PDU Final Run Report

NREL/Amoco CRADA Task #2

January 1996

Run number: P951101CF
Dates of run: 11/01/95 to 12/01/95
Feedstock: Corn fiber

1.0 Executive *Summary*

The Process Development Unit (PDU) was operated with a corn fiber feedstock for approximately 30 days using the Amoco Pretreatment Reactor (APR), the .seed fermentation train, fermentation support equipment, and the main 9000-L fermenters, with occasional operation of the distillation and centrifugation systems. The distillation column and centrifuge were operated to provide some experience with these units before Task 3. The run utilized the yeast strain L1400 to ferment glucose to ethanol in the 9000-L fennenters using the simultaneous saccharification and fermentation (SSF) process. The APR and fermentation equipment operated continuously from Nov. 2 through Nov. 22. However, contamination was a problem throughout this run. The fermentation train was shut down on Nov. 22 because of contamination and thoroughly cleaned and resterilized. From Nov. 25 through Dec. 1, the fermentation train was restarted using staged addition of the feeds (i.e., pretreated feedstock, inoculum, CSL, enzyme) in an attempt to identify the source of the contamination.

The APR was operated continuously throughout the 30 day run with only minor shutdowns. The longest shutdown (14 hours) was caused by a problem with the feeder.

Glucose yields remained somewhat constant between 25%—35%, and xylose yields (as total soluble xylose) ranged from 15%—75% throughout the run. All of these concentrations are below the target range for effective pretreatment. Higher yields were obtained when pretreatment severity was increased by increasing the temperature. Carbon balance data on three pretreatment samples were within ± 10% of complete closure, although, individual component carbon balances were more variable. Several tests also proved that phosphoric acid was not an effective acid for pretreating biomass.

Glucose, ethanol, and lactic acid were monitored during operation of the 9000-L ferrnenters. These measurements, along with sterility checks of the broth, confirmed that contaminants were continuously present during the fermentation. Coupled with inadequate pretreatment, this led to low ethanol yields between 10%—23%, and high levels of lactic and acetic acids. Several attempts to control the contamination with heat treatments and antibiotics did not work. Low conversion of the available six-carbon sugars was attributed to inadequate conversion of the starch oligomers. This problem will be solved in future runs by addition of glucoamylase. Additional ethanol production from this extra glucose as well as from the corn screenings should help control the contamination problem by making the yeast healthier.

Many of the objectives for this run were successfully met, such as, reducing operating labor, achieving target residence time and solids levels in the 9000-L fermenters, and steady and uninterrupted operation of the APR. The run served to prove performance and operation of equipment modified during Task 1 and also identify some new and existing problems that still need to be solved (e.g., CSL and enzyme transfer systems). As with the last

run of the PDU, identification and control of contamination became a major concern. With the help of a consultant, several issues were identified that should improve the performance of the fermentation and help in controlling the level of contaminates. The source of the contamination has not been well characterized; such characterization is needed to develop effective control strategies.

2.0 Introduction

The primary purpose of this run was to operate the PDU for at least 10 days to prove sustained mechanical operation of the APR and fermentation equipment, to identify and solve contamination issues, and to obtain mass balance data. Continuous SSF was conducted on pretreated corn fiber in three 9000-L fermenters operated in series. The fermentation used the yeast strain L1400 that was grown in the seed fermentation train using the 20-L, 160-L, and 1450-L fermenters. The APR and fermentation equipment were successfully operated from Nov. 1 through Nov. 22, however, contamination was present during the run. The 9000-L fermenters were then shut down, cleaned and resterilized and systematically restarted to determine the source of the contamination. This work occurred from Nov. 25 through Dec. 2.

2.1 Pilot Plant Configuration

This section provides a brief description of the PDU as background on the overall process. A simplified process flow diagram for the PDU with the APR is shown in Figure 1. The figure shows the overall flow path and equipment in the PDU. Corn fiber is pretreated by the APR and then pumped to the 9000-L fermenters. In the first 9000-L fermenter, pretreated corn fiber is combined with inoculum, cellulase enzyme (from V-321), and corn steep liquor (from V-420). The fermentation microorganism is started in a small shake flask and successively transferred to a larger shake flask, the 20-L fermenter, 160-L fermenters (V-445A/B), 1450-L fermenters (V-450A/B), and finally to the seed hold tanks (V-465A/B) to await addition to the first 9000-L fermenter. Once the first 9000-L fermenter in the train (V-455A) is filled, fermentation broth is pumped from V-455A to the next 9000-L fermenter (V-455B) in the train. Each of the remaining 9000-L fermenters (V-455C and V-455D) receives feed from the preceding fermenter. Level in each fermenter is controlled to maintain a desired residence time. Exhaust gas from the fermenters is sent to a scrubber (T-460) to remove volatile organics and odors. The beer well (V-510) receives and holds spent fermentation broth from the last fermenter (V-455D). The fourth 9000-L fermenter was not used during this run.

Fermentation broth in the beer well can be pumped to either the neutralization tank (V-602) for pH adjustment and then disposal, or pumped to the distillation column (T-501) for removal of the ethanol. Partially purified ethanol from the column is condensed and sent to the ethanol storage tank (V-506). The stream from the bottom of the column is cooled (in E-506) and sent to a feed tank (V-601). This material is then pumped to the centrifuge (FF-610) to remove the remaining solids, which drops into the cake tank (V-611). The solids are then sent to disposal through V-602. The liquid fraction from the centrifuge is collected in the centrate tank (V-610); this liquid can then be sent to disposal (through V-611 and V-602) or to the sterilization tank (V-256). Sterilized liquid is held in a feed tank (V-257) and can be used as make-up water for the process. The distillation system and the centrifuge were briefly tested with spent fermentation broth during this run. Normally spent fermentation broth was sent directly to the neutralization tank for disposal. The recycle water system was not used during this run.

3.0 Pilot Plant Operations

Operation of the pilot plant began on Nov. 1 and continued until Dec. 2 and utilized the APR, fermentation, distillation, and centrifugation equipment. Operating conditions were decided before the run and are presented in subsequent sections. Additionally, a run history and significant operational notes are presented.

3.1 Procedures and Operating Conditions

3.1.1 Feed Handling/Pretreatment Operating Conditions

Corn fiber was obtained from a corn wet-milling facility (Casco, Canada), frozen and shipped to the PDU in 55-gal drums in a refrigerated trailer. Table I shows the operating conditions at each APR sample point for this run. Raw corn fiber dry solids concentration varied from 39%— 41%. The APR was fed at a constant rate of 170 wet lb/h (82 kg/h). Adjustments were made in the steam flow rate, valve water flow rate and temperature as shown in Table 1 to obtain better conversion to monomeric sugars. The flow rate of a sulfuric acid solution was maintained nearly constant throughout the run. On Nov. 23, the acid was switched from sulfuric to phosphoric and switched back to sulfuric on Nov. 25.

3.1.2 Fermentation Operating Conditions

Operating conditions for the seed train are shown in Table 2. L1400 was grown by successive transfers from a small shake flask to a larger shake flask, and then to the 20-L, 160-L, and 1450-L fermenters, respectively. There was no pH control in the shake flask. pH was controlled at 5 with 3.0 molar NaOH in the 20-L and 160-L fermenters and with 50% NaOH in the 1450-L fermenter. Inoculum from the 1450-L fermenter was transferred to the seed hold tanks to await addition to first 9000-L fermenter. The seed tanks were agitated at 50 rpm, maintained at a gauge pressure of 0.33 bar, and cooled with circulating water.

Fermentation conditions in the 9000-L fermenters are also presented in Table 2. Corn steep liquor (CSL) and enzyme additions were made to only the fust 9000-L fermenter. The assumed cellulose concentration in the feed was only 50% of the true value, so the initial enzyme loading was closer to 5 IU/g. When data on the cellulose concentration of the feed was available, after about 7 days into the run, the enzyme loading was corrected to 10 IU/g. A 10% (w/w) inoculum was also added to first 9000-L fermenter from the seed hold tanks. pH was controlled using 50% NaOH. Level was controlled in the 9000-L fermenters to maintain a residence time of 36 h in each vessel. Solids concentrations (as total solids from corn fiber only) were generally 26%—30% after dilution of the pretreated corn fiber by enzyme and inoculum.

3.2 Run History

A time line for this run is shown in Figures 2 and 3. Operation of the APR began at 8:00 on Nov. 2 and the unit continued to feed the first 9000-L fermenter until 10:00 on Nov. 22. The APR again began feeding the fermentation train at 5:00 on Nov. 25 and continued until 7:00 on Dec 1. The APR continued to operate in the intervening period for testing, but did not feed the fermentation train. Minor shutdowns of the APR occurred throughout the run because of frozen feedstock, plugs in the transfer line, and steam blowbacks. A more serious shutdown occurred on Nov. 18 for 14 hours because of a problem with the Doering screw feeder.

Seed train fermenters were operated as shown on the time line. Inoculum was fist prepared in the 20-L fermenter on Nov. 1 and was operated thereafter as needed to maintain a viable seed supply. The 1450-L fernenter was successfully operated in the "draw and fill" mode to provide inoculum to the fist 9000-L fermenter (V-455A). Operation of the first 9000-L fermenter began on Nov. 2 and continued until Nov. 22. The 9000-L fermenters were then shut down, cleaned, and resterilized in preparation for a contamination check run that began on Nov. 25.

The purpose of the contamination check run was to isolate the source of the contamination by sequentially adding feeds to the main fermentation train, allowing sufficient time between additions for a contaminant to grow. The run began on Nov. 25 at 5:00 with filling of the first 9000-L fermenter with pretreated corn fiber. Samples were taken every 6 h and checked for contaminants. After 48 h, CSL was added to the fermenter, followed 36 h later with inoculum and finally 36 h later with enzyme.

Table 2. Fermentation Operating Conditions For Seed Train and 9000-L Fermenters

Operating Condition	Flask #1	Flask #2	20-L	160-L	1450-L	9000-L
Temperature (°C)	30	30	30	30	30	30
Agitation (rpm)	150[a]	150[a]	150	100	75	100-125
pH	5.0	5.0	5.0	5.0	5.0	5.0
Gauge Pressure (bar)	-	-	0.33	0.33	0.33	0.33
Airflow (vvm)	-	-	0.5	0.5	0.25	0.03[b]
Residence Time (h)	8[c]	8[c]	8[c]	12[c]	12[c]	36[d]
Media:						
Glucose (%)	2	2	2	2	2	[e]
Peptone (%)	2	-	-	-	-	-
Yeast Extract (%)	1	-	-	-	-	-
CSL (%)	-	1	1	1	1	1
Antifoam (corn oil, mL/L)	-	-	0.5	0.5	0.5	0.5
Enzyme (IU/g cellulose)	-	-	-	-	-	10

[a] laboratory shaker agitation
[b] air added to maintain a positive pressure in vessels
[c] typical incubation times
[d] per 9000-L vessel
[e] substrate was pretreated corn fiber

3.3 Operational Notes

The following is a discussion of significant operational notes and problems that occurred during this run.

3.3.1 Feed Handling/Pretreatment

One of the more labor intensive activities of this run was handling and storage of the frozen feedstock. Frozen feedstock in drums were received every week and place in an outdoor storage area. Drums were then moved from this storage area onto the plant floor and placed under a tarp and thawed with steam. Once thawed, the drums were lifted to the second level and individually dumped into the APR feed hopper. One person nearly full time was required to keep a ready supply of thawed feedstock. The future addition of a transfer conveyor between the PDU feed system and APR feed hopper will reduce some of the drum handling.

Three corn fiber lots were received and used for this run as follows: Lot 1, Nov. 2—8; Lot 2 Nov. 9—16; and Lot 3, Nov. 16—22. Lot compositions are shown in Table 3. Lot 3 was also used during the contamination check run that occurred from Nov. 25 through Dec 2.

The APR successfully ran for an extended period of time, although there were some minor shutdowns for a variety of reasons. Frozen feed during the early part of the run (Nov. 3) caused a 4 hour shutdown of the APR while the feed was thawed. An internal bolt broke on the variable frequency drive of feed crammer and caused a 1 hour shutdown of the APR on Nov. 5. A 3 hour shutdown occurred on Nov. 10 because of a plug in the transfer line between the APR and the first 9000-L fermenter. This was a recurring problem particularly later

Table 3. Corn Fiber Composition

Lot #	Used in	Source	Moisture (%)	Glucose (%)	Xylose (%)	Gal. (%)	Ara. (%)	Mannose (%)	Lignin (%)	ASL (1) (%)	Ash (%)	Ext. (2) (%)	Starch (3) (%)	Protein (4) (%)	C (%)	H (%)	N (%)	Analysis Source
	P950310CF	Casco	60	33.4	23.7	3.9	15.5	0.1	6.5	3.4	1	-	15.7	-	-	-	-	CAT
1	P950425CF	GTC	57.6	41.6	21.2	7.7	12.8	0	7.8	7.8	0.9	-	24.9	10.4	-	-	-	PDU
2	P950425CF	GTC	54.1	39.9	21.5	7.6	12.2	0	8.5	8.1	0.9	-	25.6	11.6	-	-	-	PDU
1	P951101CF	Casco	61	44.7	13.3	3	12.5	0.3	4.5	2.4	1	12.4	18.4	9.1	48.2	6.8	1.8	CAT
2	P951101CF	Casco	58	35.5	19.8	4	16.1	0	6.2	5	0.9	9.8	12	10	48.8	6.7	1.9	CAT
3	P951101CF	Casco	57	37.4	19.6	4	15.8	0	6.1	5	0.7	9.1	14.5	9.2	48.8	6.8	1.8	CAT

(1) Acid Soluble Lignin
(2) 95% ethanol extraction, extractives include solubilizied protein included in the protein number
(3) starch is also included in the glucose number
(4) Protein calculated from nitrogen content

in the run. Plugs occurred whenever the acid supply system to the APR failed, primarily because of failing control components. Clean out time ranged from 30 minutes to 3 hours, after which the line had to be resterilized for at least 30 minutes.

Other shutdowns that occurred were as follows: An unexplained circuit breaker trip of the pump caused a 2 hour shutdown of the APR on Nov. 16. The APR was shutdown for 14 hours on Nov. 18 because of a problem with the screw feeder. The end shafts were worn which required fabrication of new sleeves. On Nov. 21 at 20:00 a second transfer pump was connected to the discharge of the APR. Adequate pumping could not be obtained because of significant wear in the original pump.

3.3.2 Fermentation

Several issues came to the forefront during this extended run; many were either solved during the run or were addressed at the conclusion of the run. Improvements to the system will be tested during Task 3. Specific fermentation area problems included difficulty in controlling the CSL transfer into the first 9000-L fermenter, difficulties in running at high solids levels (e.g., erratic pH and temperature probe readings), and labor-intensive activities.

The systems designed to transfer inoculum, CSL and enzyme into the first 9000-L fermenter have been in a constant state of improvement since they were first tested in early 1995. During this run, the inoculum transfer system consisting of a MicroMotion flow meter and Baumann control valve, worked extremely well, controlling the feed rate of inoculum to usually within ±10% of the setpoint. The enzyme system, consisting of a MicroPump positive displacement pump and MicroMotion flow meter, performed adequately, although erratic readings from the flow meter made automated control difficult. Deposits of coagulated protein solids were discovered in the transfer line, which probably contributed to the erratic readings. The CSL system with a MicroMotion flow meter and Fisher V-notch ball valve experienced the same flow meter problems as well as dynamic plugging of the valve (i.e., the valve would plug, open up, clear, then close and plug again). The CSL, which is initially 50% solids (but diluted to 9% in the sterilization vessel) had additional proteins coagulate during batch sterilization of the material. A high temperature, short time continuous sterilization system might reduce the coagulation problem. Better control was achieved when the valve and pressure system was replaced by a peristaltic pump about halfway through the run. The erratic readings from the flow meters were thought to have come from either solids or air in the meters; check valves and smaller lines are among the solutions being considered. When bacteria were detected in the enzyme, a 0.22 micron filter was added to the transfer line in an attempt to filter sterilize the enzyme. This proved to be a poor fix; rapid plugging of the filter was a problem throughout the run.

Neutralizing the hydrolyzate in the first fermenter at the start of the run was difficult due to the high level of insoluble solids in the vessel prior to enzyme and inoculum addition. A retractable pH probe installed in the first 9000-L fermenter allows the operator to clear the probe of solids, but it quickly fouls. Keeping the agitation speed high helps to keep both the pH and temperature probes clear. Future designs should locate the pH probe in a position further above the bottom of the tank or in a recirculation line.

A labor intensive task was cleaning the 9000-L fermenters. The hydrolyzate coated the vessel surfaces and was resistant to power washing, and alkaline and acid cleaning. Several cycles of washing were required to clean the tanks using the portable CIP system and they still were not very clean. A skid-mounted system is scheduled to be installed in January 1996. A solid precipitate, identified from earlier runs as sodium carbonate, coated the agitator shaft above the liquid level in all the 9000-L fermenters, but was easily dissolved with water.

The seed train performed extremely well, with a few downtimes caused by failed (cracked diaphragm) or plugged valves or plugged exhaust filters. Excessive foam generated by sterilizing CSL in concentrated form or having too high a level in the fermenter during sterilization, clogged the exhaust filters and caused over pressure in the fermenters. The concentrated CSL in the media used for seed rebatching also caused plugging in the 0.5 in. transfer valve. While the equipment worked well, the current method for bringing up the seed through successive transfers (seed train) proved labor intensive and produced too much inoculum, causing some of it to be dumped or sit for up to 72 hours before being used.

The most serious problem was several unexplained resets of either the data acquisition and control system (DACS) or programmable logic controllers, which resets the valves to their fail positions, eliminates the set points, and resets the PID terms in the control loops to their default values. Because faulty wiring is most likely the problem, finding and fixing it will be a resource (labor and time) intensive task. In the interim, an alarm will be installed to notify the operators that a reset has occurred so that they can reset the control systems immediately. Other problems with the PLCs, such as blown fuses, were a nuisance, but not a long term problem.

The contamination issue, discussed in section 4.3 took up much of the fermentation operator's time, in troubleshooting and putting possible solutions into practice. The 9000-L fermentation train was pasteurized on two occasions in an attempt to control contamination.

3.3.3 Distillation

The distillation system was operated three times during the run, on November 12, 16, and 20. These were the first times in which the distillation system was used to concentrate ethanol and subsequently store it in the ethanol storage tank. The distillation system ran remarkably well the first two times, but was hampered with plugging problems during the third run.

On Nov. 12, approximately 6000 kg of 10 g/L ethanol was distilled. While the system was running steadily, the beer feed rate was controlled at 1360 kg/hr (6 gpm). Steam was sparged into the column at approximately 220 kg/hr producing 78 kg of greater than 50% (m/v) ethanol. Approximately 0.25 g/L ethanol was left in the bottom stream. The DACS ran the column without constant operator interaction. However, the control was not very good. The reflux ratio, reflux temperature, bottoms flow, and ethanol concentration in the distillate varied over wide ranges.

On Nov. 16, another 6000 kg of beer with approximately 10 g/L ethanol was distilled producing 44 kg of concentrated ethanol. The system ran well, except for one instance. Two hours after feed was started to the column, the temperature control on the main condenser stopped working properly. The temperature in the condenser reached 97°C and all of the ethanol evaporated. The problem was caused by changing PID parameters in an attempt to reduce the temperature distribution.

On Nov. 20, approximately 3500 kg of beer was distilled producing 21 L of concentrated ethanol. Plugging in the preheaters caused four switches back and forth between the two preheaters. The bottoms cooler also plugged several times. Plugging was probably caused by the non-ideal feed, which appeared less converted and had larger sized particles.

3.3.4 Centrifugation

The centrifuge was run periodically over the course of the run to further test the feed control valve and determine separation performance. The current control valve, a Fisher V-notch ball type, was not able to control at the desired 3 gpm. On the less digested fermentation broth, the valve would plug, which caused the control loop to open the valve. When the plug cleared, the high flow rate flooded the centrifuge.

The best separation achieved from the centrifuge on this broth was a cake slurry with approximately 34% total solids and a clear effluent with 18% total solids. This was at a minimum back drive speed and fluctuating feed rate due to dynamic plugging of the control valve. The separation will likely be improved once the feed rate control is improved and better digested material is available.

3.3.5 Utilities

Lack of a heated chemical storage facility coupled with improper handling of sodium hydroxide caused the entire starting supply of caustic to freeze. This hampered pH control during the first few days of the run, but was quickly solved. Better communication with the chemical supplier will avoid this type of problem in the future. Obtaining a constant supply of bleach for the scrubber from the NREL stockroom was also a challenge. Another supplier is being sought to handle the PDU's large demand during runs and a larger reservoir for both the scrubber chemicals (caustic and bleach or peroxide) is envisioned.

The utilities, on the whole, were consistent and adequate. The old cooling water (CW) system, slated to be replaced at the conclusion of this run, caused slow cooldowns in the fermenters, but otherwise handled the fermentation load. When both fermentation and distillation was run, the CW pumps went out on overload. By valving off non-essential vessels, distillation was run on a few selected days. The new CW system will be essential for batch deactivations of the recombinant organism.

The deionized water system, used to produce steam for the APR, required frequent recharges of the resin. The system is being expanded to double its original size to reduce recharge frequency.

4.0 Key Results

The following sections presents key results obtained during operation of the pilot plant.

4.1 Pretreatment

The composition of corn fiber used in this run (P951101CF) as well as in earlier runs are shown in Table 3. Note that extractives include some protein solubilized during the extraction process. The composition of Lots 2 and 3 (P951101CF) are very similar. However, Lot 1 taken during startup of the corn wet-milling plant has significantly higher levels of glucose and starch, which may be attributed to inadequate starch hydrolysis.

A measurement of glucose in the pretreated material with the YSI Glucose Analyzer was implemented during this run to track pretreatment performance. A comparison of YSI and HPLC results are shown in Figure 4 for different operators. At low levels (less than 2.0 g/L), the two techniques do not give comparable values. However, at higher concentrations, the values are generally fairly close. There were a few wide deviations among some of the operators, but training and standardization of the YSI method should increase the reliability of these results. The results do show that the YSI can be used to measure monomeric glucose levels in the pretreated material.

Figure 5 shows sugar production from the APR as a function of run time (time zero is defined as time of inoculation of the first 9000-L fermenter). As indicated on the plot from a run time of -25—50 hours, the APR was operated at a temperature range of. From 50—275 hours, the temperature was During the latter period the stream rate was reduced from 17 kg/h to 10 kgh, but this was also the longest period with nearly constant operating conditions. The temperature was then raised to at 275 hours and held until 375 hours. Operating conditions were more variable during the later part of the run. Data from samples not ran in the analytical laboratory are missing from 360—380 hours. Corn fiber Lot 1 was used from the beginning of the run until 160 hours, thereafter, Lots 2 and 3 with nearly identical compositions were used for the rest of the run.

The steadily decreasing sugar levels during the first part of the run (up to 160 hours) indicate decreasing pretreatment performance.
Another possible contributor is a change in corn fiber composition for lot 1, which could have occurred because of material was obtained during startup of the plant. From 160—270 hours, the performance of the unit was fairly steady with some fluctuations in the total soluble xylose values. The temperature increase at 275 hours increased total soluble xylose as well as monomeric glucose and xylose levels. The reaction temperature was lowered because of a pumping problem between 400—425 hours resulting in lower sugar levels. Additionally, a switch was made to phosphoric acid at 510 hours that also produced lower sugar levels (this will be discussed later).

Figure 6 shows some of the other sugars and acetic acid concentrations in the pretreated material. In general, all these components track with each other with higher levels indicating a more severe pretreatment.

Figures 7 and 8 present glucose and xylose yields (percent of available sugar converted to soluble sugar). As expected, glucose yields are somewhat constant and indicate the conversion of starch to glucose. At more severe pretreatment conditions, there is more glucose perhaps because of complete conversion of the starch and some of the cellulose. Xylose yield varied with the severity of the pretreatment, ranging from 12%— The target conversion of glucose is 55%—60%, which represents all of the starch and some of the cellulose. The target conversion of xylose is 85% minimum. Clearly, pretreatment in this run was inadequate.

The data at 493 hours for a mixed sulfuric/phosphoric acid pretreatment shows a loss in performance when compared to the previous point at the same operating condition. The data at 516 hours is for a phosphoric acid only pretreatment?however, the acid concentration in the feed *tank* was increased to 10% (compared to 6% for sulfuric), the acid flow rate was increased to 50 kg/h (compared to 28 kg/h for sulfuric), and the feed rate was decreased to 61 kg/h (compared to 82 kg/h for sulfuric). All of these changes increase the severity of the pretreatment, but the data shows no dramatic improvement in conversion.

Aspen Plus was used to model the behavior of several acids as shown in Table 4. The three values give the percent acid ionized, hydrogen ion concentration (weight %), and hydrogen ion concentration relative to sulfuric acid at the given temperature. Both sulfuric and nitric acid are well ionized, but both acetic and phosphoric being weak acids do not ionize as well. It was assumed that acetic acid was present in an acidic medium and so the acid did not ionize. Particularly important is the decrease in percent ionization and hydrogen ion concentration at the higher temperature for phosphoric acid. At 220°C, the hydrogen ion concentration for a phosphoric acid solution is only 2% of the comparable sulfuric acid solution, which explains the lack of conversion seen in the above data. Hydrogen ion concentration for sulfuric acid decreases at higher temperatures because the equilibrium shifts to the bisulfate ion. Note that the hydrogen ion concentration is significantly higher in a nitric acid solution when compared to sulfuric acid, particularly at the higher temperature.

Table 4. Ionization and Hydrogen Ion Concentrations of Various Acids at 1.0 Weight Percent

Acid	Temperature (°C)	
	21	220
Acetic	*0.0/ 0.01 0.0	0.01 0.01 0.0
Phosphoric	26.11 0.0761 0.23	1.71 0.0051 0.02
sulfuric	1001 0.3551 1.0	1001 0.2911 1.0
Nitric	1001 0.4531 1.35	98.61 0.4461 1.53

*% Ionization/ H^+ Concentration (wt. %) / H^+ Concentration Relative to H_2SO_4 H^+ Concentration at Temperature

Table 5 shows carbon recovery (carbon as component or component degradation product in outlet stream divided by carbon as component in feed stream) for each of the major sugars and lignin , percent of the solids solubilized, and the xylose yield for three pretreatment samples. The overall balance is within the specifications for this run (± 15%), which occurs because the low glucose balance is compensated for by the high balance on the other components. The best carbon balance data was obtained on the Nov. 17 sample (run time 333 h) when the APR appeared to achieve a steady state and corn fiber Lot 3 was being used. The first two samples were obtained with Lot 1, and as previously mentioned there is some uncertainty in the composition of this material. Also shown are the xylose yields and solids solubilized where higher values indicate greater pretreatment severity. There is no trend of poorer material balance data with extent of hydrolysis. One source of variability in this data was the insoluble solids, which was not rigorously obtained and thus may be a source of error. Correcting this problem and automating flow rate measurements should improve future carbon balances. Also, no significant levels of components were detected in the condensed flash vapor. A colder temperature is probably required to condense some of the more volatile components. All pretreatment data and detailed material balance printouts are shown in the Appendix.

