 men for 1.5 Years	0.70	0.70	0.70	0.70	0.70	0.70
TOTAL	15.15	34.31	80.54	66.07	165.09	158.93
14. Cost Sharing 20.3% (Engr. + Mark-up)	0.71	1.27	2.19	2.17	3.14	3.21
15. Plant Costs/Year - See Financial Section						
- Operating Costs/Year						
- Revenue/Year						
16. Finance Costs (30% equity) 15% interest						
- Thru Start-up, Total	3.50	9.50	24.80	20.34	50.84	48.95
- After Start-up, first year	1.60	3.60	8.45	6.94	17.33	16.70

NOTES:
1. Category #1, Battery Limit Plant, is a factor estimate - a Badger Class IV Estimate with a probable accuracy of ±25%. Based on USGC 2Q84 costs, this estimate excludes all overhead, fee and contingency.
2. Categories #2 through #13 are strictly allowances and may vary considerably based on conditions at time of implementation.
3. Categories #14 through #16 are cost indicators only and are to be used primarily as check-off items for inclusion in overall economics.

BADGER

ESTIMATE SUMMARY SHEET

CASE I

300 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FERMENTATION UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			4,000		
M	DRUMS, TANKS & REACT.	8			96,000		
P	PUMPS, COMPR., ETC.	13			28,000		
T	HEAT EXCHANGERS	3			17,000		
G	SPECIAL EQUIPMENT	10			16,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	35			161,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						545,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE I

400 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT ETHANOL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			11,000		
M	DRUMS, TANKS & REACT.	3			24,000		
P	PUMPS, COMPR., ETC.	3			7,000		
T	HEAT EXCHANGERS	6			52,000		
G	SPECIAL EQUIPMENT	-			-		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	13			94,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						290,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

PRELIMINARY ESTIMATING
TRANSMITTAL FORM
CAPITAL COST ESTIMATE

FILE NO./JOB NO.: E-0461
TRANSMITTAL DATE: 8/20/84 ISSUE II
7/2/84 ISSUE I

REQUESTED BY — DEPT: PROJECT
NAME: H.S. KLEIN

DATE REQUESTED: 6/11/84

CLIENT : SERI
PLANT TYPE : WOOD TO ALCOHOL DEMONSTRATION UNIT
CAPACITY : 1.0, 5.0 & 25.0 MM GPY OF ALCOHOL
SITE LOCATION : USGC

PERSONNEL
SALES: E.J. Whitehead
PROCESS: S.W. Fitzpatrick
PROJECT: H.S. Klein
ESTIMATE MADE BY: M.W. Brinker [signature] II
APPROVED BY: [signature] II [signature] I [signature] II

ESTIMATE FOR:	MMS	ACCURACY
See Attachments		± %
		± %
		± %
		± %
TOTAL (A-Z) M+L + OVHD @ 0 %		± %

CCE BASIS

INSTANTANEOUS COSTS AS PER 2 QRT. 1984

PRODUCTIVITY 90 %

___ JOB SITE

X USGC/HOUSTON

EXCLUSIONS FROM CAPITAL COST
OVERHEAD, G & A
FUTURE ESCALATION
TAXES
SPARE PARTS
CATALYST & CHEMICALS
START-UP
CONTINGENCY
ROYALTY
FEE

ESTIMATING APPROACH:

- ___ CAPACITY VS. CAPITAL COST CURVE BY PROCESS UNIT
- ___ EXPONENTIAL CAPACITY/COST ADJUSTMENT OF PREVIOUS PROJECT
- ___ ESCALATE PREVIOUS PROJECT COSTS ON AN OVERALL BASIS
- X FACTOR ESTIMATE, BASED ON OFFICE ESTIMATED EQUIPMENT
- ___ FACTOR ESTIMATE, WITH QUOTES FOR MAJOR EQUIPMENT ITEMS
- X OTHER: ALLOWANCES FOR BELOW-THE-LINE CLIENT ITEMS

SCOPE:

- X ONSITES
- ___ UTILITIES
- ___ TANKAGE
- ___ WASTE TREATMENT
- X OTHER SUCH AS: ALL OTHER CLIENT COSTS (BELOW-THE-LINE)

COMMENTS:

ISSUE I — Capital cost estimates for this 1.0 MM demonstration unit have been made for Case I a minimum core/cost unit and Case II, a maximized scope/cost unit w/utilities (and, hence, having a low operating cost). These 2 cases represent an optimistic (Case I) versus a pessimistic (Case II) approach.

ISSUE II — Capital Cost estimates have been made for 2 commercial units - 5.0 & 25.0 MM GPY of alcohol. Additionally, an alternate for each capacity has been estimated. Below-the-line costs for each capacity, as well as that of Issue I, are shown on an attached table.

PURPOSE: Preliminary EAD for initiation of U.S. Government's appropriation study.

DISTRIBUTION (Excluding Summary Sheets)
RD/DSM
FPF
EMH
JWK
SALES/PROCESS/PROJECT AS INDICATED ABOVE

JOB NO.: 0461
DATE: AUG. 20, 1984

SOLAR ENERGY R[illegible]ARCH INSTITUTE
COMMERCIAL PLAN. DEFINITION STUDY
WOOD TO ETHANOL: 1.0, 5.0 & 25.0 MM GAL/YR.
BATTERY LIMIT FACTOR ESTIMATE

	CASE I 1.0 MM GPY	CASE II 1.0 MM GPY	BASE 5.0 MM GPY	ALTERNATE 5.0 MM GPY	BASE 25.0 MM GPY	ALTERNATE 25.0 MM GPY
• Estimated Plant Cost, USGC 2Q84, A-Z Total Plant excluding: . Overhead . G & A . Future Escalation . Taxes . Spare Parts . Catalyst & Chemicals . Start-up . Contingency . Royalty . Fee	$ 8.0 MM	$ 19.83 MM	$ 49.0 MM	$ 40.2 MM	$ 103.4 MM	$ 99.3 MM
• Ethylalcohol produced MM GPY	1.0	1.0	5.0	5.0	25.0	25.0
• By-product furfural produced MM LBS/YR	5.2	5.2	26.0	26.0	130.3	85.0
• Export electricity produced KWH/YR	None	7.0	35.2	None	176.0	None
• Wood processed - dry basis- Metric Tons/Day	72	72	354	354	1,771	1,584

SCOPE:

- Case I - Demonstration Unit, 1.0 MM GPY of ethanol, minimum scope/cost (from Issue I). Core ISBL w/no electricity.
- Case II - Demonstration Unit, 1.0 MM GPY of ethanol, maximized scope/cost (from Issue I). Export electricity produced.
- Base Commercial Unit, 5.0 MM GPY of ethanol, with export electricity produced.
- Alternate Commercial Unit, 5.0 MM GPY of ethanol, with no electricity produced.
- Base Commercial Unit, 25.0 MM GPY of ethanol, with export electricity produced.
- Alternate Commerical Unit, 25.0 MM GPY of ethanol, including second step hydrolysis reactor and no export electricity.

BADGER

ESTIMATE SUMMARY SHEET

CASE I

100 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FEED UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.						
P	PUMPS, COMPR., ETC.						
T	HEAT EXCHANGERS						
G	SPECIAL EQUIPMENT	4			38,000		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	4			38,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						88,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

+ Portable Equipment 100,000

BADGER

ESTIMATE SUMMARY SHEET

CASE I

200 AREA

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

PLANT ACID HYDROLYSIS UNIT

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		[signature]	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			17,000		
M	DRUMS, TANKS & REACT.	17			283,000		
P	PUMPS, COMPR., ETC.	35			161,000		
T	HEAT EXCHANGERS	13			159,000		
G	SPECIAL EQUIPMENT	32			300,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	98			920,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						2,575,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE I

500 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FURFURAL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			24,000		
M	DRUMS, TANKS & REACT.	2			17,000		
P	PUMPS, COMPR., ETC.	6			8,000		
T	HEAT EXCHANGERS	8			48,000		
G	SPECIAL EQUIPMENT	-			-		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	18			97,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						
							270,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING			-			
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE I

600 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT TANKAGE BUILDING

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.	4			70,000		
P	PUMPS, COMPR., ETC.	4			10,500		
T	HEAT EXCHANGERS	1			8,000		
G	SPECIAL EQUIPMENT	1			500		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	10			89,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL ACCOUNTS						300,000
	ALLOW FOR BUILDING						60,000
	TOTAL (A-T) ACCOUNTS						360,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE I

700 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT ENVIRONMENTAL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		[illegible]	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.	2			41,300		
P	PUMPS, COMPR., ETC.	2			2,200		
T	HEAT EXCHANGERS	2			21,200		
G	SPECIAL EQUIPMENT	1			149,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	7			213,700		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						550,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