Table 5. Pretreatment Carbon Balance Data

Date Time	11/4/95 14:00	11/6/95 22:00	11/17/95 6:00
Glucose (%)	77.8	66.4	76.9
Galactose (%)	131.2	103.4	99.5
Xylose (%)	150.3	118.9	108.7
Arabinose (%)	113.6	88.9	84.3
Lignin (%)	148.9	168.9	100.3
Overall Carbon Recovery (%)	106.7	93.6	91.4
Solids Solubilized (%)	71.2	53.7	64.1
Xylose Yield (%)	63.8	18.1	61.6

4.2 Fermentations

4.2.1 Seed Train

Table 6 summarizes the cell and ethanol yields from the three seed fermenters. The results are based on YSI numbers. In general, more cells and less ethanol were produced in the 20-L fermenter. In the larger vessels, not as many cells were produced. This indicates a reduction in oxygen available to the yeast. It would be helpful in the future to have the mass spectrometer available for analysis of offgas from the 1450-L fermenters. As we work to improve all aspects of the fermentation process, we will want to improve the cell yields in the seed tanks.

Table 6. Cell and ethanol yields from the 20-L, 160-L and 1450-L fermenters. Run conditions are shown in Table 2.

Fermenter	Cell Yield (g/g)	Ethanol Yield (g/g)
20-L	0.18	0.37
	0.14	0.29
160-L	0.13	0.37
	0.07	0.40
1450-L	0.11	0.34
	0.10	0.36
	0.13	0.33
	0.11	0.46
	0.12	0.37

Since the inoculum was rebatched in the 1450-L fermenters and then held for up to 72 hours, viability was an important assay to perform on the seed. The viability of one batch dropped to 48.5% after a 60-h hold time. A sample was pulled from the seed hold tank and used to inoculate a flask with yeast extract/peptone/dextrose to determine how severe a lag the cells would go through. The yeast had been without glucose for about 36 hours. For comparison, a new yeast culture was started in the laboratory and then transferred to fresh medium to determine if these cells exhibited any lag. Figure 9 shows the difference in growth and glucose consumption between the seed-hold tank yeast and the laboratory grown yeast. The seed-hold tank yeast exhibited a lag when compared to the laboratory yeast, though the lag was only 1—2 h. This lag could increase if the cells are held for longer times in the seed hold tank without glucose. Changes will be considered in the inoculation system to avoid transferring cells in lag phase to the 9000-L fermenter.

4.2.2 SSF

Run objectives dealing with fermentation included running continuously for 10 days with a minimum of 2 days at steady state, no interruptions longer than 6 hours, and the total of all interruptions no longer than 12 hours. It was originally specified that the recombinant organism be used for this run, but problems in obtaining the microbe from Purdue resulted in less than adequate time to test it at the bench scale before the run. The parent strain, L1400, was used instead. Identifying and controlling contamination was also a criteria for the fermentation train and is discussed elsewhere in this report. A minimum of 3 stages were to be run with 24 hours residence time in each and less than 1 h variation in residence time. In addition, at least 25% solids were to be feed to the first fermenter. Mass balance closure was to be within 15%.

In reality, four stages were run in the SSF train, each with pH, temperature, and level control. Data from the fourth fermenter was not permanently recorded. The level in each fermenter was maintained at 36 hours, or about 3900 kg, instead of the 24 hours previously specified due to a low APR throughput. The fermenters were initially started up at 4500 kg to effect better mixing because the second impeller could be used. Once cellulase activity reduced the viscosity of the broth, it could be easily be mixed at the lower level. The data shown in Figure 10 gives temperature and level (weight) in the first 9000-L fermenter, which is similar to data for the other 3 fermenters. Residence time varied less than ±1 h (depicted by the dashed lines on the graph) except for a few spikes caused by either operator error or DACS problems. DACS resets caused the level to increase because the pump would turn off while feed was still entering the fermenter. Downward spikes were usually caused by loss

of feed to the fermenter. The temperature control was also smooth, with the same exceptions. The two temperature spikes at 150 h and 275 h were attempts to control contamination by pasteurizing the fermentation train. Although contaminant concentrations were significantly reduced, shown by the decrease in by-product concentrations, the contaminants were not eliminated.

Total effective solids concentration (total solids concentration of corn fiber components) in the first 9000-L fermenter is shown in Figure 11 and ranged from 24%—33%, staying above 25% except for one dip early in the run, which may have been caused by loss of feed to the fermenter from the APR. Average solids concentration was about 28%.

pH levels in the three 9000-L fermenters, seen on Figures 12—14, exhibited problems primarily at the start of the run, when the broth in the first fermenter was high in insoluble solids, causing poor mixing and erroneous pH readings from a fouling probe. After the enzyme and inoculum were added, mixing became better and pH control improved.

The fermentation train ran continuously from Nov. 2— 22, or 20 days, with no down time of the vessels or pumps. The support vessels for feeding CSL, enzyme and inoculum were trouble free, however, the control systems to transfer feeds to the first fermenter experienced some problems, as discussed earlier. Feed from the APR was also interrupted several times for various problems including plugging caused by loss of acid feed and equipment failure. Steady state operation was not achieved because of contamination problems.

Data on glucose, ethanol and lactic acid were available immediately from samples taken and analyzed by the operators using an enzymatic technique (YSI). This data were used to decide when to make process changes to control contamination or change the APR conditions in an effort to improve sugars to the fermentation. HPLC data, available later, were used for the mass balance calculations and tracking of monomeric and total soluble sugars. YSI data for the first 3 fermenters are shown in Figures 12—14. For all the fermenters, YSI data turned out to be a good indicator of contamination; when the glucose and lactic acid levels started to rise and ethanol levels began to drop, contamination was detected by plating of samples. After each pasteurization attempt, glucose spiked, then dropped off as new inoculum was added. Lactic acid levels also dropped, until the contamination reappeared.

Figure 15 shows monomeric and total soluble glucose levels in the first 3 fermenters (arrows depict time of pasteurization). In general, monomeric glucose levels in all fermenters were low except during pasteurization and during the end of the run when contaminants were reappearing. Total glucose levels tend to decrease down the fermentation train, however, the values are still high and reflect poor hydrolysis of the glucose oligomers. Addition of glucoamylase should reduce all starch oligomers to glucose and eliminate this as a source of the high oligomer concentrations.

Figure 16 shows monomeric xylose and arabinose in each of the three 9000-L fermenters. It appears from the data at the end of the run, that at least one of the contaminants consumed arabinose; this was confirmed by typing of the organism. The contaminant did not appear to use xylose as there was no sharp drop in xylose concentration. Xylose concentration in the 9000-L fermenters is decreasing near the end of the run because of a decrease in xylose concentration in the pretreated feed. Component concentrations in the third 9000-L fermenter are shown in Figure 17. The data also clearly shows the drop in arabinose concentration along with the subsequent rise in lactic and acetic acid before the pasteurization steps.

As can be seen in Figure 18, ethanol yields (based on total available C6 sugars) throughout the run were low at 7%—24%. The low yields were the result of both by-product production by the contaminant and low conversion of glucose oligomers to monomers. Several changes are scheduled for the next continuous run to improve the yield and control contamination including using the cofermenting organism.

Table 7 shows SSF material balance information based on the raw feedstock for a sample near the end of the run (Nov. 20, 10:00). This is not a steady state material balance as there were changing ethanol and by-product concentrations. The pretreatment process and SSF converted approximately 60% of the potential glucose to ethanol and other products. The ethanol process yield (actual ethanol produced divided by theoretical ethanol) was 24.4% and the metabolic yield (actual ethanol produced divided by potential ethanol from C6 sugars consumed) was 46.8%. Roughly half of the C6 sugar produced went to ethanol production, with the rest used to produced lactic and acetic acid and other by-products (e.g., cell mass). The data also shows no xylose utilization but some consumption of the arabinose, which was probably utilized by the contaminant. The overall carbon recovery for this sample was 82.1%.

Of the objectives specific to fermentation, all were achieved except the steady state criteria and carbon balance closure to ± 15%. Improving the chromatography by the using the PAD system and accounting for product losses in the exhaust stream may improve carbon balance closure.

Table 7. SSF material balance information showing percent conversion of sugars and lignin and product yields.

Conversions (%):	
Glucose	59.6
Galactose	12.9
Xylose	3.7
Arabinose	26.9
Lignin	27.3
Yields (g/100 g C6 consumed)	
Ethanol	23.9
Acetic Acid	7.8
Lactic Acid	7.8

4.3 Contamination

One of the assays performed on 9000-L fermenter samples was a yeast cell count. During this fermentation, population of viable yeast averaged 2 x 10^7 yeast cells/mL in all three 9000-L fermenters. As the contaminant cell counts increased, the number of yeast cells dropped. At one point in the fermentation, there were 4 x 10^9 bacteria/mL and 2 x 10^6 yeast/mL. Yeast growth in the first 9000-L fermenter yeast population in the other fermenters will be more rigorously tracked in Tasks 3 and 4.

Managing the contamination problem became the primary focus of the PDU microbiology lab during this run. Various detection methods were used, new samples were added, and a critical examination of the fermentation process and laboratory procedures by Jan McCrae (a microbiology consultant) were completed during this run. With Jan's help, we identified potential sources of contamination in the plant and areas in the fermentation that need improvement. These areas will be addressed before starting Task 4.

One of the objectives for this run was to spot contamination early. This is important during a run because it allows for early correction of problems. Liquid MRS broth (lactobacilli medium) and nutrient broth were used for contamination detection in all samples (fermentation, APR, etc.). A 0.5—1.0 g sample was incubated in 5

mL of sterile broth. The broth was monitored daily for bacterial growth. Samples taken from fermenters, which contained yeast, were incubated in sterile broth and nystatin. The nystatin inhibits yeast growth, allowing the bacteria to grow without competition from the yeast. Contamination appeared in the liquid media two days before the first 9000-L fermenter showed any other signs of contamination (i.e., increasing by-product concentrations [acetic or lactic acid], increasing glucose concentration, decreasing ethanol concentration or ability to see contamination microscopically). Using the liquid media provides a quick method of detecting contamination. Solid media (agar plate) was used for isolating and counting the number of bacteria in feed streams (i.e., enzyme, corn fiber, CSL, etc.) and for fermentation cell counts.

During the run, contamination first appeared in liquid MRS broth from a sample taken from the first 9000-L fermenter 12 hours after inoculation. The contamination was not seen microscopically until two days later. All feed vessels and transfer lines were sampled regularly. The same contaminant from the 9000-L fermenters, *Lactobacillus brevis*, was isolated from the enzyme tank and its transfer line. No contaminants were isolated from the APR feed and its transfer line, the CSL tank and its transfer line or the seed hold tanks and their transfer lines. The *Lactobacillus* quickly took over the fermentation and lowering the pH to 4.0 did not eliminate the contaminant. The yeast stopped consuming glucose and the ethanol concentrations dropped because of the high concentrations of acetic and lactic acid produced by the bacteria coupled with the low pH. The 9000-L fermenters were pasteurized (60°C for 2 hours), however, this decreased the bacterial load but did not eliminate it. A second pasteurization attempt (above 60°C for 8 hours) followed by additions of virginiamycin (Lactrol, SmithKline Beecham) at 2 ppm every 24 hours also did not eliminate the contaminant. The enzyme tank was also treated with the bactericide, nisalpin (Nisin, Aplin & Barrett Ltd.) at a level of 200 ppm. Unfortunately, the enzyme tank could not be sampled to see if this was effective because of a fouled sample port. After the second pasteurization, two more contaminants were isolated from the 9000-L fermenters, *Lactobacillus collonoides* and *Pediococcus acidilactici*. The Lactrol may have been more effective against the first contaminant, allowing detection of these other two organisms.

A final attempt at finding the source(s) of contamination involved the contamination check run conducted after completely cleaning out and sterilizing the fermenters and transfer lines. Each feed stream was added separately for 36—48 hours in an attempt to isolate the source of contamination. Five days from the start of the test, the first 9000-L fermenter became contaminated. This came after the APR pretreated feedstock, CSL and inoculum had been added. The inoculum had only been added for about 6 hours, making it highly unlikely it was the source of contamination. The two organisms isolated this time were *Lactobacillus collonoides* and *Lactobacillus para. paracasei*. Since the fermenter was contaminated again and the contaminants were not isolated in any of the feed streams, other areas in the plant need to be critically evaluated as contamination sources. Possible sources are cooling water, air inlet filters, too short of a CSL sterilization time, seal water, and caustic and acid used for pH control. All these areas will be sampled before Task 4 begins.

Based on the above results and consultation with Jan McCrea about possible sources, two approaches are being pursued for handling the contamination problem . The first is to expand the microbiological sampling and sample workup and testing. This will include the additional sources listed above. In addition, a more extensive microbiological workup of the APR material will be done during Task 3. Larger samples will be taken, and an anaerobic incubator will be used to test for the presence of spore formers. The CSL is currently sterilized for 20 minutes, which may be too short given the heavy bacterial load in this material. The CSL sterilization procedure will be tested by sterilizing and holding the material for at least 3 days while sampling every 24 hours for contaminants. Finally, a sterility test will be conducted on the first 9000-L fermenter. If the vessel passes, the APR feed and transfer line will be tested as a source of contamination by adding only pretreated feedstock to the fermenter and incubating for about three days. These tests should provide the information needed to identify the sources of contamination.

The second approach involves fermentation management. There will always be some low level contamination present during fermentations. The goal is to keep the contamination in check by providing an environment that favors yeast and ethanol production, while making it more difficult for a contaminant to survive and grow. Rapid

glucose utilization by the yeast during the initial stages of the fermentation will produce higher ethanol concentrations, which should inhibit the contaminants. This can be achieved by adding glucoamylase to the fermentation, which will quickly convert starch oligomers to monomeric glucose. Adding corn screenings to the corn fiber will also boost monomeric glucose levels. Using the recombinant L1400 yeast will help with contamination control because the yeast will consume xylose. Arabinose was consumed in the last run by the contaminants. Adding yeast to the fermentation during their active exponential growth phase would eliminate any lag in growth and ethanol production. Eliminating air to the fermenters and using recycled CO, or nitrogen instead may help increase ethanol yields in the second and third fermenters by maintaining a more anaerobic environment.

5.0 Review of Run Specifications

The following is the list of criteria for success defined in the Task 2 run specification, and a short discussion of how each of these criteria were met.

1. The APR and SSF train must operate for 10 days and should reach steady state for a minimum of 2 consecutive days.

> Both the APR and SSF train operated for the required 10 days as shown on the time lines (Figures 2 and 3). The APR appeared to reach a steady state from Nov. 11 (run time 180 hours) through Nov. 13 (255 hours), well encompassing the required 2 days. The SSF train did not achieve steady state (defined as steady state ethanol production) because of contamination.

2. There should be no interruption of operation for longer than 6 hours and the total of all interruptions should be no longer than 12 hours out of the best 10 consecutive days (including the 2 days at steady state).

> The APR operated for 10 days from Nov. 6 to Nov. 16 with only one minor 3 hour shutdown for a plug in the transfer line. This interval included the 2 days of steady state operation. There was no interruption in operation of the SSF train.

3. The SSF section must be contamination free for at least 7 of the 10 days (90% of living cells are yeast and 95% of the products are produced by the yeast).

> The SSF train did not meet either of the two above criteria. Concentrations of contaminants quickly

increased to values greater than the yeast cells and produced significant quantities of lactic and acetic acid.

4. Run three stages of SSF with a residence time of 1 day to within ±1 h.

The SSF train was run with three stages and residence time was controlled at 36 ± 1 h after solving some initial startup and control tuning difficulties (see Figure 10). The residence time was increased to 36 hours because of APR throughput limitations.

5. Dry feed rate should be 1 ton/d within ± 25%.

The dry feed rate was approximately 1700 lb/d well within the ± 25%.

6. The total solids in the first SSF tank should be at least 25%.

The total solids in the first SSF tank was greater than 25% (see Figure 11).

7. Close carbon balance around pretreatment and SSF to within ± 15%.

The overall carbon recoveries in the pretreatment samples were good to ± 10%, however, individual component balances showed much wider variability. The overall carbon recovery for a fermentation sample was 82%.

8. Operate the PDU with 3 operators/shift.

The PDU was successfully operated with 3 operators/shift.

6.0 Major Problem and Post Run Issues

The following is a list of significant problems and issues encountered during this run and steps that will be taken to resolve these problems before the next run.

-

- APR acid control system

  Level probes in the acid tank that were to initiate refilling of the tank did not function correctly, causing the tank to completely empty. Signal connections were checked and corrected and it is anticipated that this step will solve the problem. A new control system may be required if the problem persist.

- CSL transfer system

  The pneumatic system for transfer of the CSL did not function well. A pump and associated control system will be added to replace the pneumatic transfer system.

- Enzyme transfer system

  The flow rate measurement from the enzyme flowmeter was somewhat erratic during this run. The position of flowmeter will be changed and a check valve will be added to improve and stabilize flow through the meter. This should improve the flow rate measurement.

- Contamination

  Contamination resulted in low ethanol yields and significant levels of other by-products (lactic and acetic acid). The first step is to identify the source of the contamination. Additional checking will be done on pretreated material and other contamination sources (e.g., cooling water, seal water, enzyme, CSL, acid and base supplies). New media and incubation techniques will be tested on the pretreated material to determine $highly-resistant organisms are not being killed during pretreatment.

  Changes in procedures and operating conditions will be done to make the fermentation less favorable for contaminant growth. These changes include inoculating the fermentation with yeast during their exponential growth phase, thus, reducing the lag in yeast growth and increasing ethanol production rate. Increasing initial glucose levels in the fermentation by using glucoamylase, which should also increase ethanol levels. Higher ethanol levels may inhibit the contaminant and keep it under control.

- 9000-L fermenter back pressure control

  Large air flow rates (50--150 L/m) are required to maintain pressure in the 9000-L fermenters. This may enhance bacterial growth, particularly in the back-end fermenters. The back-pressure control valves will be replaced with valves having tighter shutoff characteristics to reduce or eliminate supplemental air.

- Carbon balance closure

  Improvements are desired in overall and individual carbon balance information for both pretreatment and SSF. These results depend on both flow rate measurements and analytical results. Work will proceed on collecting flow rate measurements from the APR (i.e., feedstock, acid, steam, valve water and flush water flow rates) on the DACS. This may provide more reliable data for the calculation of APR and SSF carbon balances. The measurement of the caustic addition rate to fermentation is also being automated to improve the SSF carbon balance. Finally, the use of the mass spectrometer for measuring ethanol concentration in the fermentation vent gases should improve the SSF balance. The system is expected to be operational for Task 4.

  Errors in analytical results will also be examined to determine appropriate confidence intervals for the carbon balance information. Additionally, a HPAEC-PAD (High Performance Anion Exchange Chromatography - Pulsed Amphometric Detection) system will be tested to see if this technique provides better analytical results.

- DACS Resets

  During the run, the fermenters were unexpectantly kicked out of run mode into a system shutdown mode causing loss of control of temperature and pH. Although, the cause is not known, it is theorized that power fluctuations are causing these problems. An audible alarm will be added to the DACS to alert the operator of changes in operating modes.

7.0 *summary*

Several of the key objectives for this run were successfully met, including implementation of mechanical fixes completed during Task 1, sustained mechanical operation of the equipment for over 10 days, meeting target feed rate, solid concentration and residence time goals in SSF, and operating with reduced labor. The APR operated successfully for the entire run.

Planned follow-up testing will provide sufficient data for analyzing the performance of the APR.

Overall carbon balance closure for the APR during this run was better than previous runs and within the target ± 15%. The wide variability in carbon balance closures for the individual sugars was disappointing. Better laboratory procedures and automating flow rate measurements should improve future carbon balances.

The overall mechanical performance of the fermentation systems were good, except for the lingering problems with CSL and enzyme transfer systems. Solutions will be in place before Task 4. The most significant problem with this run was contamination that produced low ethanol yields. Several attempts at heat pasteurization and use of an antibiotic failed to control the problem. Identification of the source is still necessary to develop an effective control strategy. However, future runs will use the enzyme, glucoamylase, to achieve rapid hydrolysis of starch oligomers to glucose. Achieving higher ethanol levels should improve the chances of controlling contamination.

8.0 Acknowledgments

The following staff members contributed either full or part-time help to the operation of the plant during this run: Brian Boynton, Nancy Combs, Jared Daniels (DOE), Jody Fanner, Kelly Ibsen, Ed Jennings, James Johnson, Tim Johnston, John Lesko (Amoco), Bob Lyons, Sam McWilliams (Stone and Webster), Jiri Mracek, Robert O'Conner, Tim Plummer, Dana Rice, Mark Ruth, Dan Schell, Larry Schwartz (Stone and Webster), Ian Thompson, Mel Tucker, and David Wellington. Analytical support was provided by John Brigham, Larry Brown, Tina Ehrman, Jim Hora, Netta Ingle, Ray Ruiz, and David Templeton. Christos Hatzis supplied the original material balance spreadsheets that were subsequently modified for use with PDU data. This report was put together with written contributions from Nancy Combs, Kelly Ibsen, Bob Lumpkin, Mark Ruth, and Dan Schell.

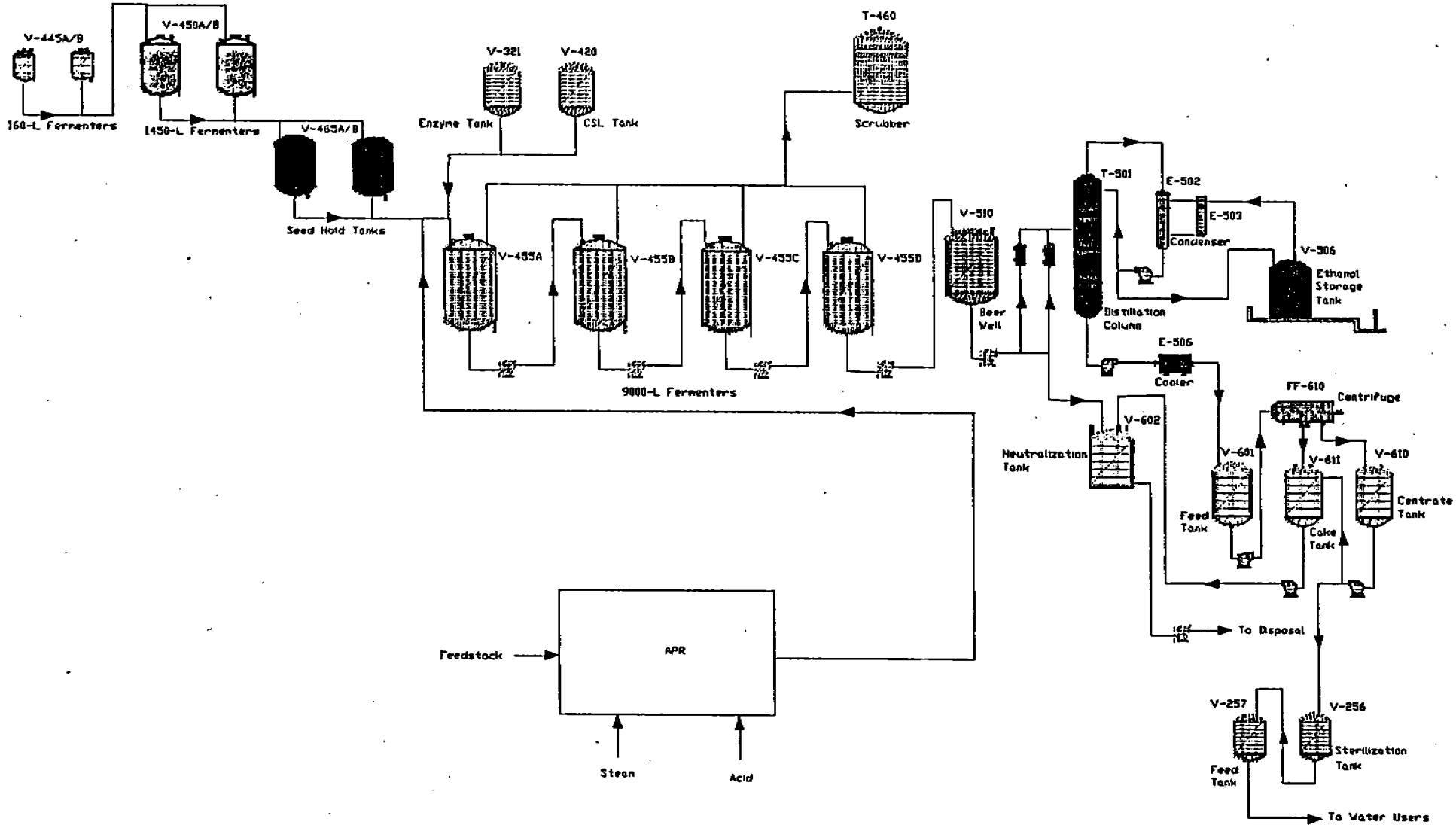
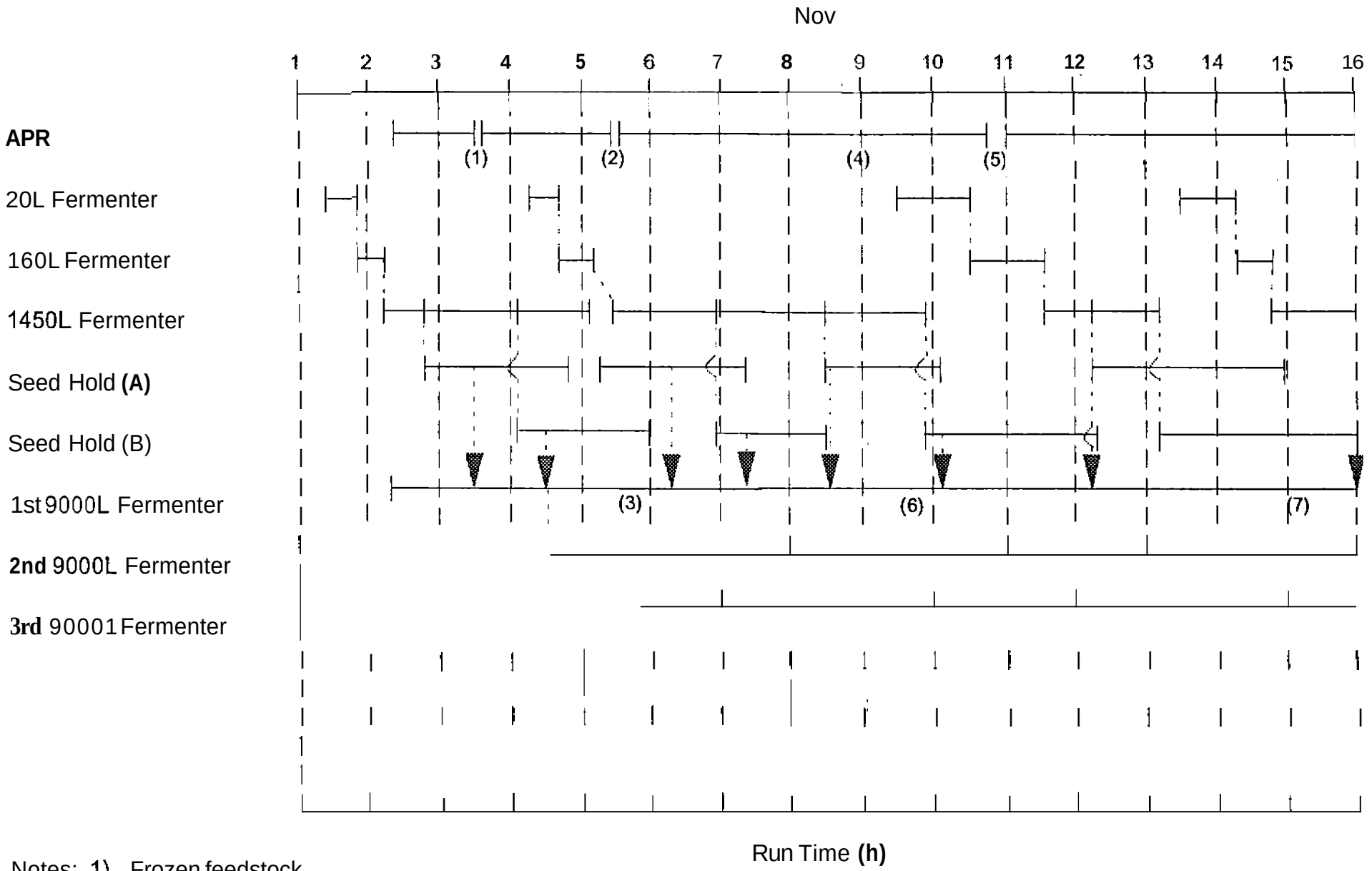