GRAND SUMMARY

GRASS ROOT PLANT

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

PLANT 1.0 MM GAL/YR WOOD TO ETHANOL

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	6			66,500		
M	DRUMS, TANKS & REACT.	60			856,200		
P	PUMPS, COMPR., ETC.	98			513,500		
T	HEAT EXCHANGERS	38			316,000		
G	SPECIAL EQUIPMENT	73			2,857,000		
H	HEATERS & STACKS	1			40,000		
	TOTAL EQUIPMENT (A-H)	276			4,649,200		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS		220,600		8,604,000	4,596,000	13,200,000
	PORT. EQ./WHS SPRS/LAB EQ.						290,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						2,300,000
	HOME OFFICE INCL G&A, OVHD			133,000			6,390,000
	GRAND TOTAL						22,180,000

For exclusions, see overall summary listing. Excl. G&A, OVHD 19,830,000

BADGER

ESTIMATE SUMMARY SHEET

CASE II

100 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FEED UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.						
P	PUMPS, COMPR., ETC.						
T	HEAT EXCHANGERS						
G	SPECIAL EQUIPMENT	5			46,000		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	5			46,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						100,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

+ Portable Equipment 100,000

BADGER

ESTIMATE SUMMARY SHEET

CASE II

200 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT ACID HYDROLYSIS UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			17,000		
M	DRUMS, TANKS & REACT.	17			283,000		
P	PUMPS, COMPR., ETC.	35			161,000		
T	HEAT EXCHANGERS	13			159,000		
G	SPECIAL EQUIPMENT	32			300,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	98			920,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						2,575,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

300 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FERMENTATION UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			4,000		
M	DRUMS, TANKS & REACT.	8			96,000		
P	PUMPS, COMPR., ETC.	13			28,000		
T	HEAT EXCHANGERS	3			17,000		
G	SPECIAL EQUIPMENT	11			26,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	36			171,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						
							570,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

Laboratory Equipment 100,000

BADGER

ESTIMATE SUMMARY SHEET

CASE II

400 AREA

CLIENT SERI

LOCATION USCG, 2084

PLANT ETHANOL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			21,500		
M	DRUMS, TANKS & REACT.	6			28,600		
P	PUMPS, COMPR., ETC.	8			15,500		
T	HEAT EXCHANGERS	10			63,000		
G	SPECIAL EQUIPMENT	1			500,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	27			628,600		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						1,200,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

500 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT FURFURAL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			24,000		
M	DRUMS, TANKS & REACT.	2			17,000		
P	PUMPS, COMPR., ETC.	6			8,000		
T	HEAT EXCHANGERS	8			48,000		
G	SPECIAL EQUIPMENT						
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	18			97,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						
							270,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

600 AREA

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2084

PLANT TANKAGE BUILDING

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.	11			177,600		
P	PUMPS, COMPR., ETC.	11			25,000		
T	HEAT EXCHANGERS	1			6,000		
G	SPECIAL EQUIPMENT	2			1,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	25			209,600		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL ACCOUNTS						800,000
	BUILDINGS/ROADS						830,000
	TOTAL (A-T) ACCOUNTS						1,630,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

700 AREA

CLIENT SERI

LOCATION USGC, 2084

PLANT ENVIRONMENTAL UNIT

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.	9			189,000		
P	PUMPS, COMPR., ETC.	13			53,000		
T	HEAT EXCHANGERS	3			23,000		
G	SPECIAL EQUIPMENT	9			271,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	34			536,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						1,655,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

800 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT UTILITIES

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.	7			65,000		
P	PUMPS, COMPR., ETC.	12			223,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	10			318,000		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	29			606,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						1,700,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

800 AREA

CLIENT SERI

LOCATION USGC, 2084

PLANT BOILERS, HB-801 A/B

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.						
P	PUMPS, COMPR., ETC.						
T	HEAT EXCHANGERS						
G	SPECIAL EQUIPMENT	2			1,070,000		
H	HEATERS & STACKS	1			40,000		
	TOTAL EQUIPMENT (A-H)	3			1,110,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						2,800,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

CASE II

800 AREA

CLIENT SERI

LOCATION USGC, 2Q84

PLANT TURBOGENERATOR GZ-811

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	6/26/84	MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.						
P	PUMPS, COMPR., ETC.						
T	HEAT EXCHANGERS						
G	SPECIAL EQUIPMENT	1			325,000		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	1			325,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						700,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

TOTAL PLANT
GRAND SUMMARY
(AREAS 100 THRU 800)

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 5 MM GAL/YR OF ETHANOL

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	6			272,000		
M	DRUMS, TANKS & REACT.	72			1,811,200		
P	PUMPS, COMPR., ETC.	176			1,580,900		
T	HEAT EXCHANGERS	42			1,637,300		
G	SPECIAL EQUIPMENT	83			6,652,600		
H	HEATERS & STACKS	2			2,900,000		
	TOTAL EQUIPMENT (A-H)	381			14,854,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS				24,420,000	12,440,000	36,860,000
	PORTABLE EQ. & LAB EQUIP.				290,000	-	290,000
	TOTAL (A-T) ACCOUNTS		520,000		24,710,000	12,440,000	37,150,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						5,100,000
U	HOME OFFICE (EXCL. G & A + OVHD)			230,000			6,750,000
	GRAND TOTAL						49,000,000

For exclusions, see overall summary listing.

BADGER

ESTIMATE SUMMARY SHEET

AREA 100

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84		
		[illegible]	

PLANT 5 MM GAL/YR OF ETHANOL FEED UNIT

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS						
M	DRUMS, TANKS & REACT.						
P	PUMPS, COMPR., ETC.	1			3,000		
T	HEAT EXCHANGERS						
G	SPECIAL EQUIPMENT	7			93,000		
H	HEATERS & STACKS						
	TOTAL EQUIPMENT (A-H)	8			96,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						200,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

Portable Equip. 190,000

BADGER

ESTIMATE SUMMARY SHEET

AREA 300

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		Pmc...	

PLANT 5 MM GAL/YR OF ETHANOL

FERMENTATION UNIT

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			18,000		
M	DRUMS, TANKS & REACT.	10			240,000		
P	PUMPS, COMPR., ETC.	28			300,000		
T	HEAT EXCHANGERS	3			90,000		
G	SPECIAL EQUIPMENT	13			180,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	55			828,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						2,110,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

Laboratory Equip. 100,000

BADGER

ESTIMATE SUMMARY SHEET

AREA 400

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 5 MM GAL/YR OF ETHANOL

ETHANOL UNIT

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			94,000		
M	DRUMS, TANKS & REACT.	6			44,000		
P	PUMPS, COMPR., ETC.	17			302,000		
T	HEAT EXCHANGERS	10			310,000		
G	SPECIAL EQUIPMENT	1			950,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	36			1,700,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						3,100,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 500

CLIENT SERI

LOCATION USGC, 2Q84

PLANT 5 MM GAL/YR OF ETHANOL FURFURAL

BASE CASE

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			95,000		
M	DRUMS, TANKS & REACT.	2			37,000		
P	PUMPS, COMPR., ETC.	12			13,000		
T	HEAT EXCHANGERS	8			215,000		
G	SPECIAL EQUIPMENT	-			-		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	24			360,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						970,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 600

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 5 MM GAL/YR OF ETHANOL BASE CASE

TANK STORAGE & BUILDINGS

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	12			430,000		
P	PUMPS, COMPR., ETC.	22			29,000		
T	HEAT EXCHANGERS	1			19,000		
G	SPECIAL EQUIPMENT	2			2,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	37			480,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS						1,300,000
	BUILDINGS & ROADS						1,600,000
	TOTAL (A-T) ACCOUNTS						2,900,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 700

CLIENT SERI

LOCATION USGC, 2Q84

PLANT 5 MM GAL/YR OF ETHANOL ENVIRONMENTAL

BASE CASE

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB/S	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	10			290,200		
P	PUMPS, COMPR., ETC.	29			150,900		
T	HEAT EXCHANGERS	7			473,300		
G	SPECIAL EQUIPMENT	12			241,600		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	58			1,156,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL		-				
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						3,140,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 800

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 5 MM GAL/YR OF ETHANOL INCL. BOILERS, FLAKT UNIT, TURBO GENERATOR AND OTHER UTILITIES

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	7			83,000		
P	PUMPS, COMPR., ETC.	21			512,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	16			3,575,000		
H	HEATERS & STACKS	2			2,900,000		
	TOTAL EQUIPMENT (A-H)	46			7,070,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						17,340,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

TOTAL PLANT
GRAND SUMMARY
(AREAS 100 THRU 800)

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

PLANT 5 MM GAL/YR OF ETHANOL

ALTERNATE CASE

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	6			272,000		
M	DRUMS, TANKS & REACT.	72			1,811,200		
P	PUMPS, COMPR., ETC.	176			1,580,900		
T	HEAT EXCHANGERS	42			1,637,300		
G	SPECIAL EQUIPMENT	82			4,582,600		
H	HEATERS & STACKS	1			1,580,000		
	TOTAL EQUIPMENT (A-H)	379			11,464,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS				19,310,000	9,950,000	29,260,000
	PORTABLE EQ. & LAB EQUIP.				290,000	-	290,000
	TOTAL (A-T) ACCOUNTS		415,000		19,600,000	9,950,000	29,550,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						4,000,000
U	HOME OFFICE (EXCL. G & A + OVHD)			228,000			6,650,000
	GRAND TOTAL						40,200,000

For exclusions, see overall summary listing.