Figure 1. PDU Process Flow Diagram



Notes: 1) Frozen feedstock

2) Fermentation pH lowered from 5.0 to 4.0, 5/11 - 16:00

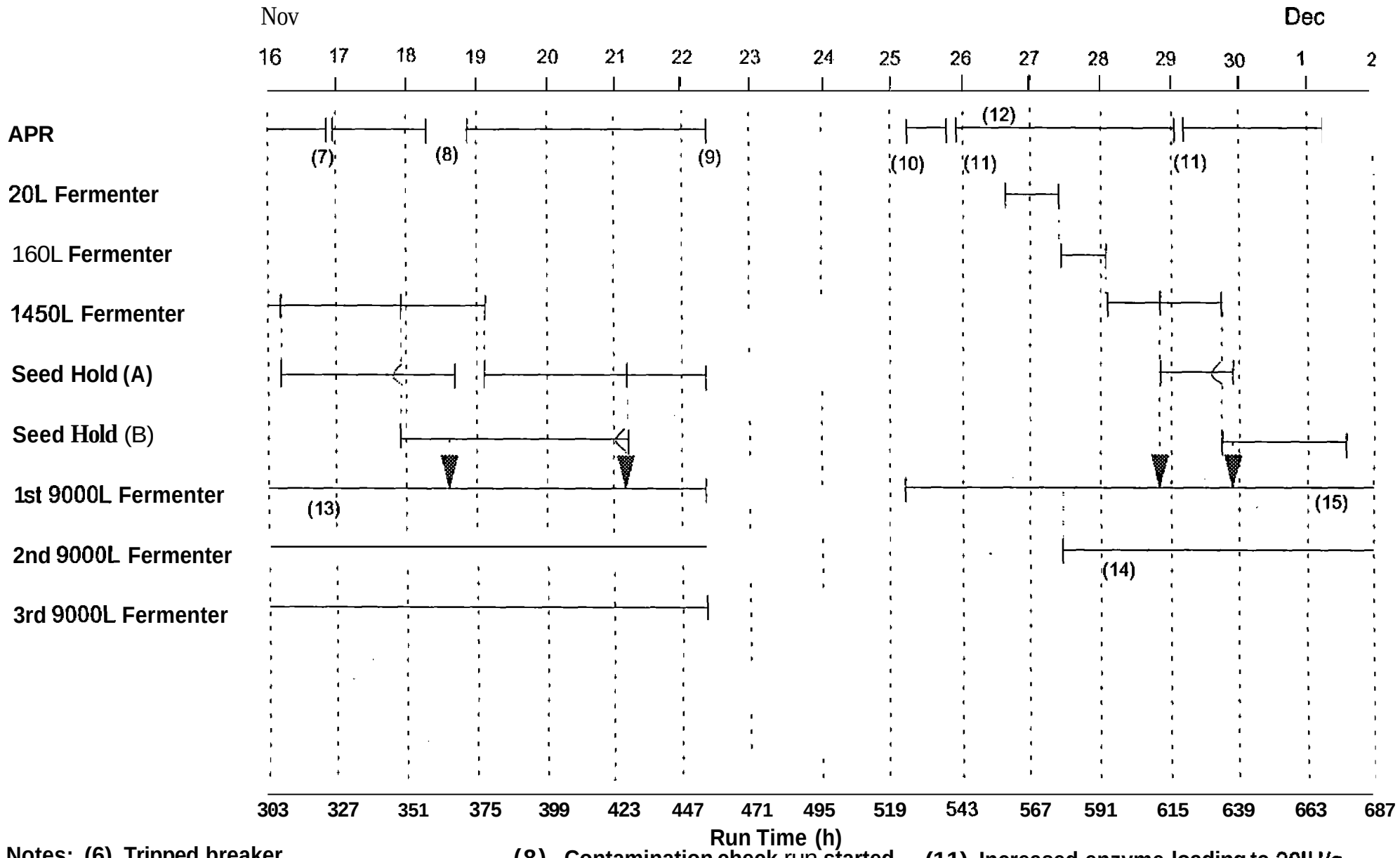
3) Changed to CF Lot #2

4) Plug in transfer line

5) Fermenters raised to 60 C for 1 h

6) Fermenters raised to 70 C for 2 h

Figure 2



Notes: (6) Tripped breaker

(7) Feed to fermenters stopped because of contamination

(8) Contamination check run started

(9) Feed plug in transfer line

(10) Numerous (6) short shutdowns

(11) Increased enzyme loading to 20IU/g

(12) Poor pH and temperature control because of thick slurries

(13) Fermenters switched to batch operation

Figure 2

Figure 4. Comparison of YSI and HPLC Monomeric Glucose

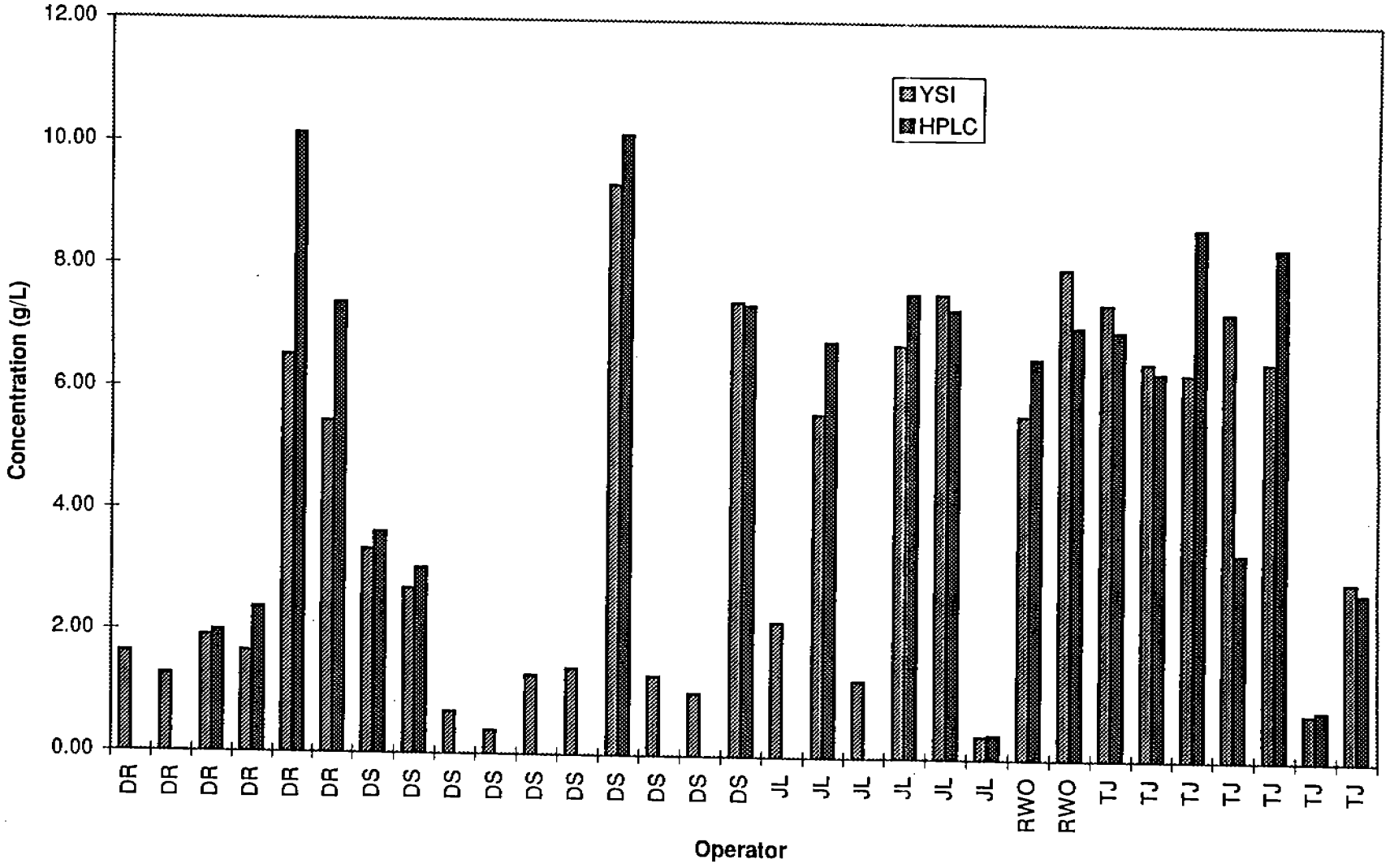


Figure 5. Pretreatment Performance

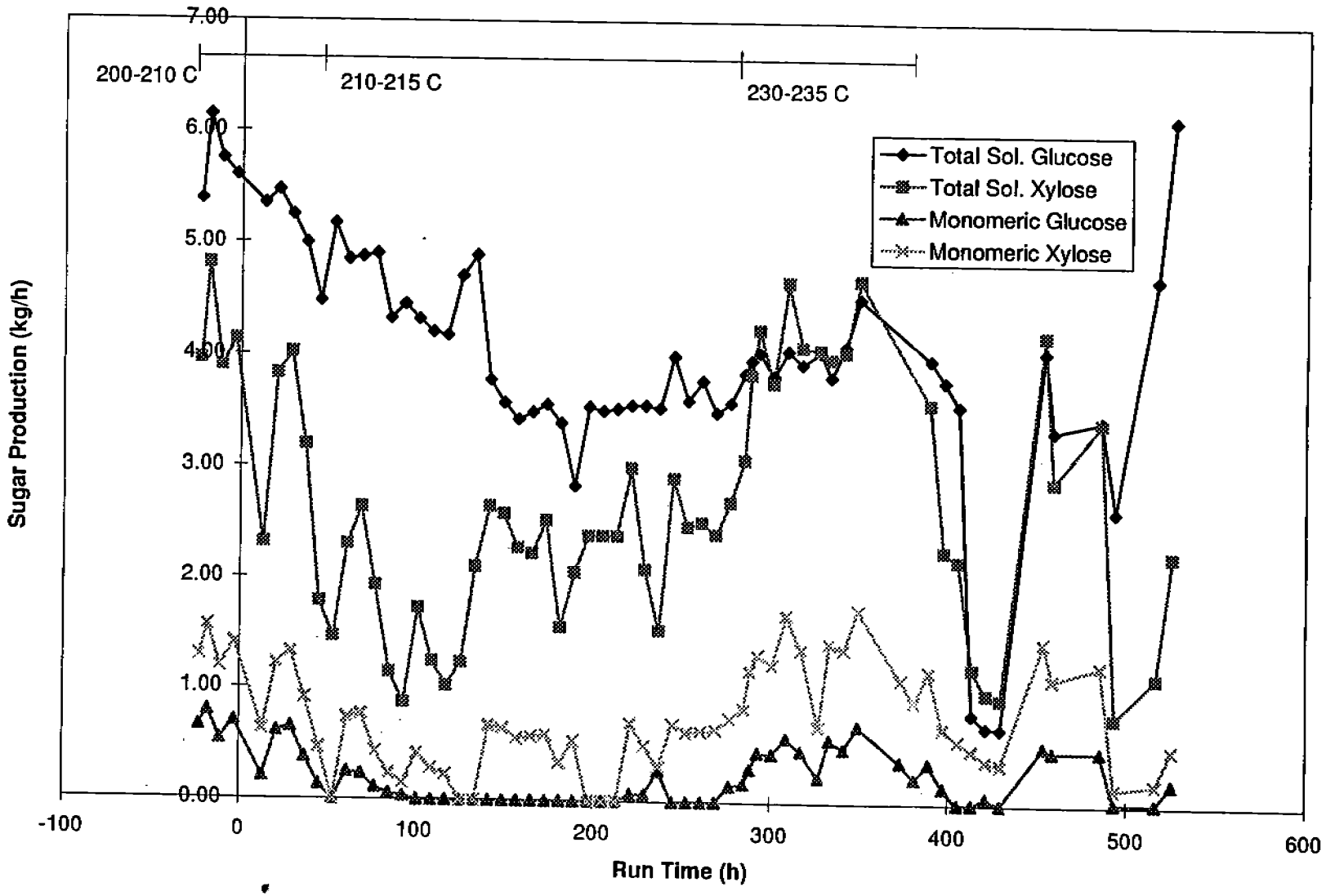
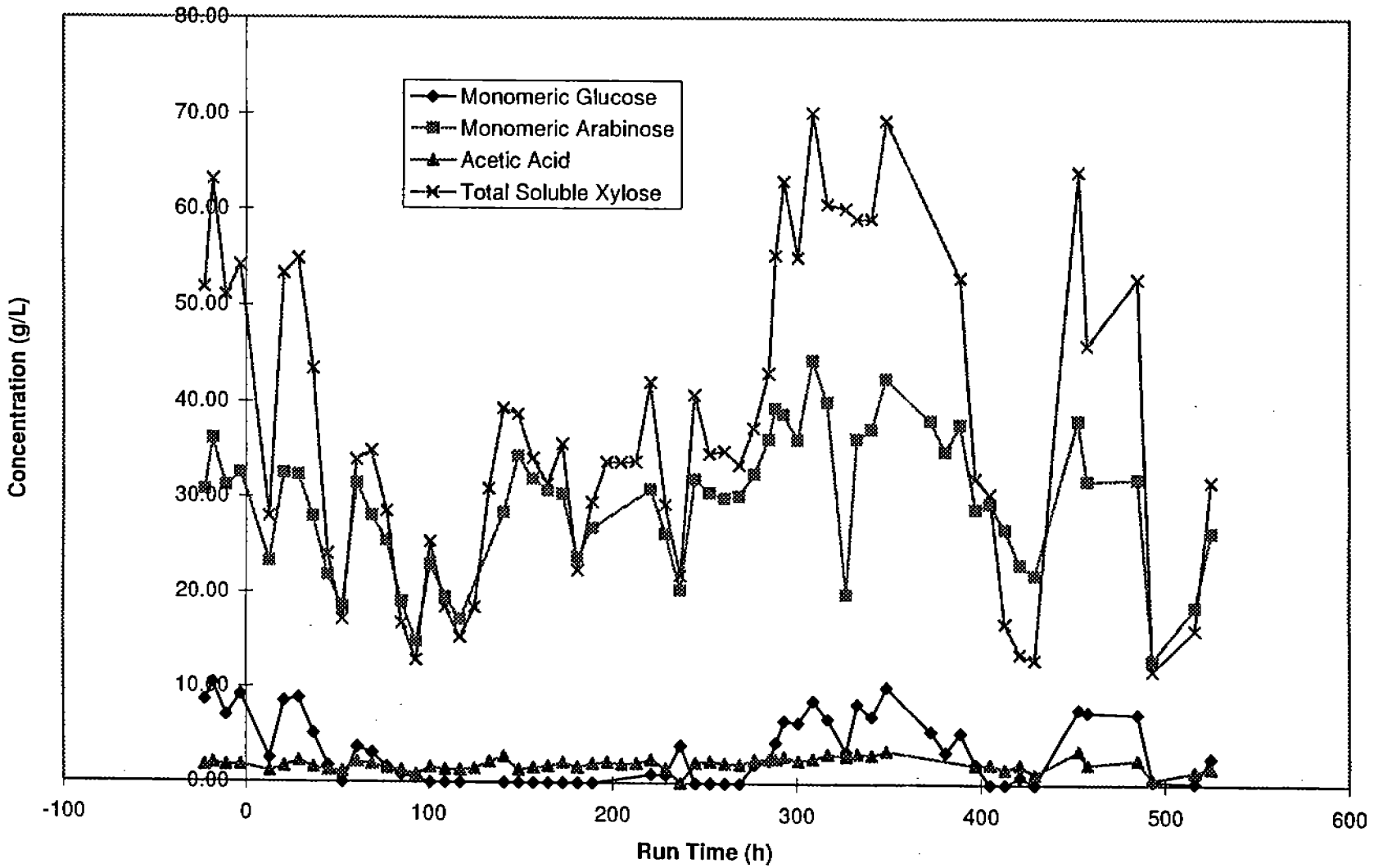


Figure 6. Component Concentrations in APR Samples



NREL/Amoco CRADA Protected Information

Figure 7. APR Sugar Yields for Corn Fiber Lot #1

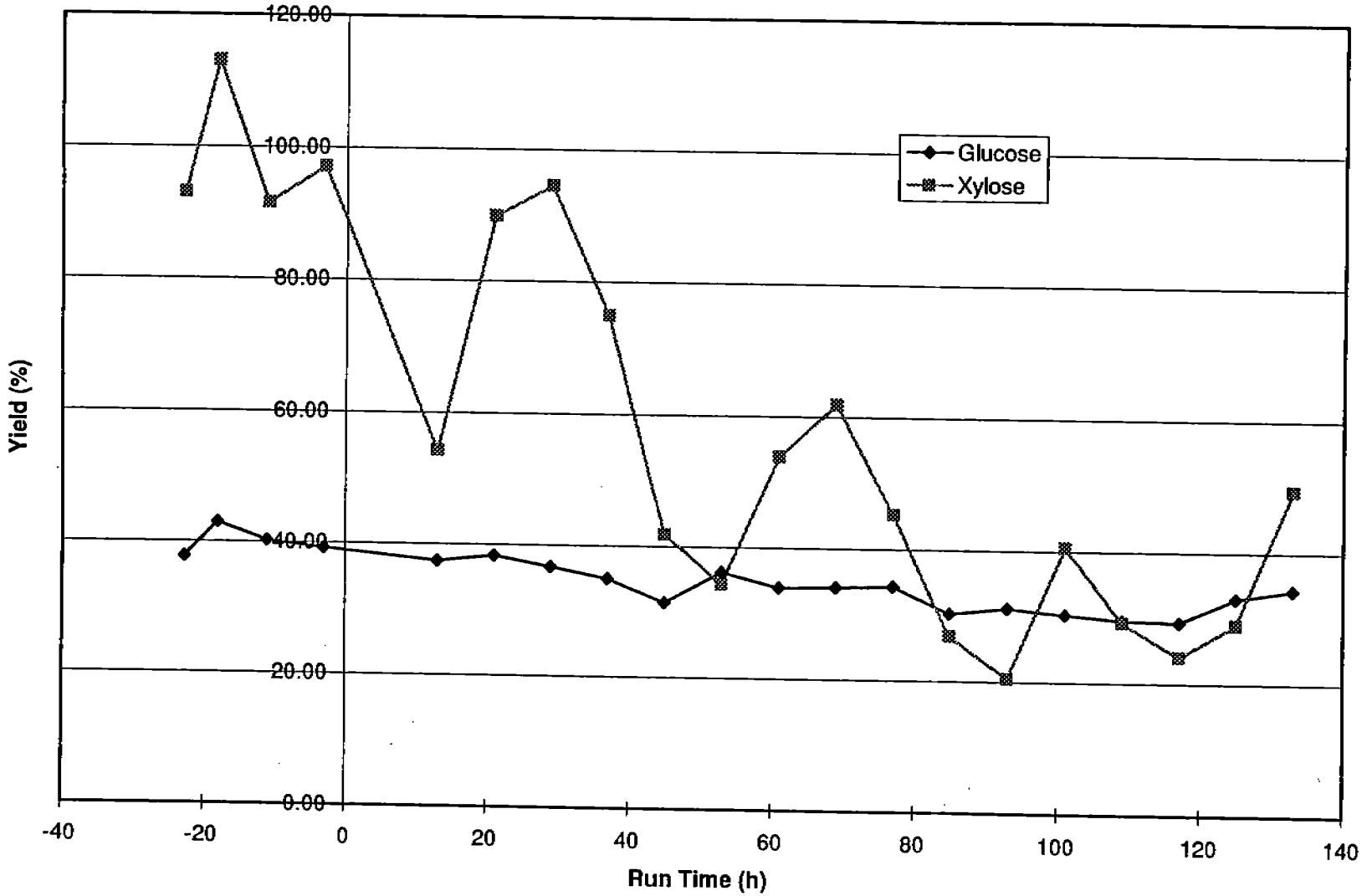


Figure 8. APR Sugar Yields for Corn Fiber Lots #2 and #3

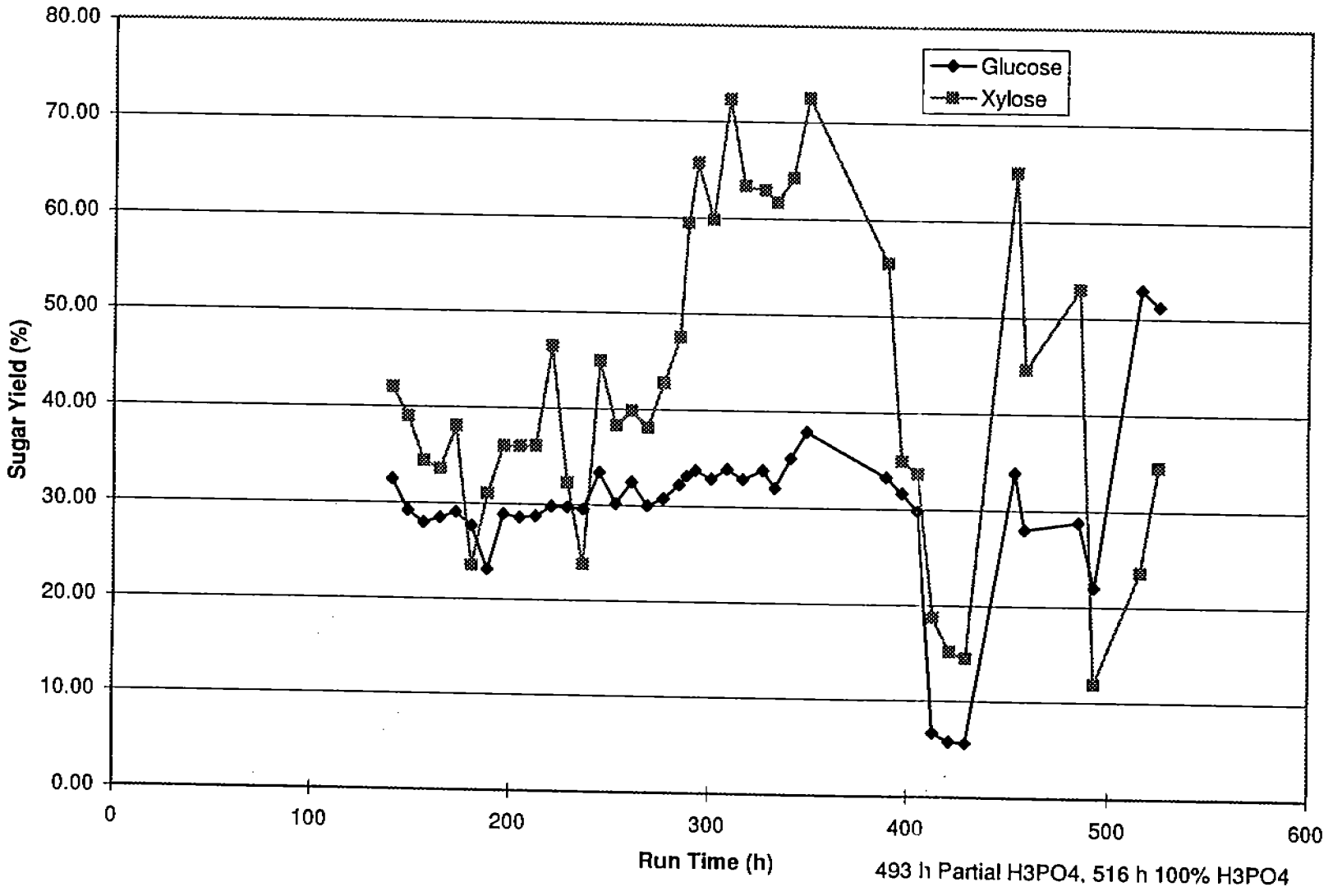


Figure 9. Growth Rate Comparison Between Yeast from the Seed Hold Tanks and a Fresh Laboratory Culture

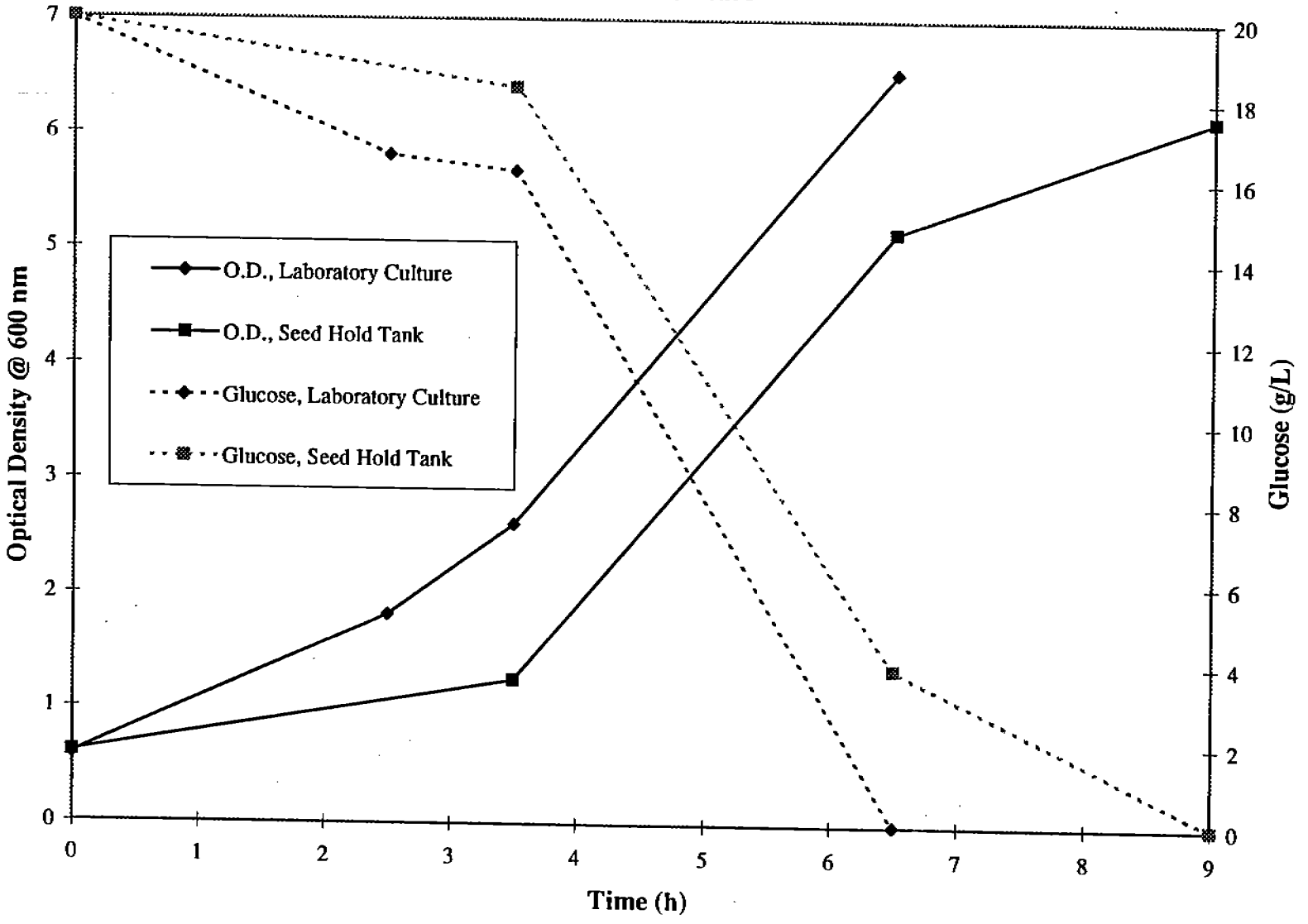


Figure 10. Weight and Temperature of First 9000-L Fermenter

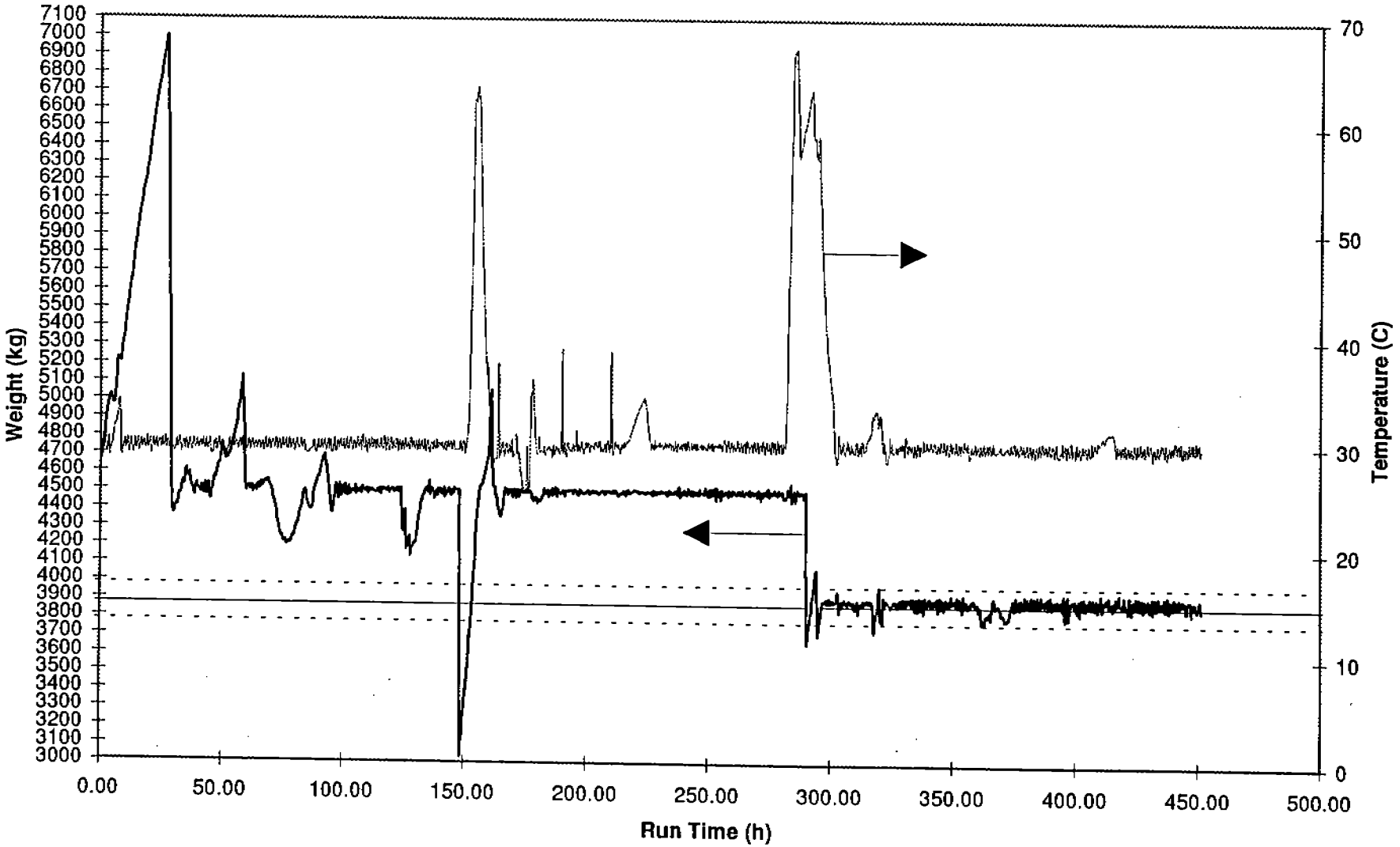


Figure 11. Effective Solids Concentration in First 9000-L Fermenter

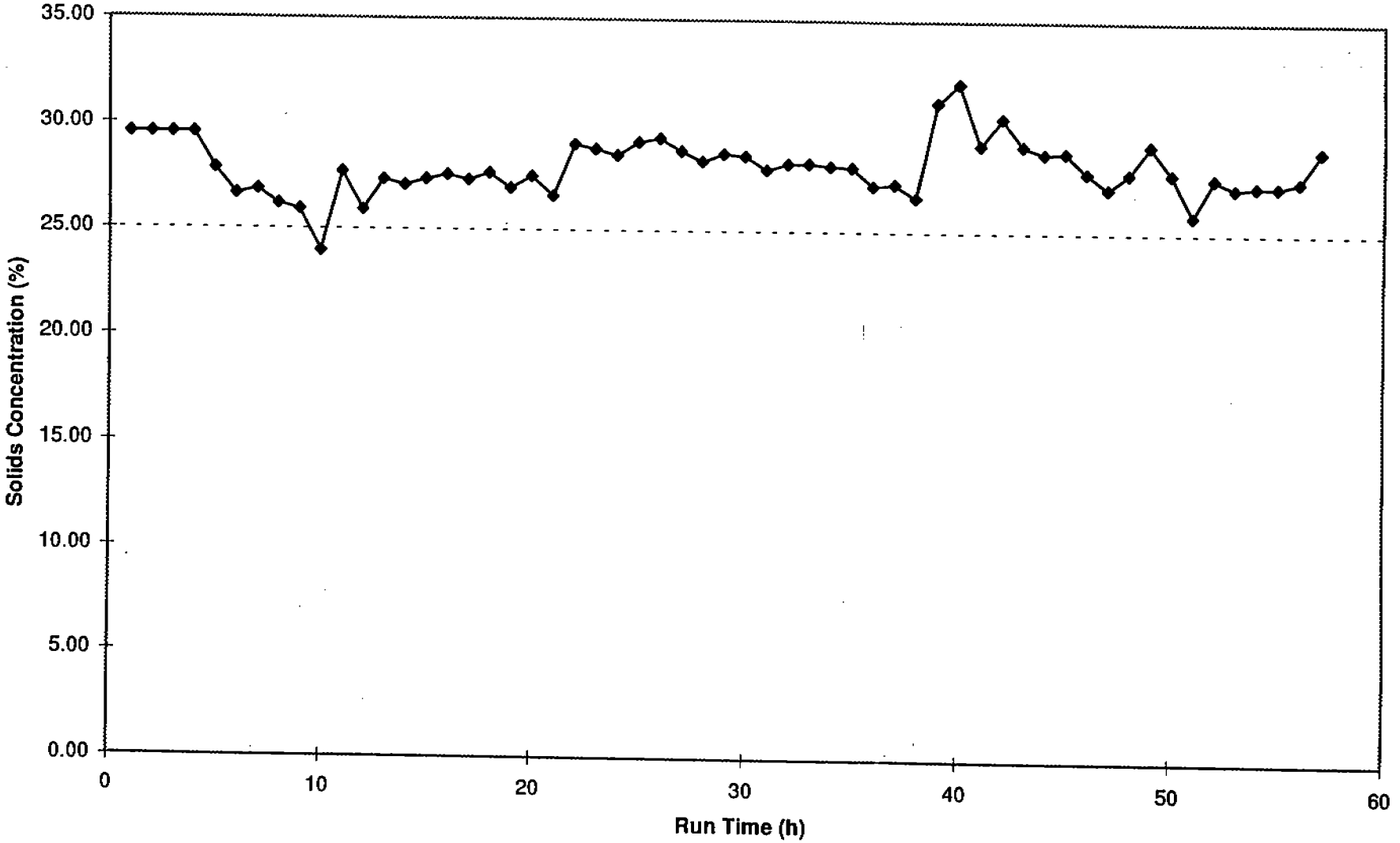


Figure 12. YSI and pH Data for First 9000-L Fermenter

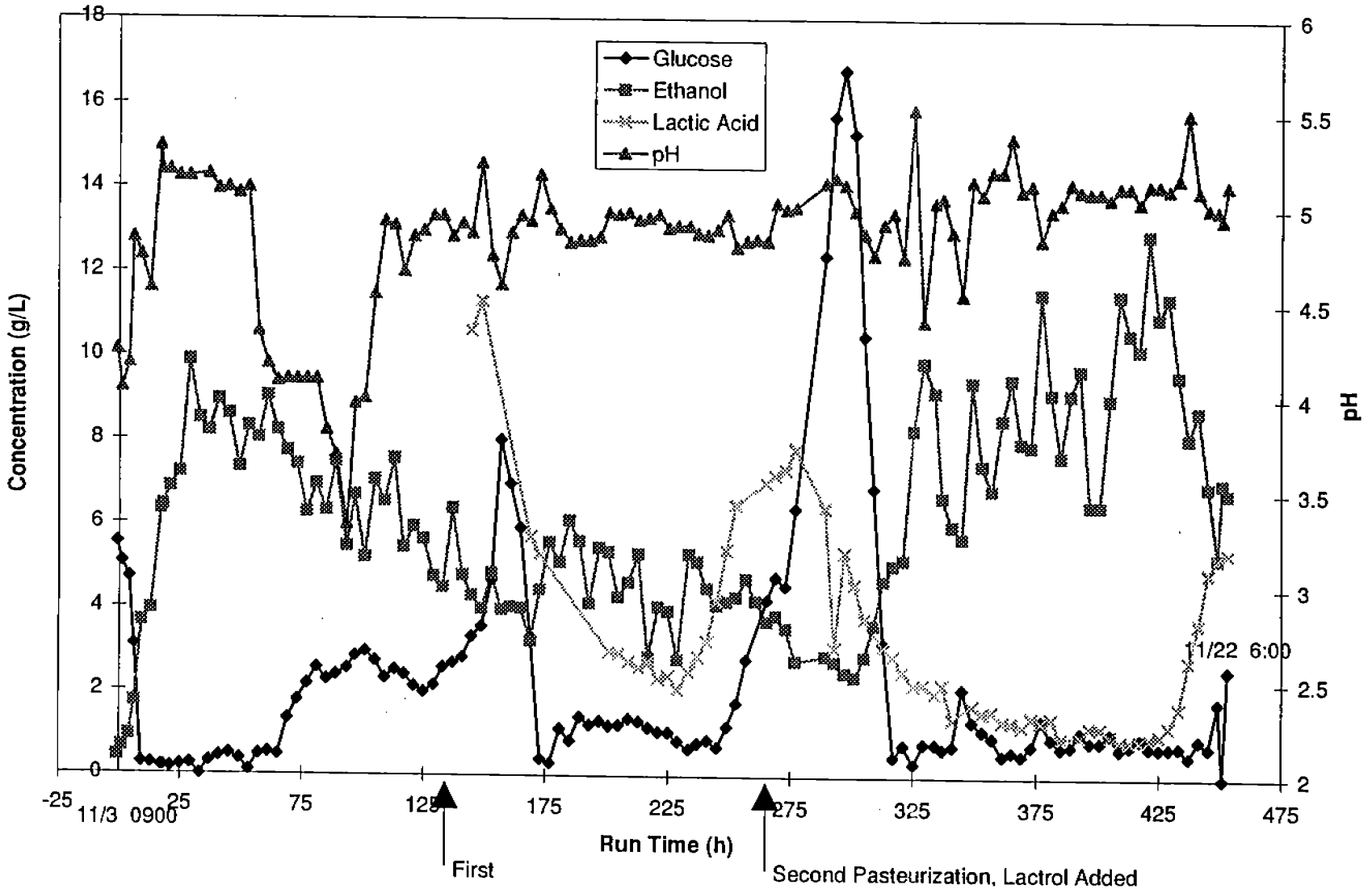


Figure 13. YSI and pH Data for Second 9000-L Fermenter

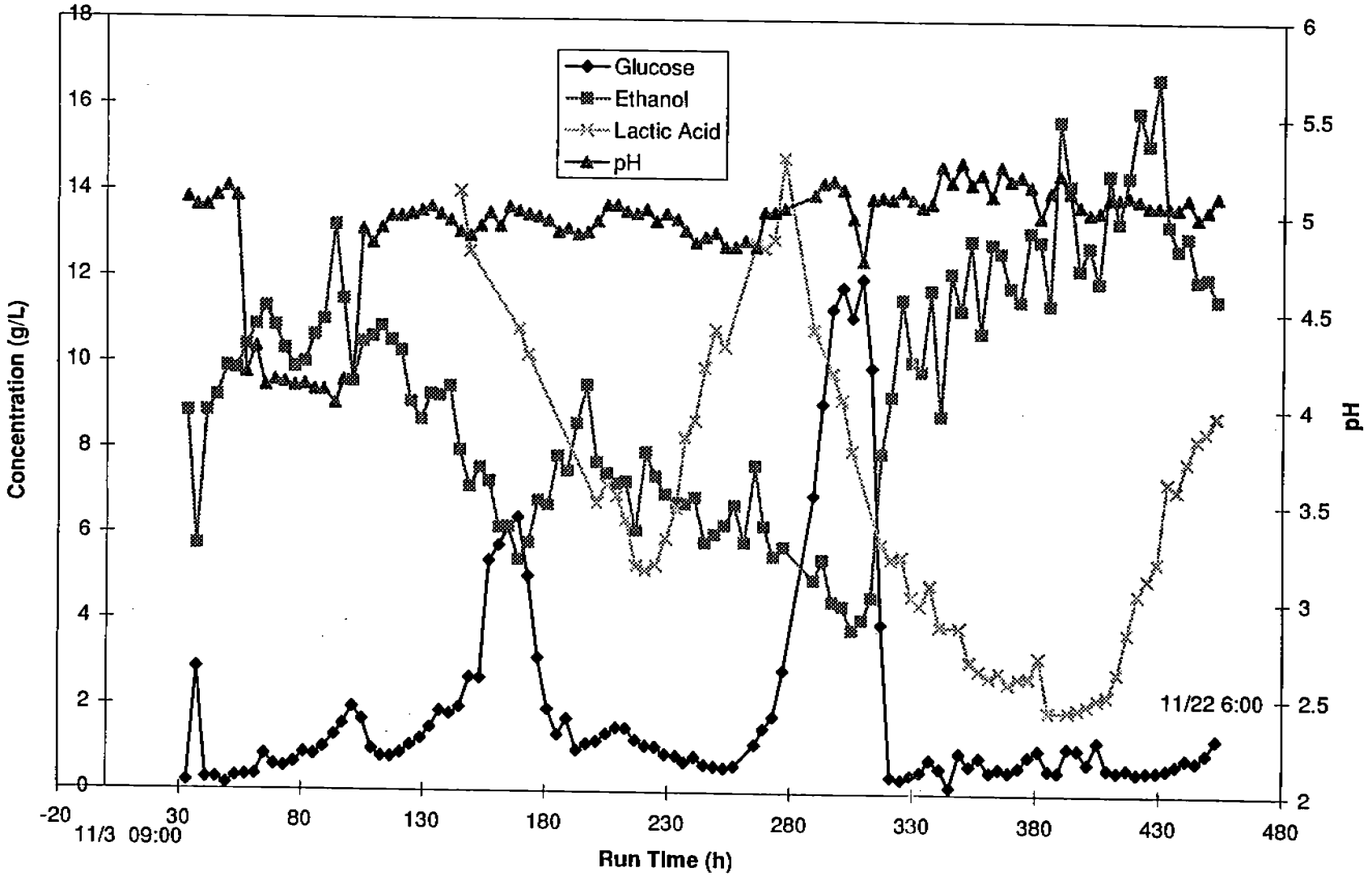


Figure 14. YSI and pH Data for Third 9000-L Fermenter

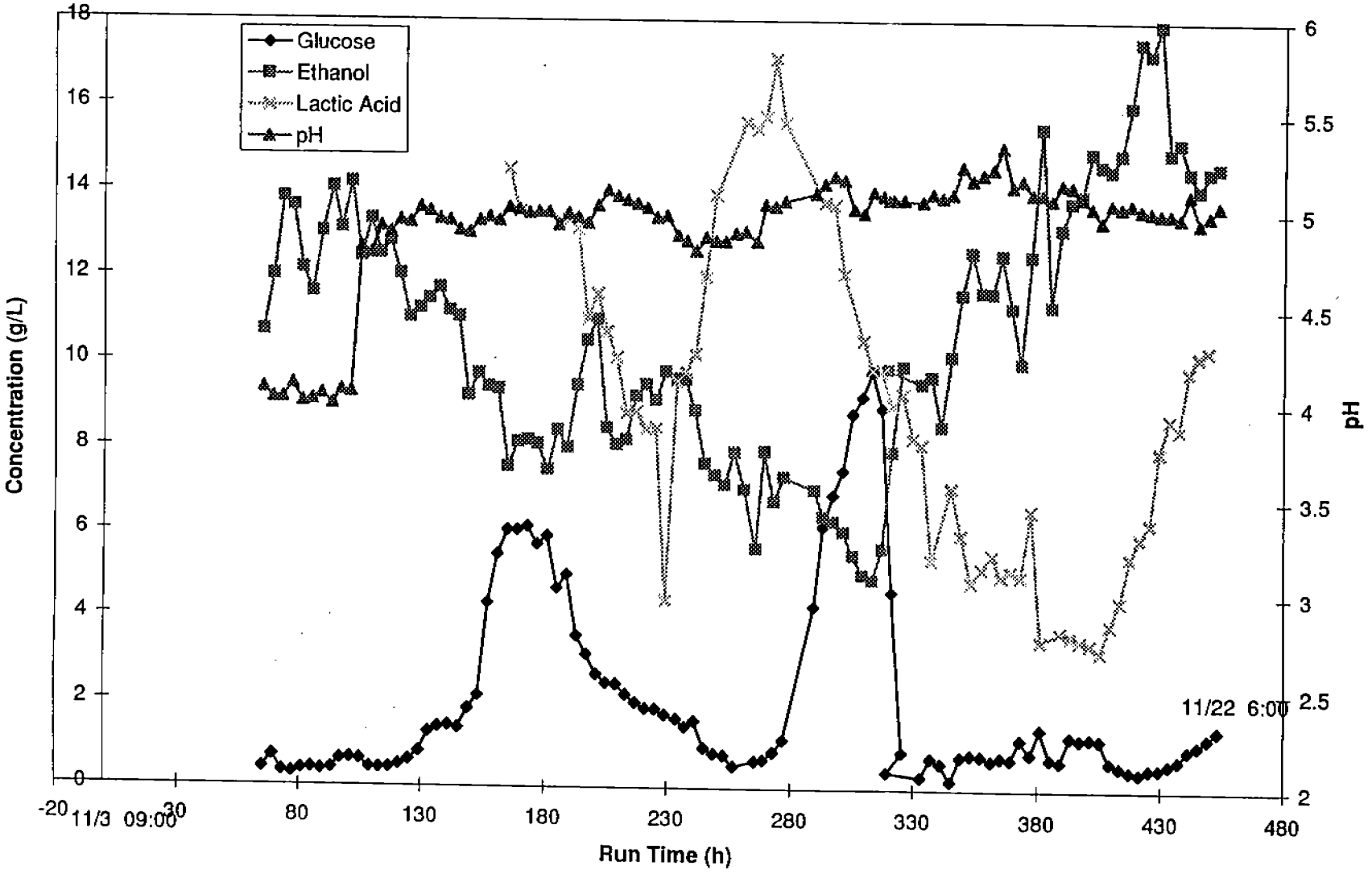


Figure 15. Monomeric and Total Soluble Glucose in 9000-L Fermenters

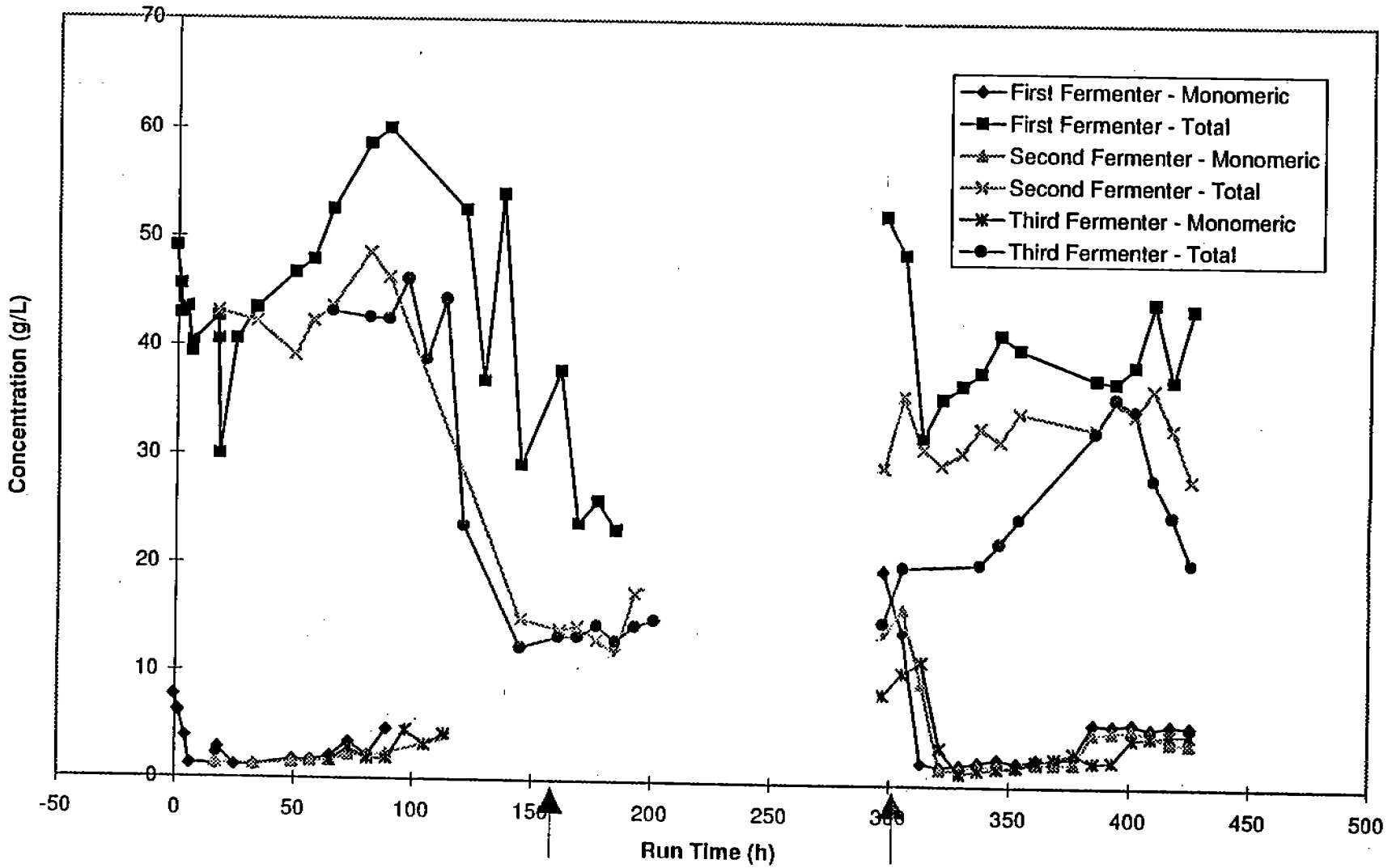


Figure 16. Monomeric Xylose and Arabinose in 9000-L Fermenters

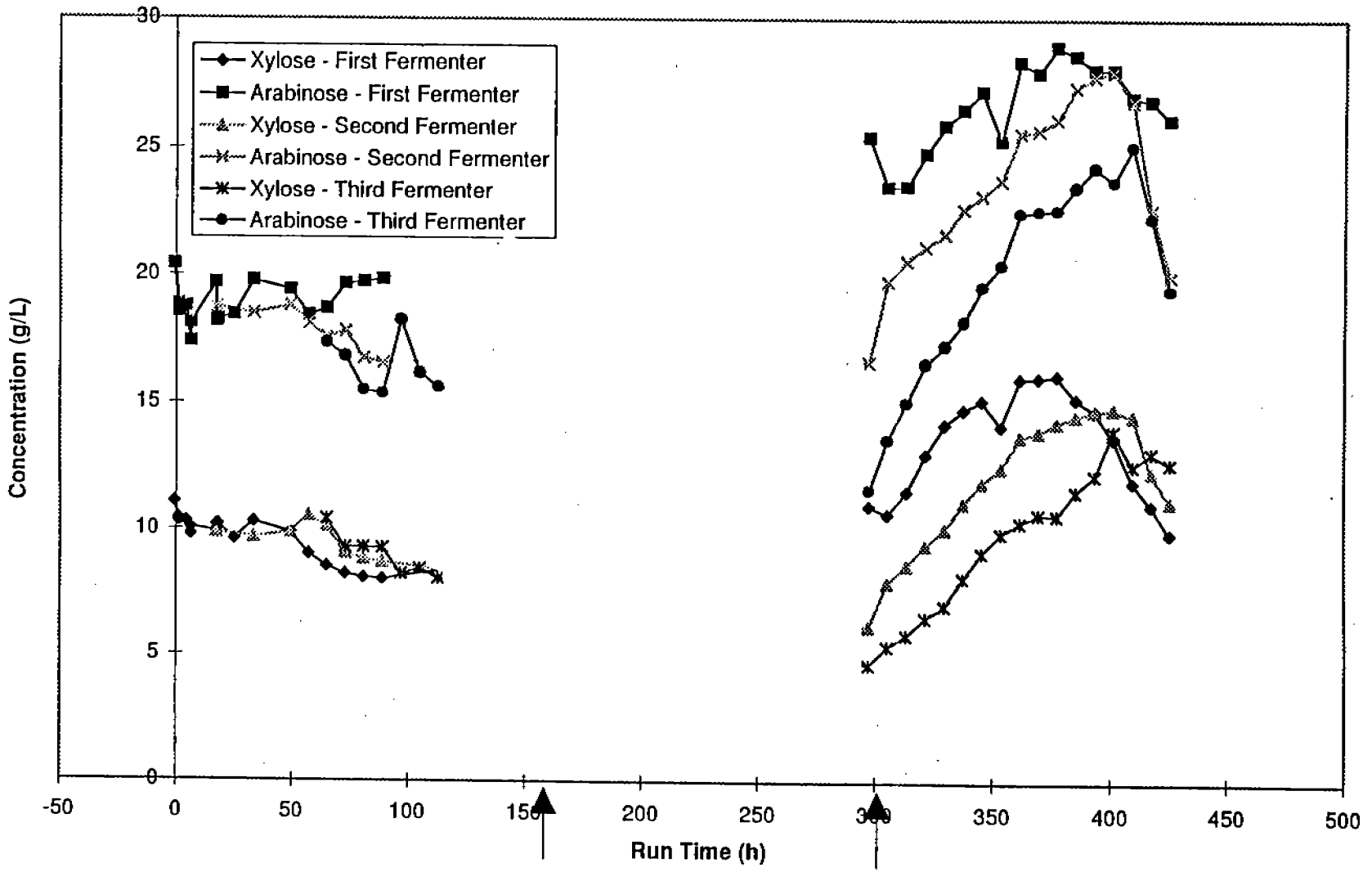


Figure 17. Component Concentrations in the Third 9000-L Fermenter

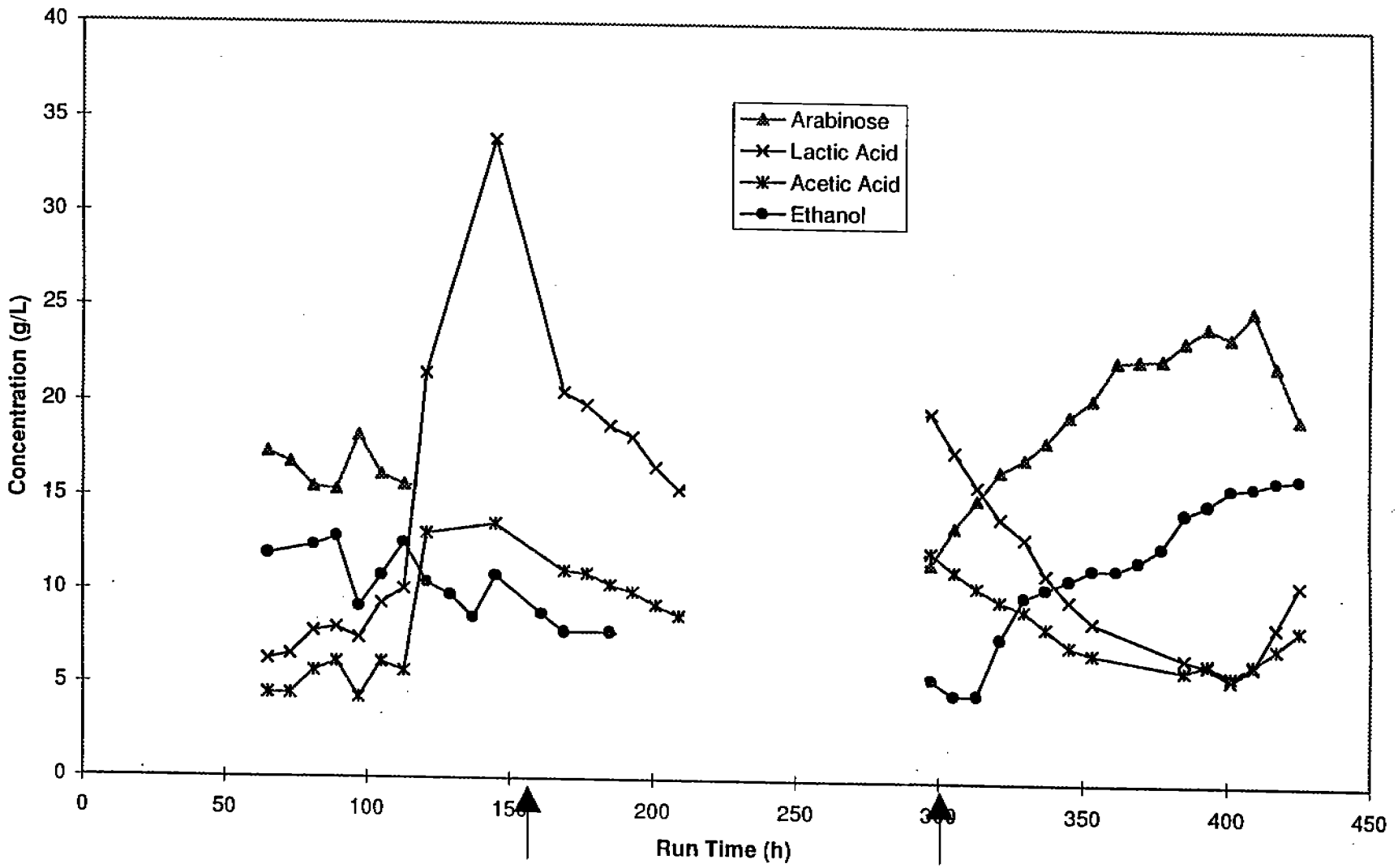
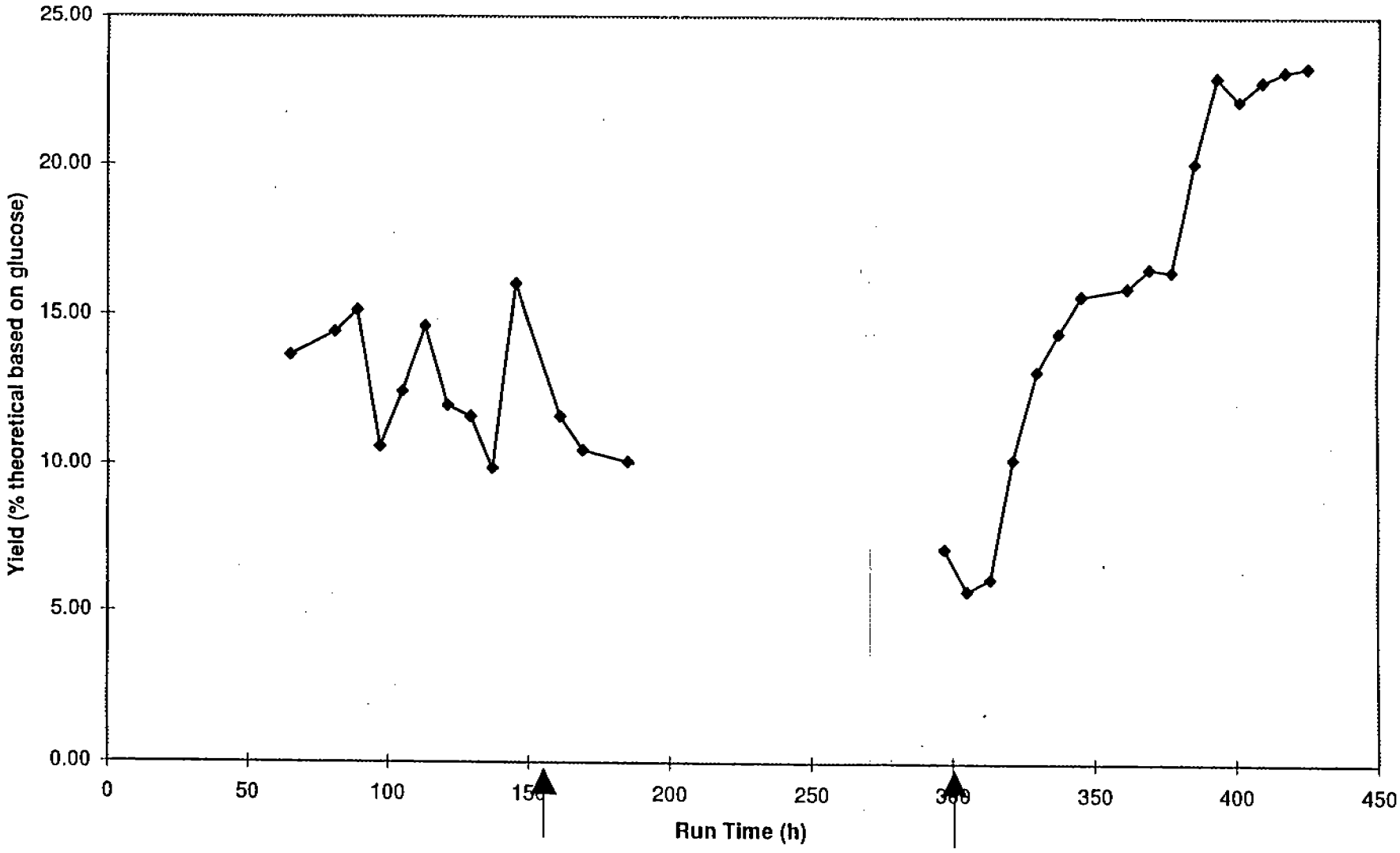


Figure 18. Ethanol Yields in Final 9000-L Fermenter



P-206 YSI Glucose Log

Monomeric Glucose Concentration in Pretreated Feedstock

Run ID# P951101CF
Page# 1

Sample Date	Sample Time	Initials	% Solids (IR)	Extrudate Weight (g)	Water Weight (g)	YSI Glucose (mg/dL)	Dilution	Actual YSI Glucose (g/L)	Comparison Glucose (g/L)	HPLC Glucose (g/L)
11/13/95	22:00	DR	20.02	5.18	20.52	29.00	5.61	1.63	1.40	0
11/14/95	6:00	DR	0.38	5.53	19.42	28.00	4.52	1.27	1.26	0
11/14/95	22:00	DR	30.92	5.45	20.41	33.00	5.78	1.91	1.49	1.99
11/15/95	6:00	DR	30.39	5.07	20.46	27.00	6.13	1.65	1.30	2.37
11/17/95	22:00	DR	31.55	2.00	18.00	52.00	12.55	6.53	5.09	10.14
11/22/95	6:00	DR	1.21	2.00	18.00	54.00	10.08	5.44	5.40	7.38
11/5/95	22:00	DS	33.30	5.16	20.59	54.00	6.20	3.35	2.57	3.63
11/6/95	6:00	DS	30.20	5.40	21.92	44.00	6.14	2.70	2.13	3.04
11/8/95	6:00	DS	5.17	5.31	20.09	14.00	4.93	0.69	0.66	0
11/9/95	6:00	DS	33.23	4.77	0.95	30.00	1.26	0.38	0.29	0
11/9/95	22:00	DS	31.90	5.00	20.06	21.00	6.17	1.29	1.01	0
11/10/95	6:00	DS	30.50	5.12	20.52	23.00	6.10	1.40	1.10	0
11/17/95	22:00	DS	31.55	5.27	20.31	157.00	5.95	9.34	7.27	10.14
11/20/95	6:00	DS	27.88	5.17	20.22	22.00	5.86	1.29	1.04	0
11/21/95	6:00	DS	28.10	4.99	20.12	17.00	6.02	1.02	0.82	0
11/22/95	6:00	DS	29.74	5.42	20.81	127.00	5.85	7.43	5.88	7.38
11/14/95	14:00	JL	30.24	5.00	20.05	36.00	6.09	2.19	1.73	0
11/16/95	14:00	JL	30.45	5.00	20.07	92.00	6.10	5.61	4.42	6.79
11/20/95	14:00	JL	28.23	5.03	20.02	21.00	5.96	1.25	1.00	0
11/22/95	11:00	JL	0.59	4.99	20.07	134.00	5.04	6.75	6.72	7.59
11/23/95	14:00	JL	31.50	5.01	19.99	124.00	6.12	7.59	5.91	7.34
11/23/95	22:00	JL	30.30	5.01	20.08	6.00	6.09	0.37	0.29	0.39
11/15/95	14:00	RWO	30.66	4.00	36.00	45.00	12.46	5.61	4.40	6.54
11/17/95	14:00	RWO	31.20	2.00	18.00	64.00	12.51	8.01	6.26	7.06
11/2/95	22:30	TJ	31.70	4.86	20.06	118.00	6.31	7.44	5.79	6.99
11/15/95	22:00	TJ	30.54	4.92	20.02	105.00	6.18	6.48	5.10	6.32
11/16/95	6:00	TJ	32.59	4.94	20.00	101.00	6.25	6.31	4.87	8.67
11/17/95	0:00	TJ	28.37	5.10	20.00	124.00	5.89	7.31	5.86	3.37
11/17/95	6:00	TJ	30.20	5.11	20.00	109.00	5.96	6.50	5.13	8.36
11/20/95	22:00	TJ	28.01	5.13	20.04	13.00	5.86	0.76	0.61	0.82
11/25/95	6:00	TJ	29.48	5.22	20.03	50.00	5.83	2.92	2.32	2.74

PDU Pretreatment Material Balance

Run #: P951101CF
Date: 11/4/99
Time: 14:00

Run Conditions: : Flash Farklemp. (O 100

Input Data:

Feed flow Rot;e (54-2C-5 lrglh):	82.0	Feed Solids concentration(%):	40.0
Steam	17.6	V-201 Add Concentration (%):	6.0
Acid Row Rate m-201-1 kg m	26.8	Lime Concentration (%):	
ume to fla* Tank m-201-3kglhl:	0.0		
Valve Water (kgm	1.0	Hydrolyzate Insoluble Solids (%):	9
Water to Funp ocam):	0.0		
Ra A Vaper (kg/h):	21.6		

Calculated Results:

Pretreatment Solids Conc. (%):	31.00439
Solids Solubilized (%):	71.25
Monomer/Total Sugar Ratio (%):	
Glucose:	12.35
Xylose:	32.79
Glactose:	50.43
Arabinose:	72.79
Mannose:	#DIV/0!

Carbon Balance: Pretreatment

	Unpretreated		Pretreated											
			In Solids			In Liquid				In Flash			Total	
Component	Dry Feed (% dry weight)	Carbon in (C-mole/h)	(% dry weight)	(C-mole/h)	(% C in Feed)	(g/L mon.)	(g/L total)	(C-mole/h)	(% C in Feed)	(g/L)	(C-mole/h)	(% C in Feed)	(C-mole/h)	(% C in Feed)
Glucose	44.7	488.290	42.9	134.740	27.6	8.8	71.58	227.329	46.6				379.998	77.6
Mannose	0.3	3.277	0	0.000	0.0	0.0	0	0.000	0.0				0.000	0.0
Galactose	3	32.771	2.04	6.470	19.7	5.8	11.5	36.523	111.4				42.993	131.2
Xylose	13.3	145.285	14.08	44.225	30.4	18.0	54.84	174.165	119.9				218.390	150.3
Arabinose	12.5	136.547	4.59	14.417	10.6	32.2	44.29	140.660	103.0				155.077	113.6
Acetic Acid							2.2	6.987		0.4	0.3		7.275	
Formic Acid							0	0.000						
Lactic Add							3.28	10.417					10.417	
Lignin	6.9	108.162	25.62	115.478	106.8		10	45.574	42.1				161.052	146.9
Furfural							0	0.000	0.0	0.1	0.1	0.0		
HMF							3.95	17.921	3.4					
Total	72.8	914.332	82.5	315,338	34.5			659.576	72.1		0.4	0.0	975.202	

Ignores protein

C - RECOVERY: 106.66%

PDU Pretreatment Material Balance

Run #: P951101CF
Date: 11/6/95
Time: 22:00

Run Conditions:	Temp (C):	flash lank Temp. (-3:	100
	Add Concentronon O :		

Input Data:

Feed flow Rate (5A-206 kgIh):	82.0	Feed Sdldr Cencontroflon (%):	39.0
Stem mgM:	10.0	V-201 Add Concentration (%):	6.0
Acid Flow Rate (FT-201-1, kg/h):	28.0	Lime Concentration (%):	
Lime to Flash Tank (FT-201-3 kg/h):	0.0		
Valve Water (kg/h):	1.0	Hydrolyzate Insoluble Solids (%):	14.86
Water to Pump (kg/h):	0.0		
R a h Vapor (kg/h):	20.4		

Calculated Results:

Pretreatment Solids Conc. (%):	31.7915
Solids Solubilized (%):	53.72
Monomer/Total Sugar Ratio (%):	
Glucose:	1.24
Xylose:	20.32
Glactose:	22.64
Arabinose:	73.89
Mannose:	#DIV/0!

Carbon Balance: Pretreatment

	Unpretreated		Pretreated											
	Dry Feed	Carbon In	In Solids			In Liquid				In Flash			Total	
Component	(% dry weight)	(C-mole/h)	(% dry weight)	(C-mole/h)	(% C in Feed)	(g/L mon.)	(g/L total)	(C-mole/h)	(% C in Feed)	(g/L)	(C-mole/h)	(% C in Feed)	(C-mole/h)	(% C in Feed)
Glucose	44.7	476.003	31.74	156.441	32.9	0.7	56.61	159.864	33.6				316.305	66.4
Mannose	0.3	3.195	0	0.000	0.0	0.0	0	0.000	0.0				0.000	0.0
Galactose	3	31.952	4.58	22.574	70.6	0.0	3.71	10.477	32.8				33.051	703.4
Xylose	13.3	141.653	25.63	126.326	89.2	3.0	14.91	42.105	29.7				166.431	110.9
Arabinose	12.5	133.133	11	54.217	40.7	16.8	22.71	64.132	48.2				118.349	88.9
Acetic Acid							1.13	3.191		0.3	0.2		3.361	
Formic Acid							0	0.000						
Lactic Acid							5.91	16.689					16.689	
Lignin	6.9	105.458	19.46	137.639	130.5		10	40.524	38.4				178.163	168.9
Furfural							0	0.000	0.0	0.0	0.0	0.0		
HMF							0	0.000	0.0					
Total	72.8	891.474	84.4	497.196	55.8			336.983	37.8		0.2	0.0	834.349	

Ignores protein
Insoluble solids levelwos Interpolated from nearest available data to the given Hme point
C - RECOVERY: 93.59%

PDU PretreatmentMaterial Balance

Run #: P951101CF
Date: 11/17/95
Time: 600

Run Conditions: Temp Ccl: flash IciW Temp. t o . 100

Add Concentmtbnpb):

Input Dato:

feed flow Rate (SA-206 kg/h):	82.0	feed Solids Concentration (%):	40.0
Steam to	10.0	V-201 Acid Concentration (%):	6.0
Acid Row Rate (FT-201-1, kg/h):	28.0	Lime Concentration (%):	
Lime to flohTank (FT-201-3 kg/h):	0.0		