BADGER

ESTIMATE SUMMARY SHEET

AREA 800

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 5 MM GAL/YR OF ETHANOL ALTERNATE CASE

INCL. BOILER, FLAKT UNIT, OTHER UTIL.

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	7			83,000		
P	PUMPS, COMPR., ETC.	21			512,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	15			1,505,000		
H	HEATERS & STACKS	1			1,580,000		
	TOTAL EQUIPMENT (A-H)	44			3,680,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						9,740,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

TOTAL PLANT

GRAND SUMMARY

(AREAS 100 THRU 800)

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2084

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 MM GAL/YR OF ETHANOL

BASE CASE

ACCT.	DESCRIPTION	# PCS	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	6			730,000		
M	DRUMS, TANKS & REACT.	76			3,768,900		
P	PUMPS, COMPR., ETC.	190			3,476,800		
T	HEAT EXCHANGERS	45			4,441,000		
G	SPECIAL EQUIPMENT	105			17,531,700		
H	HEATERS & STACKS	2			10,400,000		
	TOTAL EQUIPMENT (A-H)	424			40,348,400		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS				59,080,000	24,500,000	83,580,000
	PORTABLE EQ. & LAB EQUIP.				600,000	-	600,000
	TOTAL (A-T) ACCOUNTS		1,050	000	59,680,000	24,500,000	84,180,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						9,580,000
U	HOME OFFICE (EXCL. G & A + OVHD)			330,000			9,640,000
	GRAND TOTAL						103,400,000

For exclusions, see overall summary listing.

BADGER

ESTIMATE SUMMARY SHEET

AREA 100

CLIENT SERI

EST. NO. E-0461

LOCATION USCG, 2084

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 MM GAL/YR OF ETHANOL FEED UNIT

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	-			-		
P	PUMPS, COMPR., ETC.	1			3,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	7			194,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	8			197,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						390,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 200

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 MM GAL/YR OF ETHANOL BASE CASE

ACID HYDROLYSIS UNIT

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			193,000		
M	DRUMS, TANKS & REACT.	27			1,475,000		
P	PUMPS, COMPR., ETC.	47			580,000		
T	HEAT EXCHANGERS	13			1,514,000		
G	SPECIAL EQUIPMENT	54			5,034,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	142			8,796,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						17,700,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 300

CLIENT SERI

LOCATION USGC, 2Q84

PLANT 25 MM GAL/YR OF ETHANOL FERMENTATION UNIT

BASE CASE

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	1			45,000		
M	DRUMS, TANKS & REACT.	13			625,000		
P	PUMPS, COMPR., ETC.	32			490,000		
T	HEAT EXCHANGERS	5			230,000		
G	SPECIAL EQUIPMENT	15			478,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	66			1,868,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						4,180,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 400

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 MM GAL/YR OF ETHANOL BASE CASE
ETHANOL UNIT

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			247,000		
M	DRUMS, TANKS & REACT.	6			117,000		
P	PUMPS, COMPR., ETC.	17			797,000		
T	HEAT EXCHANGERS	11			824,000		
G	SPECIAL EQUIPMENT	1			2,500,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	37			4,485,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						7,500,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 500

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 MM GAL/YR OF ETHANOL FURFURAL UNIT BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	2			245,000		
M	DRUMS, TANKS & REACT.	2			99,000		
P	PUMPS, COMPR., ETC.	12			35,000		
T	HEAT EXCHANGERS	8			561,000		
G	SPECIAL EQUIPMENT	-			-		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	24			940,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						
							2,100,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 600

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

PLANT 25 GAL/YR OF ETHANOL BASE CASE

TANK STORAGE & BUILDINGS

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	12			653,000		
P	PUMPS, COMPR., ETC.	22			76,000		
T	HEAT EXCHANGERS	1			50,000		
G	SPECIAL EQUIPMENT	2			7,000		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	37			786,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS						3,180,000
	BLDGS/ROADS/PIPE RACKS						2,000,000
	TOTAL (A-T) ACCOUNTS						5,180,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 700