Valve Water (kg/h):	6.0	Hydrolyzate Insoluble Solids (%):	12.41
Water to Pump (kg/h):	0.0		
Flash Vapor (kg/h):	25.2		

Calculated Results:

Pretreatment Solids Conc. (%):	32.5387
Solids Solubilized (%):	64.13
Monomer/Total Sugar Ratio (%):	
Glucose:	14.74
Xylose:	35.68
Glactose:	49.46
Arabinose:	79.79
Mannose:	#DIV/0!

Carbon Balance: Pretreatment

	Unpretreated		Pretreated												
			In Solids			In Liquid				In Flash			Total	
Component	Dry Feed (% dry weight)	Carbon in (C-mole/h)	(% dry weight)	(C-mole/h)	(% C in Feed)	(g/L mon.)	(g/L total)	(C-mole/h)	(% C in Feed)	(g/L)	(C-mole/h)	(% C in Feed)	(C-mole/h)	(% C in Feed)
Glucose	36.5	398.716	37.78	148.031	37.1	8.4	56.71	156.831	39.3				306.482	76.9
Mannose	0	0.000	0	0.000	0.0	0.0	0	0.000	0.0				0.000	
Galactose	4	43.695	2.4	10.187	23.3	4.0	12.03	33.249	76.1				43,456	99.5
Xylose	19.7	215.197	18.02	70.606	32.8	21.1	59.02	163.219	75.8				233,826	108.7
Arabinose	16	174.780	5.59	21.903	12.5	36.2	45.33	125.360	71.7				147.263	84.3
Acetic Acid							3.13	8.656		0.6	0.5		9.118	
Formic Acid							0	0.000						
Lactic Acid							1.9	5.254					5.254	
Lignin	11.2	175.567	24.25	136.350	77.7		10	39.685	22.6				176.035	100.3
Furfural							0	0.000	0.0	0.1	0.2	0.0		
HMF							0.41	1.620	0.4					
Total	*79.1*	*1007.954*	*81.4*	*387.078*	*38.4*			*533.894*	*53.0*		*0.6*	*0.1*	*921.434*	

Ignoresprotein

C - RECOVERY: *91.42%*

PDU SSF Material Balance (based on raw feed)

Run #: P951101CF
Date: 11/20/95
Time: 10:00

Run Conditions:				
	Hydrolyzer Temp (C) :	210	Flash Tank Temp (C):	100
	Hydrolyzer Residence Time (min) :	-		
	Hydrolyzer Acid Concentration (%):	1.80		

Input Data:

Feed Flow Rate (SA-150 kg/h):	82	Feed Solids Concentration (%):	40	Inoculum Flow Rate (FE-465A-4, kg/h):	11
Valve Water (kg/h):	6	V-301 Acid Concentration (%):	6	Enzyme Flow Rate (FE-455A-5, kg/h):	1.4
Acid Flow Rate (kg/h):	28.00	Lime Concentration (%):	0	CSL Flow Rate (FE-455A-5, kg/h):	4
Steam to APR (kg/h):	10.00			Other Additions (kg/h):	0
Lime to Flash Tank (FI-201-3 kg/h):	0	Hydrolyzate Insoluble Solids (%):	10		
Water to Flash Tank (FI-205-1, kg/h):	0	Fermenter Insoluble Solids (%):	6	Fermentation Solids Conc. (%):	27.1
Flash Vapor (kg/h):	21.32				

Cellulose Conversion:	84.7%
Xylan Conversion:	80.6%
Overall C6-Sugar Conversion:	52.1%
Overall C5-Sugar Conversion:	14.1%
Ethanol Process Yield (% theor):	24.4%
Ethanol Metabolic Yield (% theor):	46.8%

Carbon Balance: SSF

	Carbon In														Carbon Out								Conversion	Yield
	In Feedstock																							
	In Raw Feed			In Feed Liquor			In Inoculum			In Enzyme			Total	In Solids			In Liquor			Total			
Component	(% dry wt)	(C-mole/h)	(% total in)	(g/L)	(C-mole/h)	(% Total in)	(g/L)	(C-mole/h)	(% Total in)	(g/L)	(C-mole/h)	(% Total in)	(C-mole/h)	(% dry wt)	(C-mole/h)	(% Total Out)	(g/L)	(C-mole/h)	(% Total Out)	(C-mole/h)	(In-Out)/In (%)	g product/ 100 g C6 cons
Cellobiose				0.00	0.000		0.000	0.000	#DIV/0!				0.000				3.54	14.125		14.125		
Glucose	17.4	408.547	97.2	0.00	0.000	0.0	0.0	0.000	0.0	300.0	11.955	2.8	420.502	25.85	62.543	36.8	28.36	107.498	63.2	170.041	59.56	
Galactose	4	43.495	100.0	0.00	0.000	0.0	0.0	0.000	0.0				41.695	2.91	7.041	18.5	8.18	31.006	81.5	38.047	12.93	
Mannose	0	0.000	#DIV/0!	0.00	0.000	#DIV/0!	0.0	0.000	#DIV/0!				0.000	0.00	0.000	#DIV/0!	0.00	0.000	#DIV/0!	0.000	#DIV/0!	
Xylose	19.6	214.105	100.0	0.00	0.000	0.0	0.0	0.000	0.0				214.105	17.11	43.639	20.2	43.39	164.469	79.8	206.108	3.74	
Arabinose	15.8	172.595	100.0	0.00	0.000	0.0	0.0	0.000	0.0				111.595	6.01	14.641	11.5	29.45	111.630	88.5	126.171	24.90	
Lignin	11.1	173.999	100.0	0.00	0.000	0.0			0.0				173.999	27.04	93.881	74.2	6.00	32.636	25.8	126.517	17.29	
Ethanol							6.000	2.865	100.0				2.865				15.86	78.364		78.364		23.93
Cell Mass							2.000	0.878	100.0				0.070				0.20	0.908		0.908		0.01
Carbon Dioxide																		37.750		37.750		21.86
Glycerol				0.00	0.000	0.0	0.500	0.179	0.0				0.179				1.94	7.193		7.191		2.96
Acetic Acid				2.50	5.386	98.7	0.200	0.073	1.3				5.459				6.44	24.411		14.411		7.83
Lactic Acid				2.25	4.848	96.4	0.500	0.183	3.4				5.031				6.32	23.956		23.956		7.82
Succinic Acid				0.00	0.000	0.0	0.200	0.075	100.0				0.075				0.00	0.000		0.000		0.03
Total	87.9	1011.941	97.5		10.134	1.0							1039.384	79.02	219.645	25.7		633.945	74.3	853.590		65.40

C - RECOVERY: **82.12%**

Component	% Carbon In	% Carbon Out
Glucose	40.6%	19.9%
Galactose+Mannose	4.2%	4.6%
Total C6 Sugar	37.2%	38.9%
Lignin	16.7%	14.8%
Ethanol	0.3%	9.2%
Byproducts	1.1%	11.0%

Material Flows:

Total Solids to Pretreatment Reactor (kg/h):	32.8
Total Liquids From Flash (kg/h):	71.8793
Total Flow from Flash (kg/h):	104.679
Total Liquids to Hydrolyzer (kg/h):	93.2
Total Liquid Flow to Fermentation (kg/h):	121.079

Run start data 3-Nov-95
Run Name: Amoco CRADA Task 2
Run ID#: P951101CF

Date	Time	Run time (h)	Tot. Solids Oven (%)	TDS Liquid (%)	Ins.Solids (%)	Sample Wt. (g)	HPLC (g/L)					
							Glucose	Xylose	Gal.	Arab.	Man.	Cello.
11/2/95	10:20	-23	27.26	3.18	6.65	25.08	8.58	16.86	5.24	30.68	0.00	0.00
11/2/95	15:00	-18	26.42	3.76	2.22	25.01	10.38	20.49	6.34	36.05	0.00	0.00
11/2/95	22:00	-11	26.84	3.47	4.47	25.10	6.99	15.57	5.06	31.12	0.00	0.00
11/3/95	6:00	-3	28.62	3.41	6.21	25.10	9.14	18.47	5.77	32.45	0.00	0.00
11/3/95	22:00	13	26.75	2.77	9.04	25.26	2.47	7.55	2.96	23.24	0.00	0.00
11/4/95	6:00	21	26.67	3.74	3.37	26.03	8.50	17.00	5.44	32.45	0.00	0.00
11/4/95	14:00	29	27.93	3.54	9.00	25.40	8.84	17.98	5.80	32.24	0.00	0.00
11/4/95	22:00	37	28.31	3.17	8.12	25.94	5.10	12.36	4.08	27.87	0.00	0.00
11/5/95	6:00	45	27.47	2.58	11.04	25.68	1.73	6.20	2.43	21.76	0.00	0.00
11/5/95	14:00	53	30.05	2.37	14.16	25.00	0.00	0.00	0.00	18.48	0.00	0.00
11/5/95	22:00	61	29.21	3.22	7.78	24.94	3.63	10.83	3.91	31.40	0.00	0.00
11/6/95	6:00	69	25.18	2.92	6.69	25.01	3.04	10.07	3.66	27.99	0.00	0.00
11/6/95	14:00	77	28.72	2.14	14.72	25.25	1.56	6.36	1.87	25.37	0.00	0.00
11/6/95	22:00	85	27.99	2.00	14.86	24.95	0.79	3.40	0.94	18.94	0.00	0.00
11/7/95	6:00	93	31.23	1.70	19.69	25.13	0.50	2.25	0.62	14.78	0.00	0.00
11/7/95	14:00	101	29.91	2.66	12.09	25.03	0.00	6.04	0.00	22.95	0.00	0.00
11/7/95	22:00	109	30.20	2.44	13.85	25.08	0.00	4.09	0.00	19.46	0.00	0.00
11/8/95	6:00	117	32.50	2.41	15.81	24.95	0.00	3.40	0.00	17.08	0.00	0.00
11/8/95	14:00	125	29.99	2.75	11.56	25.00						
11/8/95	22:00	133	29.78	2.80	11.15	25.19						
11/9/95	6:00	141	32.55	2.72	13.78	25.07	0.00	9.93	4.73	28.34	0.00	0.00
11/9/95	14:00	149	30.17	2.92	10.54	24.98	0.00	9.69	3.08	34.27	0.00	0.00
11/9/95	22:00	157	30.34	2.68	12.31	25.06	0.00	8.30	2.67	31.89	0.00	0.00
11/10/95	6:00	165	29.65	2.87	10.51	25.03	0.00	8.08	0.00	30.65	0.00	0.00
11/10/95	14:00	173	29.54	2.61	12.15	25.01	0.00	8.29	2.66	30.31	0.00	0.00
11/10/95	22:00	181	30.94	2.38	14.78	25.01	0.00	4.85	0.00	23.68	0.00	0.00
11/11/95	6:00	189	29.28	0.00	29.28	25.09	0.00	7.70	2.52	26.72	0.00	0.00
11/11/95	14:00	197	28.32	2.58	11.45	25.13						
11/11/95	22:00	205	27.77	2.60	10.74	24.95						
11/12/95	6:00	213	29.54	2.57	12.39	25.01						
11/12/95	14:00	221	29.18	2.94	9.60	24.90	0.90	9.80	3.06	30.81	0.00	0.00

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	HPLC (g/L)						
			Succinic	Lactic	Glycerol	Acetic	EtOH	HMF	furfural
11/2/95	10:20	-23	0.00	2.80	0.42	1.72	0.00	1.66	0.00
11/2/95	15:00	-18	0.00	5.62	0.25	1.98	0.00	0.47	0.00
11/2/95	22:00	-11	0.00	4.08	0.28	1.72	0.00	0.71	0.00
11/3/95	6:00	-3	0.00	3.74	0.00	1.78	0.00	0.34	0.00
11/3/95	22:00	13	0.00	3.78	0.00	1.16	0.00	0.00	0.00
11/4/95	6:00	21	0.00	5.44	0.39	1.62	0.00	0.36	0.00
11/4/95	14:00	29	0.00	3.28	0.00	2.20	0.00	3.95	0.00
11/4/95	22:00	37	0.00	3.64	0.00	1.57	0.00	0.23	0.00
11/5/95	6:00	45	0.00	3.74	0.00	1.25	0.00	0.00	0.00
11/5/95	14:00	53	0.00	5.50	0.42	1.14	0.00	0.00	0.00
11/5/95	22:00	61	0.00	4.73	0.75	2.13	0.00	0.00	0.00
11/6/95	6:00	69	0.00	3.85	0.62	1.89	0.00	0.00	0.00
11/6/95	14:00	77	0.00	4.46	0.00	1.46	0.00	0.00	0.00
11/6/95	22:00	85	0.00	6.62	0.56	1.26	0.00	0.00	0.00
11/7/95	6:00	93	0.00	6.30	0.49	0.82	0.00	0.00	0.00
11/7/95	14:00	101	0.00	5.19	0.18	1.58	0.00	0.00	0.00
11/7/95	22:00	109	0.00	5.07	0.00	1.33	0.00	0.00	0.00
11/8/95	6:00	117	0.00	5.14	0.38	1.28	0.00	0.00	0.00
11/8/95	14:00	125	0.00	6.01	0.28	1.47	0.00	0.00	0.00
11/8/95	22:00	133	0.00	5.53	0.46	2.18	0.00	0.00	0.00
11/9/95	6:00	141	0.00	2.67	0.96	2.72	0.00	0.00	0.00
11/9/95	14:00	149	0.00	1.25	0.18	1.33	0.00	0.00	0.00
11/9/95	22:00	157	0.00	2.60	0.62	1.56	0.00	0.00	0.00
11/10/95	6:00	165	0.00	2.49	0.99	1.72	0.00	0.00	0.00
11/10/95	14:00	173	0.00	2.10	11.15	2.10	0.00	0.18	0.00
11/10/95	22:00	181	0.00	2.02	0.20	1.64	0.00	0.00	0.00
11/11/95	6:00	189	0.00	1.60	0.35	1.99	0.00	0.10	0.00
11/11/95	14:00	197		1.88	0.20	2.14	0.00	0.12	0.00
11/11/95	22:00	205		1.89	0.00	1.92	0.00	0.00	0.00
11/12/95	6:00	213		1.92	0.00	2.04	0.00	0.00	0.00
11/12/95	14:00	221	0.00	1.95	0.00	2.46	0.00	0.00	0.00

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	Liquor Analysis (Total Sugars) Glucose	Xylose	Galactose	Arabinose	Mannose
11/2/95	10:20	-23	70.67	51.91	10.87	42.22	0.00
11/2/95	15:00	-18	80.50	63.09	12.96	49.50	0.00
11/2/95	22:00	-11	75.42	51.08	10.95	44.09	0.00
11/3/95	6:00	-3	73.46	54.17	11.20	43.86	0.00
11/3/95	22:00	13	64.63	27.90	6.51	32.20	0.00
11/4/95	6:00	21	76.26	53.32	11.33	45.13	0.00
11/4/95	14:00	29	71.58	54.84	11.50	44.29	0.00
11/4/95	22:00	37	68.09	43.42	9.43	39.80	0.00
11/5/95	6:00	45	60.55	23.98	5.62	29.96	0.00
11/5/95	14:00	53	60.64	17.12	4.66	22.91	0.00
11/5/95	22:00	61	71.71	33.90	9.34	33.75	0.00
11/6/95	6:00	69	64.49	34.81	8.86	32.13	0.00
11/6/95	14:00	77	72.44	28.48	6.72	34.02	0.00
11/6/95	22:00	85	63.46	16.71	4.15	25.45	0.00
11/7/95	6:00	93	65.62	12.81	3.10	21.76	0.00
11/7/95	14:00	101	63.51	25.29	7.21	31.74	0.00
11/7/95	22:00	109	62.25	18.34	5.54	28.63	0.00
11/8/95	6:00	117	62.67	15.28	4.62	25.04	0.00
11/8/95	14:00	125	70.58	18.42	5.28	28.60	0.00
11/8/95	22:00	133	71.81	30.83	7.99	35.27	0.00
11/9/95	6:00	141	56.24	39.30	9.69	41.37	0.00
11/9/95	14:00	149	53.65	38.69	10.05	39.53	0.00
11/9/95	22:00	157	51.32	34.04	9.04	35.03	0.00
11/10/95	6:00	165	49.40	31.40	8.47	33.00	0.00
11/10/95	14:00	173	50.37	35.56	8.96	37.40	0.00
11/10/95	22:00	181	48.81	22.36	6.09	30.81	0.00
11/11/95	6:00	189	40.58	29.44	17.72	12.56	0.00
11/11/95	14:00	197	50.08	33.68	8.91	35.94	0.00
11/11/95	22:00	205	49.59	33.67	8.75	35.19	0.00
11/12/95	6:00	213	49.84	33.71	8.89	36.21	0.00
11/12/95	14:00	221	49.93	42.05	10.13	41.93	0.00

Run start data 3-Nov-95
Run Name: Amoco CRADA Task 2
Run ID#: P951101CF

Date	Time	Run time (h)	Tot. Solids Oven (%)	TDS Liquid (%)	Ins.Solids (%)	Sample Wt. (g)	HPLC (g/L)					
							Glucose	Xylose	Gal.	Arab.	Man.	Cello.
11/12/95	22:00	229	30.00	2.63	12.33	24.93	0.88	6.93	2.20	26.13	0.00	0.00
11/13/95	6:00	237	31.41	2.44	14.72	24.97	3.89	4.41	1.34	20.24	0.00	0.00
11/13/95	14:00	245	27.83	2.87	9.12	25.06	0.00	9.69	2.95	31.88	0.00	0.00
11/13/95	22:00	253	27.41	2.72	9.82	25.15	0.00	8.62	2.65	30.40	0.00	0.00
11/14/95	6:00	261	27.66	2.68	10.17	25.02	0.00	8.71	2.89	29.89	0.00	0.00
11/14/95	14:00	269	28.67	2.76	10.45	25.04	0.00	8.94	2.85	30.09	0.00	0.00
11/14/95	22:00	277	29.04	2.89	9.86	25.00	1.99	10.32	3.18	32.48	0.00	0.00
11/15/95	6:00	285	28.90	2.91	9.73	25.17	2.37	11.65	3.96	36.08	0.00	3.82
11/15/95	9:30	289	30.90	3.34	8.28	25.02	4.25	16.92	5.09	39.37	0.00	0.00
11/15/95	14:00	293	29.72	3.37	7.10	24.91	6.54	19.56	5.46	38.73	0.00	0.00
11/15/95	22:00	301	27.93	3.13	7.41	24.92	6.32	18.03	4.88	36.03	0.00	0.00
11/16/95	6:00	309	30.58	3.61	6.18	24.97	8.67	25.20	6.77	44.39	0.00	0.00
11/16/95	14:00	317	34.59	3.41	10.30	24.97	6.79	20.32	5.98	40.03	0.00	0.00
11/17/95	0:00	327	31.72	3.23	9.61	25.06	3.37	10.10	3.03	19.84	0.00	0.00
11/17/95	6:00	333	34.75	3.13	12.41	24.92	8.36	21.06	5.95	36.17	0.00	0.00
11/17/95	14:00	341	28.53	3.26	7.03	25.01	7.06	20.07	5.90	37.17	0.00	0.00
11/17/95	22:00	349	28.22	3.50	5.27	25.07	10.14	25.67	7.34	42.50	0.00	0.00
11/18/95	22:00	373	34.60	3.24	11.92	25.44	5.44	16.33	4.99	38.08	0.00	0.00
11/19/95	6:00	381	30.65	3.10	10.16	25.65	3.28	13.21	4.01	34.84	0.00	0.00
11/19/95	14:00	389	27.17	3.10	7.02	24.96	5.31	17.42	5.05	37.67	0.00	0.00
11/19/95	22:00	397	26.31	2.50	10.20	24.94	2.05	9.48	3.38	28.78	0.00	0.00
11/20/95	6:00	405	26.61	2.27	12.01	25.09	0.00	7.85	2.44	29.33	0.00	0.00
11/20/95	14:00	413	32.49	0.00	32.49	25.27	0.00	6.72	2.13	26.69	0.00	0.00
11/20/95	22:00	421	29.35	0.00	29.35	25.31	0.82	5.35	1.78	23.00	0.00	0.00
11/21/95	6:00	429	30.92	0.00	30.92	25.23	0.00	4.94	1.66	21.94	0.00	0.00
11/22/95	6:00	453	29.87	3.20	8.44	24.98	7.83	22.06	6.16	38.13	0.00	0.00
11/22/95	11:00	458	32.46	0.00	32.46	25.25	7.59	17.76	5.51	31.80	0.00	0.00
11/23/95	14:00	485	35.20	0.00	35.20	25.16	7.34	19.08	5.50	31.94	0.00	0.00
11/23/95	22:00	493	33.59	0.00	33.59	25.80	0.39	2.29	0.88	13.04	0.00	0.00
11/24/95	21:00	516	26.52	2.86	8.08	24.98	0.24	2.75	1.18	18.56	0.00	0.00
11/25/95	6:00	525	26.20	2.79	8.39	25.18	2.74	7.08	2.39	26.38	0.00	0.00

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	HPLC (g/L)						
			Succinic	Lactic	Glycerol	Acetic	EtOH	HMF	furfural
11/12/95	22:00	229	0.00	2.11	0.41	1.53	0.00	0.00	0.00
11/13/95	6:00	237	0.00	1.97	0.00	0.00	0.00	0.00	0.00
11/13/95	14:00	245	0.00	2.01	0.41	2.13	0.00	0.15	0.00
11/13/95	22:00	253	0.00	1.98	0.41	2.27	0.00	0.12	0.00
11/14/95	6:00	261	0.00	2.10	0.44	2.05	0.00	0.00	0.00
11/14/95	14:00	269	0.00	2.09	0.47	1.97	0.00	0.15	0.00
11/14/95	22:00	277	0.00	2.20	0.51	2.50	0.00	0.21	0.00
11/15/95	6:00	285	0.00	2.13	0.50	2.54	0.00	0.24	0.00
11/15/95	9:30	289	0.83	2.16	0.46	2.53	0.00	0.34	0.00
11/15/95	14:00	293	0.00	2.08	4.82	2.80	0.00	0.40	0.00
11/15/95	22:00	301	0.00	2.12	4.27	2.37	0.00	0.33	0.00
11/16/95	6:00	309	0.00	2.19	0.49	2.60	0.00	0.46	0.00
11/16/95	14:00	317	0.00	2.30	0.56	3.11	0.00	0.42	0.00
11/17/95	0:00	327	0.00	1.57	0.00	2.88	0.00	0.44	0.00
11/17/95	6:00	333	0.00	1.90	0.41	3.13	0.00	0.41	0.00
11/17/95	14:00	341	0.00	1.25	4.37	2.96	0.00	0.43	0.00
11/17/95	22:00	349	0.00	1.59	0.00	3.42	0.00	0.49	0.00
11/18/95	22:00	373							
11/19/95	6:00	381							
11/19/95	14:00	389							
11/19/95	22:00	397	0.00	0.84	0.00	1.99	0.00	0.10	0.00
11/20/95	6:00	405	0.00	0.71	0.28	2.06	0.00	0.19	0.00
11/20/95	14:00	413	0.00	1.26	0.00	1.59	0.00	0.00	0.00
11/20/95	22:00	421	0.00	0.47	0.00	2.03	0.00	0.00	0.00
11/21/95	6:00	429	0.00	0.62	0.00	1.07	0.00	0.00	0.00
11/22/95	6:00	453	0.00	0.77	0.27	3.51	0.00	0.48	0.00
11/22/95	11:00	458	0.00	1.59	1.74	2.13	0.00	0.25	0.00
11/23/95	14:00	485	0.00	1.82	0.15	2.59	0.00	0.30	0.00
11/23/95	22:00	493	0.00	0.85	0.00	0.54	0.00	0.00	0.00
11/24/95	21:00	516	0.00	0.95	0.00	1.36	0.00	0.00	0.00
11/25/95	6:00	525	0.00	1.43	0.00	1.75	0.00	0.00	0.00

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	Liquor Analysis (Total Sugars) Glucose	Xylose	Galactose	Arabinose	Mannose
11/12/95	22:00	229	49.91	29.24	7.37	34.73	0.00
11/13/95	6:00	237	50.26	21.80	5.66	28.57	0.00
11/13/95	14:00	245	56.07	40.74	10.02	45.05	0.00
11/13/95	22:00	253	50.47	34.57	8.27	40.39	0.00
11/14/95	6:00	261	52.54	34.86	8.42	40.23	0.00
11/14/95	14:00	269	48.65	33.39	8.77	37.97	0.00
11/14/95	22:00	277	49.68	37.30	9.67	40.54	0.00
11/15/95	6:00	285	53.98	43.00	11.62	45.90	0.00
11/15/95	9:30	289	57.12	55.27	13.47	50.96	0.00
11/15/95	14:00	293	59.93	62.93	13.09	50.90	0.00
11/15/95	22:00	301	56.05	55.05	11.64	46.34	0.00
11/16/95	6:00	309	60.87	70.12	14.52	55.23	0.00
11/16/95	14:00	317	58.27	60.57	12.36	46.61	0.00
11/17/95	0:00	327	59.85	60.10	12.09	45.16	0.00
11/17/95	6:00	333	56.71	59.02	12.03	45.33	0.00
11/17/95	14:00	341	59.90	59.07	12.34	48.47	0.00
11/17/95	22:00	349	67.05	69.34	14.15	54.63	0.00
11/18/95	22:00	373					
11/19/95	6:00	381					
11/19/95	14:00	389	58.94	53.02	11.79	44.32	0.00
11/19/95	22:00	397	53.69	32.05	8.12	36.90	0.00
11/20/95	6:00	405	49.95	30.43	7.62	35.08	0.00
11/20/95	14:00	413	11.16	16.86	4.35	33.25	0.00
11/20/95	22:00	421	9.59	13.63	3.46	28.01	0.00
11/21/95	6:00	429	9.43	13.06	3.36	28.30	0.00
11/22/95	6:00	453	61.81	63.97	13.07	51.78	0.00
11/22/95	11:00	458	53.32	45.98	10.42	42.36	0.00
11/23/95	14:00	485	53.23	52.90	11.52	44.99	0.00
11/23/95	22:00	493	40.67	11.90	3.49	21.19	0.00
11/24/95	21:00	516	67.34	16.19	4.64	24.17	0.00
11/25/95	6:00	525	87.02	31.66	7.64	33.50	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CRADA Task 2
Run ID#: P951101CF

Date	Time	Run time (h)	Tot. Solids Oven (%)	TDS Liquid (%)	Ins.Solids (%)	Sample Wt. (g)	HPLC (g/L)					
							Glucose	Xylose	Gal.	Arab.	Man.	Cello.
11/2/95	10:20	-23	27.26	3.18	6.65	25.08	8.58	16.86	5.24	30.68	0.00	0.00
11/2/95	15:00	-18	26.42	3.76	2.22	25.01	10.38	20.49	6.34	36.05	0.00	0.00
11/2/95	22:00	-11	26.84	3.47	4.47	25.10	6.99	15.57	5.06	31.12	0.00	0.00
11/3/95	6:00	-3	28.62	3.41	6.21	25.10	9.14	18.47	5.77	32.45	0.00	0.00
11/3/95	22:00	13	26.75	2.77	9.04	25.26	2.47	7.55	2.96	23.24	0.00	0.00
11/4/95	6:00	21	26.67	3.74	3.37	26.03	8.50	17.00	5.44	32.45	0.00	0.00
11/4/95	14:00	29	27.93	3.54	9.00	25.40	8.84	17.98	5.80	32.24	0.00	0.00
11/4/95	22:00	37	28.31	3.17	8.12	25.94	5.10	12.36	4.08	27.87	0.00	0.00
11/5/95	6:00	45	27.47	2.58	11.04	25.68	1.73	6.20	2.43	21.76	0.00	0.00
11/5/95	14:00	53	30.05	2.37	14.16	25.00	0.00	0.00	0.00	18.48	0.00	0.00
11/5/95	22:00	61	29.21	3.22	7.78	24.94	3.63	10.83	3.91	31.40	0.00	0.00
11/6/95	6:00	69	25.18	2.92	6.69	25.01	3.04	10.07	3.66	27.99	0.00	0.00
11/6/95	14:00	77	28.72	2.14	14.72	25.25	1.56	6.36	1.87	25.37	0.00	0.00
11/6/95	22:00	85	27.99	2.00	14.86	24.95	0.79	3.40	0.94	18.94	0.00	0.00
11/7/95	6:00	93	31.23	1.70	19.69	25.13	0.50	2.25	0.62	14.78	0.00	0.00
11/7/95	14:00	101	29.91	2.66	12.09	25.03	0.00	6.04	0.00	22.95	0.00	0.00
11/7/95	22:00	109	30.20	2.44	13.85	25.08	0.00	4.09	0.00	19.46	0.00	0.00
11/8/95	6:00	117	32.50	2.41	15.81	24.95	0.00	3.40	0.00	17.08	0.00	0.00
11/8/95	14:00	125	29.99	2.75	11.56	25.00						
11/8/95	22:00	133	29.78	2.80	11.15	25.19						
11/9/95	6:00	141	32.55	2.72	13.78	25.07	0.00	9.93	4.73	28.34	0.00	0.00
11/9/95	14:00	149	30.17	2.92	10.54	24.98	0.00	9.69	3.08	34.27	0.00	0.00
11/9/95	22:00	157	30.34	2.68	12.31	25.06	0.00	8.30	2.67	31.89	0.00	0.00
11/10/95	6:00	165	29.65	2.87	10.51	25.03	0.00	8.08	0.00	30.65	0.00	0.00
11/10/95	14:00	173	29.54	2.61	12.15	25.01	0.00	8.29	2.66	30.31	0.00	0.00
11/10/95	22:00	181	30.94	2.38	14.78	25.01	0.00	4.85	0.00	23.68	0.00	0.00
11/11/95	6:00	189	29.28	0.00	29.28	25.09	0.00	7.70	2.52	26.72	0.00	0.00
11/11/95	14:00	197	28.32	2.58	11.45	25.13						
11/11/95	22:00	205	27.77	2.60	10.74	24.95						
11/12/95	6:00	213	29.54	2.57	12.39	25.01						

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	HPLC (g/L)						
			Succinic	Lactic	Glycerol	Acetic	EtOH	HMF	furfural
11/2/95	10:20	-23	0.00	2.80	0.42	1.72	0.00	1.66	0.00
11/2/95	15:00	-18	0.00	5.62	0.25	1.98	0.00	0.47	0.00
11/2/95	22:00	-11	0.00	4.08	0.28	1.72	0.00	0.71	0.00
11/3/95	6:00	-3	0.00	3.74	0.00	1.78	0.00	0.34	0.00
11/3/95	22:00	13	0.00	3.78	0.00	1.16	0.00	0.00	0.00
11/4/95	6:00	21	0.00	5.44	0.39	1.62	0.00	0.36	0.00
11/4/95	14:00	29	0.00	3.28	0.00	2.20	0.00	3.95	0.00
11/4/95	22:00	37	0.00	3.64	0.00	1.57	0.00	0.23	0.00
11/5/95	6:00	45	0.00	3.74	0.00	1.25	0.00	0.00	0.00
11/5/95	14:00	53	0.00	5.50	0.42	1.14	0.00	0.00	0.00
11/5/95	22:00	61	0.00	4.73	0.75	2.13	0.00	0.00	0.00
11/6/95	6:00	69	0.00	3.85	0.62	1.89	0.00	0.00	0.00
11/6/95	14:00	77	0.00	4.46	0.00	1.46	0.00	0.00	0.00
11/6/95	22:00	85	0.00	6.62	0.56	1.26	0.00	0.00	0.00
11/7/95	6:00	93	0.00	6.30	0.49	0.82	0.00	0.00	0.00
11/7/95	14:00	101	0.00	5.19	0.18	1.58	0.00	0.00	0.00
11/7/95	22:00	109	0.00	5.07	0.00	1.33	0.00	0.00	0.00
11/8/95	6:00	117	0.00	5.14	0.38	1.28	0.00	0.00	0.00
11/8/95	14:00	125	0.00	6.01	0.28	1.47	0.00	0.00	0.00
11/8/95	22:00	133	0.00	5.53	0.46	2.18	0.00	0.00	0.00
11/9/95	6:00	141	0.00	2.67	0.96	2.72	0.00	0.00	0.00
11/9/95	14:00	149	0.00	1.25	0.18	1.33	0.00	0.00	0.00
11/9/95	22:00	157	0.00	2.60	0.62	1.56	0.00	0.00	0.00
11/10/95	6:00	165	0.00	2.49	0.99	1.72	0.00	0.00	0.00
11/10/95	14:00	173	0.00	2.10	11.15	2.10	0.00	0.18	0.00
11/10/95	22:00	181	0.00	2.02	0.20	1.64	0.00	0.00	0.00
11/11/95	6:00	189	0.00	1.60	0.35	1.99	0.00	0.10	0.00
11/11/95	14:00	197		1.88	0.20	2.14	0.00	0.12	0.00
11/11/95	22:00	205		1.89	0.00	1.92	0.00	0.00	0.00
11/12/95	6:00	213		1.92	0.00	2.04	0.00	0.00	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	Liquor Analysis (Total Sugars)				
			Glucose	Xylose	Galactose	Arabinose	Mannose
11/2/95	10:20	-23	70.67	51.91	10.87	42.22	0.00
11/2/95	15:00	-18	80.50	63.09	12.96	49.50	0.00
11/2/95	22:00	-11	75.42	51.08	10.95	44.09	0.00
11/3/95	6:00	-3	73.46	54.17	11.20	43.86	0.00
11/3/95	22:00	13	64.63	27.90	6.51	32.20	0.00
11/4/95	6:00	21	76.26	53.32	11.33	45.13	0.00
11/4/95	14:00	29	71.58	54.84	11.50	44.29	0.00
11/4/95	22:00	37	68.09	43.42	9.43	39.80	0.00
11/5/95	6:00	45	60.55	23.98	5.62	29.96	0.00
11/5/95	14:00	53	60.64	17.12	4.66	22.91	0.00
11/5/95	22:00	61	71.71	33.90	9.34	33.75	0.00
11/6/95	6:00	69	64.49	34.81	8.86	32.13	0.00
11/6/95	14:00	77	72.44	28.48	6.72	34.02	0.00
11/6/95	22:00	85	63.46	16.71	4.15	25.45	0.00
11/7/95	6:00	93	65.62	12.81	3.10	21.76	0.00
11/7/95	14:00	101	63.51	25.29	7.21	31.74	0.00
11/7/95	22:00	109	62.25	18.34	5.54	28.63	0.00
11/8/95	6:00	117	62.67	15.28	4.62	25.04	0.00
11/8/95	14:00	125	70.58	18.42	5.28	28.60	0.00
11/8/95	22:00	133	71.81	30.83	7.99	35.27	0.00
11/9/95	6:00	141	56.24	39.30	9.69	41.37	0.00
11/9/95	14:00	149	53.65	38.69	10.05	39.53	0.00
11/9/95	22:00	157	51.32	34.04	9.04	35.03	0.00
11/10/95	6:00	165	49.40	31.40	8.47	33.00	0.00
11/10/95	14:00	173	50.37	35.56	8.96	37.40	0.00
11/10/95	22:00	181	48.81	22.36	6.09	30.81	0.00
11/11/95	6:00	189	40.58	29.44	17.72	12.56	0.00
11/11/95	14:00	197	50.08	33.68	8.91	35.94	0.00
11/11/95	22:00	205	49.59	33.67	8.75	35.19	0.00
11/12/95	6:00	213	49.84	33.71	8.89	36.21	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CRADA Task 2
Run ID#: P951101CF