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

PLANT 25 MM GAL/YR OF ETHANOL BASE CASE

ENVIRONMENTAL UNIT

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	9			615,900		
P	PUMPS, COMPR., ETC.	30			356,800		
T	HEAT EXCHANGERS	7			1,262,000		
G	SPECIAL EQUIPMENT	12			646,700		
H	HEATERS & STACKS	-			-		
	TOTAL EQUIPMENT (A-H)	58			2,871,400		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	TOTAL (C-R) ACCOUNTS						
	TOTAL (A-T) ACCOUNTS						6,830,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

AREA 800

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2Q84

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		[signature]	

PLANT 25 MM GAL/YR OF ETHANOL INCL. BOILERS, FLAKT UNIT, TURBO GENERATOR & OTHER UTILITIES

BASE CASE

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	7			184,000		
P	PUMPS, COMPR., ETC.	29			1,139,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	14			8,682,000		
H	HEATERS & STACKS	2			10,400,000		
	TOTAL EQUIPMENT (A-H)	52			20,405,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS						36,500,000
	BUILDINGS & STRUCTURES						3,200,000
	TOTAL (A-T) ACCOUNTS						39,700,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						

BADGER

ESTIMATE SUMMARY SHEET

TOTAL PLANT

GRAND SUMMARY

(AREAS 100 THRU 800)

CLIENT SERI

LOCATION USGC, 2Q84

PLANT 25 MM GAL/YR OF ETHANOL

ALTERNATE CASE

EST. NO. E-0461

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		MWB	

ACCT.	DESCRIPTION	# PCS.	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	6			730,000		
M	DRUMS, TANKS & REACT.	85			3,949,900		
P	PUMPS, COMPR., ETC.	203			3,604,800		
T	HEAT EXCHANGERS	46			4,484,000		
G	SPECIAL EQUIPMENT	110			15,302,700		
H	HEATERS & STACKS	2			8,870,000		
	TOTAL EQUIPMENT (A-H)	452			36,941,400		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
Q	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS				55,592,000	23,800,000	79,392,000
	PORTABLE EQ. & LAB EQUIP.				600,000	-	600,000
	TOTAL (A-T) ACCOUNTS		1,000,000		56,192,000	23,800,000	79,992,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						9,500,000
U	HOME OFFICE (EXCL. G & A + OVHD)			337,000			9,808,000
	GRAND TOTAL						99,300,000

For exclusions, see overall summary listing.

BADGER

ESTIMATE SUMMARY SHEET

AREA 800

CLIENT SERI

EST. NO. E-0461

LOCATION USGC, 2084

ISSUE	DATE	BY	CHKD.
I	8/15/84	MWB	
		[signature]	

PLANT 25 MM GAL/YR OF ETHANOL ALTERNATE CASE

INCL. BOILERS, FLAKT UNIT, TURBO GENERATOR, & OTHER UTILITIES

ACCT.	DESCRIPTION	# PCS	MANHOURS S/C	MANHOURS DIRECT	MATERIAL $	LABOR $	TOTAL $
A	TOWERS	-			-		
M	DRUMS, TANKS & REACT.	7			184,000		
P	PUMPS, COMPR., ETC.	30			1,081,000		
T	HEAT EXCHANGERS	-			-		
G	SPECIAL EQUIPMENT	14			6,432,000		
H	HEATERS & STACKS	2			8,870,000		
	TOTAL EQUIPMENT (A-H)	53			16,567,000		
C	PIPING						
D	STRUCTURES						
E	ELECTRICAL						
K	INSTRUMENTATION						
F	FIREPROTECTION						
B	BUILDINGS						
J	FOUNDATIONS & EARTHWORK						
O	SEWERS						
S	SITE DEVELOPMENT						
N	INSULATION						
R	PAINTING						
	SUBTOTAL (A-T) ACCOUNTS						31,800,000
	BUILDINGS & STRUCTURES						2,600,000
	TOTAL (A-T) ACCOUNTS						34,400,000
V	INSURANCE & TAXES						
W	OVERSEAS SHIPPING						
	TOTAL V & W ACCOUNTS						
X	TEMPORARY CONSTRUCTION						
Y	FIELD OFFICE						
Z	EQUIP., TOOLS & SUPPLIES						
	TOTAL X, Y, & Z ACCOUNTS						
U	HOME OFFICE						
	GRAND TOTAL						