Date	Time	Run time (h)	Tot. Solids Oven (%)	TDS Liquid (%)	Ins.Solids (%)	Sample Wt. (g)	HPLC (g/L)					
							Glucose	Xylose	Gal.	Arab.	Man.	Cello.
11/12/95	14:00	221	29.18	2.94	9.60	24.90	0.90	9.80	3.06	30.81	0.00	0.00
11/12/95	22:00	229	30.00	2.63	12.33	24.93	0.88	6.93	2.20	26.13	0.00	0.00
11/13/95	6:00	237	31.41	2.44	14.72	24.97	3.89	4.41	1.34	20.24	0.00	0.00
11/13/95	14:00	245	27.83	2.87	9.12	25.06	0.00	9.69	2.95	31.88	0.00	0.00
11/13/95	22:00	253	27.41	2.72	9.82	25.15	0.00	8.62	2.65	30.40	0.00	0.00
11/14/95	6:00	261	27.66	2.68	10.17	25.02	0.00	8.71	2.89	29.89	0.00	0.00
11/14/95	14:00	269	28.67	2.76	10.45	25.04	0.00	8.94	2.85	30.09	0.00	0.00
11/14/95	22:00	277	29.04	2.89	9.86	25.00	1.99	10.32	3.18	32.48	0.00	0.00
11/15/95	6:00	285	28.90	2.91	9.73	25.17	2.37	11.65	3.96	36.08	0.00	3.82
11/15/95	9:30	289	30.90	3.34	8.28	25.02	4.25	16.92	5.09	39.37	0.00	0.00
11/15/95	14:00	293	29.72	3.37	7.10	24.91	6.54	19.56	5.46	38.73	0.00	0.00
11/15/95	22:00	301	27.93	3.13	7.41	24.92	6.32	18.03	4.88	36.03	0.00	0.00
11/16/95	6:00	309	30.58	3.61	6.18	24.97	8.67	25.20	6.77	44.39	0.00	0.00
11/16/95	14:00	317	34.59	3.41	10.30	24.97	6.79	20.32	5.98	40.03	0.00	0.00
11/17/95	0:00	327	31.72	3.23	9.61	25.06	3.37	10.10	3.03	19.84	0.00	0.00
11/17/95	6:00	333	34.75	3.13	12.41	24.92	8.36	21.06	5.95	36.17	0.00	0.00
11/17/95	14:00	341	28.53	3.26	7.03	25.01	7.06	20.07	5.90	37.17	0.00	0.00
11/17/95	22:00	349	28.22	3.50	5.27	25.07	10.14	25.67	7.34	42.50	0.00	0.00
11/18/95	22:00	373	34.60	3.24	11.92	25.44	5.44	16.33	4.99	38.08	0.00	0.00
11/19/95	6:00	381	30.65	3.10	10.16	25.65	3.28	13.21	4.01	34.84	0.00	0.00
11/19/95	14:00	389	27.17	3.10	7.02	24.96	5.31	17.42	5.05	37.67	0.00	0.00
11/19/95	22:00	397	26.31	2.50	10.20	24.94	2.05	9.48	3.38	28.78	0.00	0.00
11/20/95	6:00	405	26.61	2.27	12.01	25.09	0.00	7.85	2.44	29.33	0.00	0.00
11/20/95	14:00	413	32.49	0.00	32.49	25.27	0.00	6.72	2.13	26.69	0.00	0.00
11/20/95	22:00	421	29.35	0.00	29.35	25.31	0.82	5.35	1.78	23.00	0.00	0.00
11/21/95	6:00	429	30.92	0.00	30.92	25.23	0.00	4.94	1.66	21.94	0.00	0.00
11/22/95	6:00	453	29.87	3.20	8.44	24.98	7.83	22.06	6.16	38.13	0.00	0.00
11/22/95	11:00	458	32.46	0.00	32.46	25.25	7.59	17.76	5.51	31.80	0.00	0.00
11/23/95	14:00	485	35.20	0.00	35.20	25.16	7.34	19.08	5.50	31.94	0.00	0.00
11/23/95	22:00	493	33.59	0.00	33.59	25.80	0.39	2.29	0.88	13.04	0.00	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	HPLC (g/L)						
			Succinic	Lactic	Glycerol	Acetic	EtOH	HMF	furfural
11/12/95	14:00	221	0.00	1.95	0.00	2.46	0.00	0.00	0.00
11/12/95	22:00	229	0.00	2.11	0.41	1.53	0.00	0.00	0.00
11/13/95	6:00	237	0.00	1.97	0.00	0.00	0.00	0.00	0.00
11/13/95	14:00	245	0.00	2.01	0.41	2.13	0.00	0.15	0.00
11/13/95	22:00	253	0.00	1.98	0.41	2.27	0.00	0.12	0.00
11/14/95	6:00	261	0.00	2.10	0.44	2.05	0.00	0.00	0.00
11/14/95	14:00	269	0.00	2.09	0.47	1.97	0.00	0.15	0.00
11/14/95	22:00	277	0.00	2.20	0.51	2.50	0.00	0.21	0.00
11/15/95	6:00	285	0.00	2.13	0.50	2.54	0.00	0.24	0.00
11/15/95	9:30	289	0.83	2.16	0.46	2.53	0.00	0.34	0.00
11/15/95	14:00	293	0.00	2.08	4.82	2.80	0.00	0.40	0.00
11/15/95	22:00	301	0.00	2.12	4.27	2.37	0.00	0.33	0.00
11/16/95	6:00	309	0.00	2.19	0.49	2.60	0.00	0.46	0.00
11/16/95	14:00	317	0.00	2.30	0.56	3.11	0.00	0.42	0.00
11/17/95	0:00	327	0.00	1.57	0.00	2.88	0.00	0.44	0.00
11/17/95	6:00	333	0.00	1.90	0.41	3.13	0.00	0.41	0.00
11/17/95	14:00	341	0.00	1.25	4.37	2.96	0.00	0.43	0.00
11/17/95	22:00	349	0.00	1.59	0.00	3.42	0.00	0.49	0.00
11/18/95	22:00	373							
11/19/95	6:00	381							
11/19/95	14:00	389							
11/19/95	22:00	397	0.00	0.84	0.00	1.99	0.00	0.10	0.00
11/20/95	6:00	405	0.00	0.71	0.28	2.06	0.00	0.19	0.00
11/20/95	14:00	413	0.00	1.26	0.00	1.59	0.00	0.00	0.00
11/20/95	22:00	421	0.00	0.47	0.00	2.03	0.00	0.00	0.00
11/21/95	6:00	429	0.00	0.62	0.00	1.07	0.00	0.00	0.00
11/22/95	6:00	453	0.00	0.77	0.27	3.51	0.00	0.48	0.00
11/22/95	11:00	458	0.00	1.59	1.74	2.13	0.00	0.25	0.00
11/23/95	14:00	485	0.00	1.82	0.15	2.59	0.00	0.30	0.00
11/23/95	22:00	493	0.00	0.85	0.00	0.54	0.00	0.00	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	Liquor Analysis (Total Sugars)				
			Glucose	Xylose	Galactose	Arabinose	Mannose
11/12/95	14:00	221	49.93	42.05	10.13	41.93	0.00
11/12/95	22:00	229	49.91	29.24	7.37	34.73	0.00
11/13/95	6:00	237	50.26	21.80	5.66	28.57	0.00
11/13/95	14:00	245	56.07	40.74	10.02	45.05	0.00
11/13/95	22:00	253	50.47	34.57	8.27	40.39	0.00
11/14/95	6:00	261	52.54	34.86	8.42	40.23	0.00
11/14/95	14:00	269	48.65	33.39	8.77	37.97	0.00
11/14/95	22:00	277	49.68	37.30	9.67	40.54	0.00
11/15/95	6:00	285	53.98	43.00	11.62	45.90	0.00
11/15/95	9:30	289	57.12	55.27	13.47	50.96	0.00
11/15/95	14:00	293	59.93	62.93	13.09	50.90	0.00
11/15/95	22:00	301	56.05	55.05	11.64	46.34	0.00
11/16/95	6:00	309	60.87	70.12	14.52	55.23	0.00
11/16/95	14:00	317	58.27	60.57	12.36	46.61	0.00
11/17/95	0:00	327	59.85	60.10	12.09	45.16	0.00
11/17/95	6:00	333	56.71	59.02	12.03	45.33	0.00
11/17/95	14:00	341	59.90	59.07	12.34	48.47	0.00
11/17/95	22:00	349	67.05	69.34	14.15	54.63	0.00
11/18/95	22:00	373					
11/19/95	6:00	381					
11/19/95	14:00	389	58.94	53.02	11.79	44.32	0.00
11/19/95	22:00	397	53.69	32.05	8.12	36.90	0.00
11/20/95	6:00	405	49.95	30.43	7.62	35.08	0.00
11/20/95	14:00	413	11.16	16.86	4.35	33.25	0.00
11/20/95	22:00	421	9.59	13.63	3.46	28.01	0.00
11/21/95	6:00	429	9.43	13.06	3.36	28.30	0.00
11/22/95	6:00	453	61.81	63.97	13.07	51.78	0.00
11/22/95	11:00	458	53.32	45.98	10.42	42.36	0.00
11/23/95	14:00	485	53.23	52.90	11.52	44.99	0.00
11/23/95	22:00	493	40.67	11.90	3.49	21.19	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CRADA Task 2
Run ID#: P951101CF

Date	Time	Run time (h)	Tot. Solids Oven (%)	TDS Liquid (%)	Ins.Solids (%)	Sample Wt. (g)	HPLC (g/L)					
							Glucose	Xylose	Gal.	Arab.	Man.	Cello.
11/24/95	21:00	516	26.52	2.86	8.08	24.98	0.24	2.75	1.18	18.56	0.00	0.00
11/25/95	6:00	525	26.20	2.79	8.39	25.18	2.74	7.08	2.39	26.38	0.00	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	HPLC (g/L)						
			Succinic	Lactic	Glycerol	Acetic	EtOH	HMF	furfural
11/24/95	21:00	516	0.00	0.95	0.00	1.36	0.00	0.00	0.00
11/25/95	6:00	525	0.00	1.43	0.00	1.75	0.00	0.00	0.00

APR Sample Data

Run start data 3-Nov-95
Run Name: Amoco CR
Run ID#: P951101CI

Date	Time	Run time (h)	Liquor Analysis (Total Sugars)				
			Glucose	Xylose	Galactose	Arabinose	Mannose
11/24/95	21:00	516	67.34	16.19	4.64	24.17	0.00
11/25/95	6:00	525	87.02	31.66	7.64	33.50	0.00

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A YSI Gluc (g/L)	455A YSI EtOH (g/L)	455A pH Micro	455A Total Solids Oven (%)	455A HPLC (g/L) Glucose	455A Xylose	455A Gal.	455A Arab.	455A Man.	455A Cello.	455A Succinic	455A Lactic	455A Glycerol	455A Acetic
11/3/95	8:15	-0.75	5.54	0.43	4.25	20.65	7.75	11.11	3.38	20.40	0.00	0.00	0.00	4.14	0.61	3.03
11/3/95	10:00	1	5.08	0.66	4.05	19.17	6.41	10.47	3.05	18.83	0.00	0.00	0.00	4.52	0.75	2.85
11/3/95	10:15	1.25				19.05	6.24	10.33	3.05	18.54	0.00	0.00	0.00	4.44	0.67	2.75
11/3/95	13:00	4	4.71	0.92	4.18											
11/3/95	13:15	4.25				19.29	3.96	10.33	3.07	18.73	0.00	0.00	0.00	4.46	0.82	2.94
11/3/95	15:10	6.17				18.47	1.33	9.81	2.83	17.40	0.00	0.00	0.00	5.59	1.20	2.82
11/3/95	15:15	6.25	3.10	1.73	4.84	20.34	1.37	10.09	2.99	18.10	0.00	0.00	0.00	4.96	0.97	2.86
11/3/95	18:10	9.17	0.28	3.65	4.75											
11/3/95	22:00	13.00	0.26	3.95	4.58											
11/4/95	2:00	17.00				21.85	1.30	9.92	1.80	19.66	0.00	0.00	0.00	4.77	1.14	3.29
11/4/95	2:15	17.25	0.20	6.33	5.33	19.38	2.36	10.18	2.83	18.17	0.00	7.42	0.00	4.99	1.02	2.65
11/4/95	3:00	18.00	0.20	6.43	5.20	19.43	2.87	10.20	2.25	18.25	0.00	7.19	0.00	5.08	1.17	2.89
11/4/95	6:00	21.00	0.17	6.86	5.20											
11/4/95	10:00	25.00	0.22	7.21	5.17	20.22	1.22	9.63	1.73	18.43	0.00	0.00	0.00	4.99	1.16	3.08
11/4/95	14:10	29.17	0.25	9.88	5.17											
11/4/95	18:10	33.17		8.49		21.32	1.22	10.31	1.92	19.76	0.00	0.00	0.00	4.85	1.15	3.33
11/4/95	22:00	37.00	0.32	8.20	5.18											
11/5/95	2:00	41.00	0.44	8.94	5.10											
11/5/95	6:00	45.00	0.50	8.60	5.11											
11/5/95	10:15	49.25	0.38	7.34	5.08	21.77	1.80	9.89	2.11	19.40	0.00	7.49	0.00	6.02	5.60	8.73
11/5/95	14:00	53.00	0.11	8.31	5.11											
11/5/95	18:05	57.08	0.49	8.04	4.35	21.77	1.75	9.04	2.02	18.40	0.00	8.02	0.00	5.40	1.23	3.32
11/5/95	22:00	61.00	0.54	9.02	4.18											
11/6/95	2:00	65.00	0.48	8.22	4.09	23.41	2.16	8.55	1.90	18.68	0.00	8.80	0.00	5.71	1.23	3.57
11/6/95	6:00	69.00	1.34	7.72	4.10											
11/6/95	10:00	73.00	1.78	7.41	4.10		3.51	8.25	1.75	19.65	0.00	7.40	0.00	5.88	1.17	3.34
11/6/95	14:00	77.00	2.18	6.27	4.10											
11/6/95	18:00	81.00	2.56	6.93	4.10	24.60	2.26	8.10	1.81	19.73	0.00	9.30	0.00	5.94	1.21	3.30
11/6/95	22:00	85.00	2.28	6.32	3.83											
11/7/95	2:00	89.00	2.39	7.48	3.70	23.42	4.74	8.04	1.82	19.84	0.00	9.30	0.00	5.87	1.14	3.05
11/7/95	6:30	93.50	2.55	5.46	3.33											
11/7/95	10:00	97.00	2.84	6.68	3.97											
11/7/95	14:00	101.00	2.95	5.20	4.00											
11/7/95	18:00	105.00	2.73	7.05	4.55											
11/7/95	22:00	109.00	2.32	6.54	4.93											
11/8/95	2:00	113.00	2.51	7.56	4.91											
11/8/95	6:00	117.00	2.41	5.44	4.67											
11/8/95	10:00	121.00	2.13	5.93	4.85	25.30										
11/8/95	14:15	125.00	1.99	5.63	4.88											
11/8/95	18:15	129.25	2.15	4.75	4.96	25.72										
11/8/95	22:00	133.00	2.58	4.50	4.96											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A YSI Gluc (g/L)	455A YSI EtOH (g/L)	455A pH Micro	455A Total Solids Oven (%)	455A Glucose	455A Xylose	455A Gal.	455A Arab.	455A Man.	455A Cello.	455A Succinic	455A Lactic	455A Glycerol	455A Acetic
							HPLC (g/L)									
11/9/95	2:00	137.00	2.68	6.36	4.85	24.80										
11/9/95	6:00	141.00	2.82	4.78	4.92											
11/9/95	10:00	145.00	3.31	4.30	4.87	24.59										
11/9/95	14:10	149.00	3.56	3.98	5.24								0.00	10.86	0.68	4.99
11/9/95	18:15	153.25	4.68	4.84	4.75											
11/9/95	22:00	157.00	8.00	3.96	4.60											
11/10/95	2:00	161.00	6.96	4.02	4.87											
11/10/95	2:15	161.25				20.82										
11/10/95	6:00	165.00	5.92	4.00	4.96								0.00	10.59	1.35	6.41
11/10/95	10:00	169.00	3.30	3.22	4.93	21.62										
11/10/95	14:00	173.00	0.40	4.44	5.18								0.00	9.32	3.30	5.51
11/10/95	18:00	177.00	0.30	5.56	5.00	22.12										
11/10/95	22:00	181.00	1.12	5.10	4.89								0.00	8.49	3.40	5.26
11/11/95	2:00	185.00	0.84	6.09	4.82	23.29										
11/11/95	6:00	189.00	1.40	5.60	4.83								0.00	7.37	3.65	4.88
11/11/95	10:00	193.00	1.21	4.12	4.83	24.00										
11/11/95	14:00	197.00	1.30	5.44	4.85								0.00	6.18	1.48	4.50
11/11/95	18:00	201.00	1.19	5.34	4.98	25.46										
11/11/95	22:00	205.00	1.21	4.28	4.97								0.00	5.54	1.53	4.35
11/12/95	2:00	209.00	1.36	4.63	4.98	24.95										
11/12/95	6:00	213.00	1.30	5.30	4.94								0.00	7.22	2.26	6.02
11/12/95	10:00	217.00	1.15	2.86	4.95	22.86										
11/12/95	14:00	221.00	1.06	4.04	4.97											
11/12/95	18:00	225.00	1.05	3.94	4.90	24.70										
11/12/95	22:05	229.00	0.84	2.78	4.91											
11/13/95	2:30	233.50	0.66	5.30	4.91	24.18										
11/13/95	6:15	237.00	0.79	5.12	4.87											
11/13/95	10:00	241.00	0.86	4.50	4.86											
11/13/95	14:00	245.00	0.71	4.08	4.89											
11/13/95	18:00	249.00	1.19	4.16	4.97											
11/13/95	22:00	253.00	1.75	4.28	4.80											
11/14/95	2:00	257.00	2.79	4.73	4.83											
11/14/95	6:00	261.00		4.19	4.84											
11/14/95	10:30	265.50	4.21	3.71	4.83											
11/14/95	14:00	269.00	4.76	3.84	5.03											
11/14/95	18:00	273.00	4.56	3.54	5.00											
11/14/95	22:00	277.00	6.39	2.76	5.01											
11/15/95	10:15	289.25	12.40	2.88	5.14											
11/15/95	14:00	293.00	15.70	2.74	5.17											
11/15/95	18:00	297.00	16.80	2.48	5.13		19.82	10.97	3.37	25.46	3.77	6.82	0.00	7.99	1.11	6.89
11/15/95	22:00	301.00	15.30	2.38	4.99											
11/16/95	2:00	305.00	10.50	2.86	4.87		14.15	10.65	3.23	23.51	2.81	5.79	0.00	5.88	0.96	5.23

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A YSI Gluc (g/L)	455A YSI EtOH (g/L)	455A pH Micro	455A Total Solids Oven (%)	455A Glucose	455A Xylose	455A Gal.	455A Arab.	455A Man.	455A Cello.	455A Succinic	455A Lactic	455A Glycerol	455A Acetic
							HPLC (g/L)									
11/16/95	6:00	309.00	6.87	3.62	4.76											
11/16/95	10:00	313.00	3.19	4.68	4.92		2.20	11.55	3.41	23.52	0.00	4.84	0.00	5.24	3.99	5.18
11/16/95	14:00	317.00	0.48	5.04	4.98											
11/16/95	18:00	321.00	0.76	5.18	4.75		1.88	13.02	3.71	24.82	0.00	5.33	0.00	4.28	3.45	4.36
11/16/95	22:15	325.25	0.33	8.26	5.53											
11/17/95	2:10	329.17					2.06	14.22	3.78	25.92	0.00	5.67	0.00	3.61	3.88	4.36
11/17/95	2:20	329.30	0.80	9.86	4.41											
11/17/95	6:00	334.00	0.79	9.16	5.04											
11/17/95	10:00	337.00	0.68	6.66	5.06		2.31	14.77	3.70	26.52	0.00	5.75	0.00	3.47	1.44	4.81
11/17/95	14:00	341.00	0.75	5.98	4.88											
11/17/95	18:00	345.00	2.10	5.70	4.55		2.65	15.14	3.62	27.24	0.00	6.46	0.00	2.71	2.34	3.95
11/17/95	22:00	349.00	1.34	9.40	5.15											
11/18/95	2:00	353.00	1.12	7.42	5.08		2.34	14.15	3.33	25.33	0.00	6.32	0.00	2.46	3.41	3.98
11/18/95	6:00	357.00	0.96	6.84	5.20											
11/18/95	10:15	361.25	0.53	8.51	5.20		2.66	15.99	3.30	28.38	0.00	6.79				
11/18/95	14:00	365.00	0.62	9.46	5.38											
11/18/95	18:00	369.00	0.53	7.95	5.10		2.59	16.04	2.97	27.96	0.00	6.94				
11/18/95	22:00	373.00	0.76	7.88	5.13											
11/19/95	2:00	377.00	1.36	11.50	4.84		2.92	16.12	3.04	28.97	0.00	6.87				
11/19/95	6:00	381.00	0.94	9.12	4.99											
11/19/95	10:00	385.00	0.72	7.64	5.03		5.93	15.20	3.08	28.61	0.00	4.38	0.00	2.47	1.58	4.73
11/19/95	14:00	389.00	0.77	9.11	5.14											
11/19/95	18:00	393.00	1.08	9.69	5.10		5.82	14.72	3.13	28.07	0.00	4.52	0.00	1.68	0.89	3.77
11/19/95	22:00	397.00	0.86	6.46	5.09											
11/20/95	2:00	401.00	0.86	6.46	5.09		5.98	13.66	2.86	28.08	0.00	4.83	0.00	1.91	1.16	3.89
11/20/95	6:00	405.00	1.06	9.00	5.06											
11/20/95	10:00	409.00	0.70	11.48	5.12		5.56	11.94	2.46	26.99	0.00	5.00	0.00	2.02	1.62	4.46
11/20/95	14:00	413.00	0.78	10.56	5.12											
11/20/95	18:00	417.00	0.93	10.18	5.04		5.85	11.03	2.28	26.88	0.00	5.85	0.00	2.00	1.45	3.83
11/20/95	22:00	421.00	0.74	12.90	5.13											
11/21/95	2:00	425.00	0.72	10.94	5.13		5.74	9.91	2.05	26.15	0.00	4.77	0.00	1.99	1.22	3.46
11/21/95	6:00	429.00	0.72	11.40	5.11											
11/21/95	10:00	433.00	0.75	9.56	5.17											
11/21/95	14:00	437.00	0.53	8.08	5.51											
11/21/95	18:00	441.00	0.92	8.72	5.10											
11/21/95	22:00	445.00	0.75	6.92	5.01											
11/22/95	2:00	449.00	1.80	5.24	5.00											
11/22/95	3:45	450.75	0.00	7.01	4.95											
11/22/95	6:00	453.00	2.56	6.76	5.13											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A HPLC (g/L) EtOH	455A HPLC (g/L) HMF	455A HPLC (g/L) furfural	455A GC Ethanol	455A Liquor Analysis (Total Dissolved Sugars) Glucose	455A Liquor Analysis (Total Dissolved Sugars) Xylose	455A Liquor Analysis (Total Dissolved Sugars) Galactose	455A Liquor Analysis (Total Dissolved Sugars) Arabinose	455A Liquor Analysis (Total Dissolved Sugars) Mannose	455A Lactic (YSI) (g/L)
11/3/95	8:15	-0.75		0.20	0.00		49.13	36.00	6.93	25.93	0.00	
11/3/95	10:00	1		0.18	0.00	1.45	45.61	33.58	6.81	25.60	0.00	
11/3/95	10:15	1.25		0.07	0.00	1.42	42.95	31.63	6.39	23.86	0.00	
11/3/95	13:00	4										
11/3/95	13:15	4.25		0.05	0.00	2.88	43.53	33.83	6.70	25.37	0.00	
11/3/95	15:10	6.17		0.24	0.00	4.91	39.41	31.67	6.38	23.41	0.00	
11/3/95	15:15	6.25		0.06	0.00	4.40	40.40	32.96	6.54	24.16	0.00	
11/3/95	18:10	9.17										
11/3/95	22:00	13.00										
11/4/95	2:00	17.00		0.21	0.00		42.70	34.74	6.56	26.33	0.00	
11/4/95	2:15	17.25		0.21	0.00	7.58	40.59	33.41	5.79	24.84	0.00	
11/4/95	3:00	18.00		0.21	0.00	7.89	29.99	33.58	5.73	24.87	0.00	
11/4/95	6:00	21.00										
11/4/95	10:00	25.00		0.19	0.00	8.64	40.59	34.31	5.81	25.15	0.00	
11/4/95	14:10	29.17										
11/4/95	18:10	33.17		0.25	0.00	8.93	43.49	37.01	6.29	26.86	0.00	
11/4/95	22:00	37.00										
11/5/95	2:00	41.00										
11/5/95	6:00	45.00										
11/5/95	10:15	49.25	N/A	0.00	0.05	9.81	46.71	48.00	7.30	27.13	0.00	
11/5/95	14:00	53.00										
11/5/95	18:05	57.08		0.00	0.05	9.40	47.91	42.98	6.94	25.38	0.00	
11/5/95	22:00	61.00										
11/6/95	2:00	65.00	N/A	0.00	0.02	8.64	52.56	44.64	7.39	26.46	0.00	
11/6/95	6:00	69.00										
11/6/95	10:00	73.00		0.16	0.00							
11/6/95	14:00	77.00										
11/6/95	18:00	81.00		0.11	0.00	7.71	58.65	36.15	6.81	28.10	0.00	
11/6/95	22:00	85.00										
11/7/95	2:00	89.00		0.11	0.00	6.82	60.07	35.26	6.71	28.04	0.00	
11/7/95	6:30	93.50										
11/7/95	10:00	97.00										
11/7/95	14:00	101.00										
11/7/95	18:00	105.00										
11/7/95	22:00	109.00										
11/8/95	2:00	113.00										
11/8/95	6:00	117.00										
11/8/95	10:00	121.00										
11/8/95	14:15	125.00					52.55	28.04	6.24	18.66	0.00	
11/8/95	18:15	129.25										
11/8/95	22:00	133.00					36.91	26.90	6.28	16.51	0.00	

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A HPLC (g/L) EtOH	455A HMF	455A furfural	455A GC Ethanol	455A Liquor Analysis (Total Dissolved Sugars) Glucose	455A Xylose	455A Galactose	455A Arabinose	455A Mannose	455A Lactic (YSI) (g/L)
11/9/95	2:00	137.00				5.92	54.03	29.64	7.22	20.52	0.00	
11/9/95	6:00	141.00										
11/9/95	10:00	145.00		0.00	0.47	4.82	29.19	18.71	5.14	13.64	0.00	10.60
11/9/95	14:10	149.00										11.30
11/9/95	18:15	153.25										
11/9/95	22:00	157.00										
11/10/95	2:00	161.00										
11/10/95	2:15	161.25		0.00	0.03	4.28	37.85	21.23	5.26	16.40	0.00	
11/10/95	6:00	165.00										
11/10/95	10:00	169.00		0.14	0.00	5.95	23.82	22.07	5.03	18.67	0.00	5.70
11/10/95	14:00	173.00										5.28
11/10/95	18:00	177.00		0.15	0.00	6.58	25.86	24.96	5.53	20.54	0.00	
11/10/95	22:00	181.00										
11/11/95	2:00	185.00		0.15	0.00	5.72	23.19	25.20	5.36	21.27	0.00	
11/11/95	6:00	189.00										
11/11/95	10:00	193.00		0.06	0.00							
11/11/95	14:00	197.00										
11/11/95	18:00	201.00		0.05	0.00							
11/11/95	22:00	205.00										2.98
11/12/95	2:00	209.00		0.10	0.00							2.93
11/12/95	6:00	213.00										2.73
11/12/95	10:00	217.00										2.60
11/12/95	14:00	221.00										2.72
11/12/95	18:00	225.00										2.32
11/12/95	22:05	229.00										2.40
11/13/95	2:30	233.50										2.08
11/13/95	6:15	237.00										2.50
11/13/95	10:00	241.00										2.86
11/13/95	14:00	245.00										3.24
11/13/95	18:00	249.00										4.20
11/13/95	22:00	253.00										5.40
11/14/95	2:00	257.00										6.47
11/14/95	6:00	261.00										
11/14/95	10:30	265.50										
11/14/95	14:00	269.00										7.01
11/14/95	18:00	273.00										7.19
11/14/95	22:00	277.00										7.30
11/15/95	10:15	289.25										7.82
11/15/95	14:00	293.00										6.40
11/15/95	18:00	297.00		0.12	0.00	1.55	52.38	38.34	8.24	29.04	0.00	3.10
11/15/95	22:00	301.00										5.36
11/16/95	2:00	305.00		0.13	0.00	2.62	48.81	37.66	7.73	27.73	0.00	4.60
												3.79

All 9000-L Fermenter Data

Date	Time	Run time (h)	455A HPLC (g/L) EtOH	455A HPLC (g/L) HMF	455A HPLC (g/L) furfural	455A GC Ethanol	455A Liquor Analysis (Total Dissolved Sugars) Glucose	455A Xylose	455A Galactose	455A Arabinose	455A Mannose	455A Lactic (YSI) (g/L)
11/16/95	6:00	309.00										
11/16/95	10:00	313.00		0.47	0.00	8.55	32.04	38.61	7.46	27.65	0.00	3.10
11/16/95	14:00	317.00										2.88
11/16/95	18:00	321.00		0.21	0.00	9.39	35.63	45.23	8.57	31.80	0.00	2.50
11/16/95	22:15	325.25										2.20
11/17/95	2:10	329.17		0.23	0.00	10.06	36.87	48.20	8.80	33.36	0.00	
11/17/95	2:20	329.30										2.20
11/17/95	6:00	334.00										2.02
11/17/95	10:00	337.00		0.22	0.00	9.66	38.08	48.51	8.96	34.49	0.00	2.22
11/17/95	14:00	341.00										1.38
11/17/95	18:00	345.00		0.23	0.00	10.22	41.55	50.35	9.26	35.52	0.00	
11/17/95	22:00	349.00										1.72
11/18/95	2:00	353.00		0.23	0.00	10.64	40.21	50.99	9.24	35.82	0.00	1.53
11/18/95	6:00	357.00										1.58
11/18/95	10:15	361.25				11.16						1.35
11/18/95	14:00	365.00										1.31
11/18/95	18:00	369.00				12.24						1.23
11/18/95	22:00	373.00										1.44
11/19/95	2:00	377.00				13.08						1.34
11/19/95	6:00	381.00										1.42
11/19/95	10:00	385.00		0.30	0.00	12.56	37.47	44.93	7.80	30.05	0.00	0.96
11/19/95	14:00	389.00										
11/19/95	18:00	393.00		0.25	0.00	12.47	37.16	44.55	7.65	29.72	0.00	1.01
11/19/95	22:00	397.00										1.20
11/20/95	2:00	401.00		0.23	0.00	12.26	38.76	42.97	7.50	29.57	0.00	1.20
11/20/95	6:00	405.00										1.02
11/20/95	10:00	409.00		0.00	0.00	12.00	44.50	44.05	8.37	35.55	0.00	0.90
11/20/95	14:00	413.00										0.88
11/20/95	18:00	417.00		0.18	0.00	11.53	37.42	44.41	9.05	32.94	0.00	0.92
11/20/95	22:00	421.00										0.95
11/21/95	2:00	425.00		0.03	0.06	10.68	43.97	37.70	7.69	32.00	0.00	1.02
11/21/95	6:00	429.00										1.24
11/21/95	10:00	433.00										1.69
11/21/95	14:00	437.00										2.78
11/21/95	18:00	441.00										3.68
11/21/95	22:00	445.00										4.90
11/22/95	2:00	449.00										5.22
11/22/95	3:45	450.75										
11/22/95	6:00	453.00										5.36

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B YSI Gluc (g/L)	455B YSI EtOH (g/L)	455B pH Micro	455B Total Solids Oven (%)	455B Total Solids TDS (%)	455B HPLC (g/L) Glucose	455B HPLC (g/L) Xylose	455B HPLC (g/L) Gal.	455B HPLC (g/L) Arab.	455B HPLC (g/L) Man.	455B HPLC (g/L) Cello.	455B HPLC (g/L) Succinic	455B HPLC (g/L) Lactic	455B HPLC (g/L) Glycerol
11/3/95	8:15	-0.75														
11/3/95	10:00	1														
11/3/95	10:15	1.25														
11/3/95	13:00	4														
11/3/95	13:15	4.25														
11/3/95	15:10	6.17														
11/3/95	15:15	6.25														
11/3/95	18:10	9.17														
11/3/95	22:00	13.00														
11/4/95	2:00	17.00				20.71		1.40	9.86	1.75	18.74	0.00	0.00	0.00	4.53	0.84
11/4/95	2:15	17.25														
11/4/95	3:00	18.00														
11/4/95	6:00	21.00														
11/4/95	10:00	25.00														
11/4/95	14:10	29.17	0.23	8.67	5.20											
11/4/95	18:10	33.17	0.20	8.85	5.07	20.43		1.31	9.68	1.71	18.47	0.00	0.00	0.00	4.64	0.84
11/4/95	22:00	37.00	2.86	5.72	5.03											
11/5/95	2:00	41.00	0.28	8.86	5.03											
11/5/95	6:00	45.00	0.28	9.22	5.08											
11/5/95	10:15	49.25	0.14	9.90	5.13	20.65		1.53	9.89	1.76	18.78	0.00	0.00	0.00	4.57	1.21
11/5/95	14:00	53.00	0.31	9.85	5.08											
11/5/95	18:05	57.08	0.33	10.40	4.17	20.08		1.64	10.56	2.18	18.10	0.00	8.13	0.00	5.28	1.39
11/5/95	22:00	61.00	0.36	10.86	4.30											
11/6/95	2:00	65.00	0.82	11.30	4.10	20.91	3.74	1.70	10.12	2.11	17.56	0.00	8.82	0.00	6.08	1.45
11/6/95	6:00	69.00	0.58	10.84	4.13											
11/6/95	10:00	73.00	0.55	10.30	4.12			2.27	9.05	1.72	17.80	0.00	8.11	0.00	6.78	1.29
11/6/95	14:00	77.00	0.64	9.88	4.10											
11/6/95	18:00	81.00	0.87	10.00	4.11	21.46		2.17	8.83	1.67	16.74	0.00	8.63	0.00	7.86	1.54
11/6/95	22:00	85.00	0.84	10.62	4.08											
11/7/95	2:00	89.00	1.00	11.00	4.08	21.70	2.58	2.53	8.70	1.67	16.58	0.00	8.93	0.00	8.40	1.87
11/7/95	6:30	93.50	1.29	13.20	4.01											
11/7/95	10:00	97.00	1.55	11.48	4.13											
11/7/95	14:00	101.00	1.95	9.56	4.14											
11/7/95	18:00	105.00	1.66	10.48	4.91											
11/7/95	22:00	109.00	0.97	10.60	4.84											
11/8/95	2:00	113.00	0.80	10.84	4.92											
11/8/95	6:00	117.00	0.79	10.52	4.98											
11/8/95	10:00	121.00	0.89	10.28	4.98	21.41										
11/8/95	14:15	125.00	1.06	9.10	4.99											
11/8/95	18:15	129.25	1.22	8.68	5.01	18.34										
11/8/95	22:00	133.00	1.48	9.28	5.03											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B YSI Gluc (g/L)	455B YSI EtOH (g/L)	455B pH Micro	455B Total Solids Oven (%)	455B Total Solids TDS (%)	455B HPLC (g/L) Glucose	455B Xylose	455B Gal.	455B Arab.	455B Man.	455B Cello.	455B Succinic	455B Lactic	455B Glycerol
11/9/95	2:00	137.00	1.86	9.24	4.99	22.18										
11/9/95	6:00	141.00	1.80	9.46	4.96											
11/9/95	10:00	145.00	1.96	7.96	4.90	24.86										
11/9/95	14:10	149.00	2.65	7.12	4.88									0.00	15.92	2.77
11/9/95	18:15	153.25	2.64	7.56	4.93											
11/9/95	22:00	157.00	5.38	7.24	5.00											
11/10/95	2:00	161.00	5.74	6.16	4.93											
11/10/95	2:15	161.25				22.97										
11/10/95	6:00	165.00	6.16	6.18	5.03									0.00	18.86	1.73
11/10/95	10:00	169.00	6.40	5.40	5.01	22.16										
11/10/95	14:00	173.00	5.02	5.80	4.99									0.00	16.92	3.19
11/10/95	18:00	177.00	3.12	6.80	4.98	22.42										
11/10/95	22:00	181.00	1.92	6.69	4.96									0.00	14.50	3.40
11/11/95	2:00	185.00	1.33	7.84	4.90	22.51										
11/11/95	6:00	189.00	1.70	7.49	4.92									0.00	13.84	1.78
11/11/95	10:00	193.00	0.97	8.60	4.89	23.06										
11/11/95	14:00	197.00	1.11	9.50	4.90									0.00	12.87	1.93
11/11/95	18:00	201.00	1.17	7.70	4.96	23.26										
11/11/95	22:00	205.00	1.35	7.43	5.04									0.00	11.06	1.68
11/12/95	2:00	209.00	1.49	7.19	5.04	24.34										
11/12/95	6:00	213.00	1.48	7.24	5.01									0.00	9.75	1.82
11/12/95	10:00	217.00	1.21	6.10	5.00	23.11										
11/12/95	14:00	221.00	1.08	7.94	5.02											
11/12/95	18:00	225.00	1.05	7.38	4.96	22.70										
11/12/95	22:05	229.00	0.89	6.96	5.00											
11/13/95	2:30	233.50	0.85	6.77	4.97	23.62										
11/13/95	6:15	237.00	0.70	6.73	4.91											
11/13/95	10:00	241.00	0.82	6.88	4.85											
11/13/95	14:00	245.00	0.64	5.82	4.88											
11/13/95	18:00	249.00	0.61	6.01	4.90											
11/13/95	22:00	253.00	0.57	6.23	4.83											
11/14/95	2:00	257.00	0.62	6.70	4.83											
11/14/95	6:00	261.00		5.83	4.86											
11/14/95	10:30	265.50	1.12	7.64	4.83											
11/14/95	14:00	269.00	1.50	6.22	5.01											
11/14/95	18:00	273.00	1.78	5.51	5.01											
11/14/95	22:00	277.00	2.86	5.72	5.03											
11/15/95	10:15	289.25	6.95	4.96	5.10											
11/15/95	14:00	293.00	9.10	5.44	5.16											
11/15/95	18:00	297.00	11.30	4.46	5.17			13.67	6.14	2.17	16.64	2.36	4.74	0.00	14.30	1.28
11/15/95	22:00	301.00	11.80	4.36	5.13											
11/16/95	2:00	305.00	11.10	3.80	4.98			16.32	7.90	2.60	19.78	2.68	5.54	0.00	11.76	1.11

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B YSI Gluc (g/L)	455B YSI EtOH (g/L)	455B pH Micro	455B Total Solids Oven (%)	455B Total Solids TDS (%)	455B HPLC (g/L) Glucose	455B HPLC (g/L) Xylose	455B HPLC (g/L) Gal.	455B HPLC (g/L) Arab.	455B HPLC (g/L) Man.	455B HPLC (g/L) Cello.	455B HPLC (g/L) Succinic	455B HPLC (g/L) Lactic	455B HPLC (g/L) Glycerol
11/16/95	6:00	309.00	12.00	4.04	4.76											
11/16/95	10:00	313.00	9.95	4.56	5.08			9.52	8.60	2.73	20.61	0.00	5.38	0.00	9.83	1.24
11/16/95	14:00	317.00	3.95	7.94	5.09											
11/16/95	18:00	321.00	0.40	9.26	5.08			1.60	9.42	2.88	21.12	0.00	4.81	0.00	8.83	2.16
11/16/95	22:15	325.25	0.33	11.52	5.12											
11/17/95	2:10	329.17						1.58	10.06	2.97	21.62	0.00	4.92	0.00	7.85	1.89
11/17/95	2:20	329.30	0.44	10.08	5.08											
11/17/95	6:00	334.00	0.52	9.86	5.04											
11/17/95	10:00	337.00	0.80	11.74	5.06			1.98	11.08	3.10	22.63	0.00	5.00	0.00	6.39	2.93
11/17/95	14:00	341.00	0.60	8.82	5.25											
11/17/95	18:00	345.00	0.17	12.14	5.17			1.93	11.89	3.09	23.14	0.00	5.46	0.00	5.48	1.97
11/17/95	22:00	349.00	0.96	11.28	5.27											
11/18/95	2:00	353.00	0.67	12.90	5.16			2.00	12.49	3.04	23.74	0.00	5.84	0.00	5.04	1.45
11/18/95	6:00	357.00	0.86	10.76	5.21											
11/18/95	10:15	361.25	0.53	12.82	5.10			2.24	13.71	3.07	25.60	0.00	5.82			
11/18/95	14:00	365.00	0.61	12.62	5.25											
11/18/95	18:00	369.00	0.54	11.82	5.18			2.21	13.90	2.94	25.71	0.00	5.91			
11/18/95	22:00	373.00	0.64	11.50	5.20											
11/19/95	2:00	377.00	0.90	13.10	5.15			2.28	14.27	2.87	26.15	0.00	5.87			
11/19/95	6:00	381.00	1.04	12.88	4.99											
11/19/95	10:00	385.00	0.59	11.42	5.12			5.05	14.54	2.90	27.40	0.00	4.08	0.00	3.81	1.36
11/19/95	14:00	389.00	0.55	15.68	5.21											
11/19/95	18:00	393.00	1.10	14.20	5.12			5.19	14.73	2.88	27.80	0.00	4.25	0.00	3.41	1.26
11/19/95	22:00	397.00	1.06	12.24	5.05											
11/20/95	2:00	401.00	0.74	12.76	5.01			5.33	14.80	2.86	28.02	0.00	4.42	0.00	3.46	1.36
11/20/95	6:00	405.00	1.24	11.94	5.02											
11/20/95	10:00	409.00	0.62	14.44	5.09			5.07	14.51	2.86	26.85	0.00	4.59	0.00	4.41	1.74
11/20/95	14:00	413.00	0.56	13.34	5.09											
11/20/95	18:00	417.00	0.62	14.40	5.10			4.32	12.32	2.46	22.63	0.00	4.46	0.00	6.71	2.12
11/20/95	22:00	421.00	0.52	15.90	5.08											
11/21/95	2:00	425.00	0.57	15.14	5.05			4.17	11.15	2.26	20.00	0.00	4.39	0.00	8.62	1.93
11/21/95	6:00	429.00	0.58	16.68	5.05											
11/21/95	10:00	433.00	0.63	13.28	5.05											
11/21/95	14:00	437.00	0.71	12.72	5.04											
11/21/95	18:00	441.00	0.86	13.00	5.09											
11/21/95	22:00	445.00	0.80	12.00	4.99											
11/22/95	2:00	449.00	0.98	12.06	5.03											
11/22/95	3:45	450.75														
11/22/95	6:00	453.00	1.31	11.54	5.10											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B HPLC (g/L) Acetic	455B EtOH	455B HMF	455B furfural	455B GC Ethanol	455B Liquor Analysis (Total Dissolved Sugars) Glucose	455B Xylose	455B Galactose	455B Arabinose	455B Mannose	455B Lactic (YSI) (g/L)
11/3/95	8:15	-0.75											
11/3/95	10:00	1											
11/3/95	10:15	1.25											
11/3/95	13:00	4											
11/3/95	13:15	4.25											
11/3/95	15:10	6.17											
11/3/95	15:15	6.25											
11/3/95	18:10	9.17											
11/3/95	22:00	13.00											
11/4/95	2:00	17.00	2.85		0.00	0.00	9.58	43.15	36.43	6.66	26.94	0.00	
11/4/95	2:15	17.25											
11/4/95	3:00	18.00											
11/4/95	6:00	21.00											
11/4/95	10:00	25.00											
11/4/95	14:10	29.17											
11/4/95	18:10	33.17	2.90		0.02	0.00	8.78	42.22	35.70	6.04	25.87	0.00	
11/4/95	22:00	37.00											
11/5/95	2:00	41.00											
11/5/95	6:00	45.00											
11/5/95	10:15	49.25	3.20		0.29	0.00	11.23	39.14	33.68	6.15	24.50	0.00	
11/5/95	14:00	53.00											
11/5/95	18:05	57.08	3.86		0.00	0.06	12.10	42.31	50.36	7.67	26.11	0.00	
11/5/95	22:00	61.00											
11/6/95	2:00	65.00	4.25	N/A	0.00	0.05	11.80	43.62	48.58	7.35	24.87	0.00	
11/6/95	6:00	69.00											
11/6/95	10:00	73.00	4.08		0.00	0.00							
11/6/95	14:00	77.00											
11/6/95	18:00	81.00	4.75		0.00	0.00	11.13	48.57	36.90	6.52	24.65	0.00	
11/6/95	22:00	85.00											
11/7/95	2:00	89.00	5.29		0.21	0.00	10.86	46.30	33.73	6.04	23.02	0.00	
11/7/95	6:30	93.50											
11/7/95	10:00	97.00											
11/7/95	14:00	101.00											
11/7/95	18:00	105.00											
11/7/95	22:00	109.00											
11/8/95	2:00	113.00											
11/8/95	6:00	117.00											
11/8/95	10:00	121.00											
11/8/95	14:15	125.00											
11/8/95	18:15	129.25											
11/8/95	22:00	133.00											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B HPLC (g/L) Acetic	455B EtOH	455B HMF	455B furfural	455B GC Ethanol	455B Liquor Analysis (Total Dissolved Sugars) Glucose	455B Xylose	455B Galactose	455B Arabinose	455B Mannose	455B Lactic (YSI) (g/L)
11/9/95	2:00	137.00											
11/9/95	6:00	141.00											
11/9/95	10:00	145.00	8.95		0.00	0.05	7.94	14.98	14.64	4.39	8.14	0.00	14.00
11/9/95	14:10	149.00											12.60
11/9/95	18:15	153.25											
11/9/95	22:00	157.00											
11/10/95	2:00	161.00											
11/10/95	2:15	161.25	11.01		0.00	0.06	5.91	14.01	10.34	3.68	7.66	0.00	
11/10/95	6:00	165.00											
11/10/95	10:00	169.00	9.06		0.00	0.00	5.86	14.31	13.33	3.60	11.53	0.00	10.80
11/10/95	14:00	173.00											10.20
11/10/95	18:00	177.00	7.95		0.00	0.00	6.89	13.07	15.32	3.87	13.09	0.00	
11/10/95	22:00	181.00											
11/11/95	2:00	185.00	7.66		0.00	0.00	7.56	11.95	16.37	3.97	14.13	0.00	
11/11/95	6:00	189.00											
11/11/95	10:00	193.00	7.43		0.03	0.00		17.51	19.54	4.98	14.92	0.00	
11/11/95	14:00	197.00											
11/11/95	18:00	201.00	6.45		0.03	0.00							
11/11/95	22:00	205.00											6.76
11/12/95	2:00	209.00	6.11		0.04	0.00							7.18
11/12/95	6:00	213.00											6.93
11/12/95	10:00	217.00											6.34
11/12/95	14:00	221.00											5.28
11/12/95	18:00	225.00											5.18
11/12/95	22:05	229.00											5.28
11/13/95	2:30	233.50											5.91
11/13/95	6:15	237.00											6.65
11/13/95	10:00	241.00											8.30
11/13/95	14:00	245.00											8.68
11/13/95	18:00	249.00											9.93
11/13/95	22:00	253.00											10.80
11/14/95	2:00	257.00											10.40
11/14/95	6:00	261.00											
11/14/95	10:30	265.50											
11/14/95	14:00	269.00											12.80
11/14/95	18:00	273.00											12.70
11/14/95	22:00	277.00											12.90
11/15/95	10:15	289.25											14.80
11/15/95	14:00	293.00											10.80
11/15/95	18:00	297.00	9.45		0.06	0.00	3.77	29.20	25.97	6.25	20.39	0.00	
11/15/95	22:00	301.00											9.80
11/16/95	2:00	305.00	8.19		0.07	0.00	3.23	35.87	30.45	6.87	23.14	0.00	9.18
													8.00

All 9000-L Fermenter Data

Date	Time	Run time (h)	455B HPLC (g/L) Acetic	455B EtOH	455B HMF	455B furfural	455B GC Ethanol	455B Liquor Analysis (Total Dissolved Sugars) Glucose	455B Xylose	455B Galactose	455B Arabinose	455B Mannose	455B Lactic (YSI) (g/L)
11/16/95	6:00	309.00											
11/16/95	10:00	313.00	7.25		0.11	0.00	7.63	31.03	35.67	7.43	26.49	0.00	
11/16/95	14:00	317.00											5.82
11/16/95	18:00	321.00	7.20		0.31	0.00	10.21	29.56	38.28	7.79	27.58	0.00	5.46
11/16/95	22:15	325.25											5.52
11/17/95	2:10	329.17	6.57		0.15	0.00	10.54	30.67	40.03	7.97	28.40	0.00	
11/17/95	2:20	329.30											4.60
11/17/95	6:00	334.00											4.40
11/17/95	10:00	337.00	5.51		0.15	0.00	10.97	32.95	40.98	8.13	29.67	0.00	4.86
11/17/95	14:00	341.00											3.90
11/17/95	18:00	345.00	5.31		0.16	0.00	11.67	31.72	42.38	8.19	30.55	0.00	
11/17/95	22:00	349.00											3.88
11/18/95	2:00	353.00	5.29		0.20	0.00	12.22	34.40	44.74	8.37	31.58	0.00	3.10
11/18/95	6:00	357.00											2.88
11/18/95	10:15	361.25					11.98						2.72
11/18/95	14:00	365.00											2.84
11/18/95	18:00	369.00					12.82						2.58
11/18/95	22:00	373.00											2.72
11/19/95	2:00	377.00					13.69						2.72
11/19/95	6:00	381.00											3.20
11/19/95	10:00	385.00	4.81		0.25	0.00	15.55	32.88	43.53	7.58	28.23	0.00	1.94
11/19/95	14:00	389.00											1.94
11/19/95	18:00	393.00	4.49		0.25	0.00	16.04	35.48	46.95	8.20	30.24	0.00	2.00
11/19/95	22:00	397.00											2.10
11/20/95	2:00	401.00	4.68		0.03	0.00	8.77	34.25	44.73	7.82	28.86	0.00	2.24
11/20/95	6:00	405.00											2.32
11/20/95	10:00	409.00	5.38		0.24	0.00	15.29	36.60	46.47	9.13	33.12	0.00	2.85
11/20/95	14:00	413.00											3.76
11/20/95	18:00	417.00	6.60		0.26	0.00	15.18	32.90	43.39	8.57	29.49	0.00	4.66
11/20/95	22:00	421.00											5.01
11/21/95	2:00	425.00	7.22		0.20	0.00		28.25	38.91	7.82	25.67	0.00	5.42
11/21/95	6:00	429.00											7.30
11/21/95	10:00	433.00											7.10
11/21/95	14:00	437.00											7.76
11/21/95	18:00	441.00											8.30
11/21/95	22:00	445.00											8.48
11/22/95	2:00	449.00											
11/22/95	3:45	450.75											8.84
11/22/95	6:00	453.00											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C YSI Gluc (g/L)	455C YSI EtOH (g/L)	455C pH Micro	455C Oven (%)	455C TDS (%)	455C Glucose	455C Xylose	455C Gal.	455C Arab.	455C Man.	455C HPLC (g/L) Cello.	455C Succinic	455C Lactic	455C Glycerol
11/3/95	8:15	-0.75														
11/3/95	10:00	1														
11/3/95	10:15	1.25														
11/3/95	13:00	4														
11/3/95	13:15	4.25														
11/3/95	15:10	6.17														
11/3/95	15:15	6.25														
11/3/95	18:10	9.17														
11/3/95	22:00	13.00														
11/4/95	2:00	17.00														
11/4/95	2:15	17.25														
11/4/95	3:00	18.00														
11/4/95	6:00	21.00														
11/4/95	10:00	25.00														
11/4/95	14:10	29.17														
11/4/95	18:10	33.17														
11/4/95	22:00	37.00														
11/5/95	2:00	41.00														
11/5/95	6:00	45.00														
11/5/95	10:15	49.25														
11/5/95	14:00	53.00														
11/5/95	18:05	57.08														
11/5/95	22:00	61.00														
11/6/95	2:00	65.00	0.42	10.70	4.08	20.48		1.73	10.43	2.27	17.36	0.00	8.57	0.00	6.30	1.41
11/6/95	6:00	69.00	0.70	12.00	4.03											
11/6/95	10:00	73.00	0.35	13.80	4.03	19.38		2.93	9.31	1.67	16.82	0.00	7.42	0.00	6.58	0.99
11/6/95	14:00	77.00	0.31	13.60	4.10											
11/6/95	18:00	81.00	0.39	12.16	4.01	20.64		1.92	9.29	1.66	15.51	0.00	8.17	0.00	7.79	1.25
11/6/95	22:00	85.00	0.42	11.60	4.02											
11/7/95	2:00	89.00	0.38	13.00	4.05	19.74		1.98	9.28	1.68	15.39	0.00	8.30	0.00	8.00	1.14
11/7/95	6:30	93.50	0.42	14.04	4.00											
11/7/95	10:00	97.00	0.63	13.10	4.07	20.80		4.64	8.24	1.72	18.23	0.00	8.67	0.00	7.43	1.57
11/7/95	14:00	101.00	0.66	14.16	4.06											
11/7/95	18:00	105.00	0.63	12.44	4.81	20.36		3.30	8.44	1.71	16.18	0.00	8.09	0.00	9.31	1.74
11/7/95	22:00	109.00	0.45	13.30	4.78											
11/8/95	2:00	113.00	0.44	12.50	4.92	20.65		4.33	8.05	1.66	15.64	0.00	8.32	0.00	10.10	1.68
11/8/95	6:00	117.00	0.44	12.80	4.89											
11/8/95	10:00	121.00	0.51	12.04	4.95	22.95	3.22									
11/8/95	14:15	125.00	0.62	11.02	4.94									0.00	21.53	2.42
11/8/95	18:15	129.25	0.82	11.24	5.02	22.74										
11/8/95	22:00	133.00	1.28	11.46	5.00											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C YSI Gluc (g/L)	455C YSI EtOH (g/L)	455C pH Micro	455C Oven (%)	455C TDS (%)	455C Glucose	455C Xylose	455C Gal.	455C Arab.	455C Man.	455C Cello.	455C Succinic	455C Lactic	455C Glycerol
								HPLC (g/L)								
11/9/95	2:00	137.00	1.40	11.72	4.96	24.52										
11/9/95	6:00	141.00	1.44	11.18	4.95											
11/9/95	10:00	145.00	1.38	11.04	4.90	22.25										
11/9/95	14:10	149.00	1.83	9.20	4.89									0.00	33.88	3.26
11/9/95	18:15	153.25	2.14	9.72	4.95											
11/9/95	22:00	157.00	4.30	9.42	4.97											
11/10/95	2:00	161.00	5.46	9.36	4.95	21.88										
11/10/95	2:15	161.25														
11/10/95	6:00	165.00	6.04	7.54	5.02											
11/10/95	10:00	169.00	6.04	8.12	5.01	22.42										
11/10/95	14:00	173.00	6.12	8.16	4.99									0.18	20.56	1.66
11/10/95	18:00	177.00	5.70	8.08	5.00	22.65										
11/10/95	22:00	181.00	5.89	7.47	5.00									0.39	19.89	1.82
11/11/95	2:00	185.00	4.66	8.40	4.93	22.79										
11/11/95	6:00	189.00	4.99	8.00	4.99									0.36	18.83	1.83
11/11/95	10:00	193.00	3.54	9.46	4.97	22.30										
11/11/95	14:00	197.00	3.11	10.50	4.94									0.39	18.23	2.31
11/11/95	18:00	201.00	2.64	11.00	5.03	22.89										
11/11/95	22:00	205.00	2.44	8.46	5.11									0.00	16.64	2.06
11/12/95	2:00	209.00	2.41	8.07	5.08	22.85										
11/12/95	6:00	213.00	2.18	8.19	5.06									0.00	15.45	2.09
11/12/95	10:00	217.00	1.98	9.20	5.04	22.52										
11/12/95	14:00	221.00	1.85	9.48	5.02											
11/12/95	18:00	225.00	1.84	9.12	4.97	23.05										
11/12/95	22:05	229.00	1.71	9.78	4.98											
11/13/95	2:30	233.50	1.61	9.62	4.88	22.67										
11/13/95	6:15	237.00	1.43	9.60	4.85											
11/13/95	10:00	241.00	1.56	8.88	4.80											
11/13/95	14:00	245.00	0.94	7.64	4.87											
11/13/95	18:00	249.00	0.81	7.36	4.85											
11/13/95	22:00	253.00	0.78	7.13	4.85											
11/14/95	2:00	257.00	0.52	7.90	4.89											
11/14/95	6:00	261.00		7.03	4.90											
11/14/95	10:30	265.50	0.65	5.63	4.85											
11/14/95	14:00	269.00	0.68	7.92	5.04											
11/14/95	18:00	273.00	0.86	6.74	5.03											
11/14/95	22:00	277.00	1.15	7.33	5.06											
11/15/95	10:15	289.25	4.25	7.02	5.10											
11/15/95	14:00	293.00	6.15	6.38	5.15											
11/15/95	18:00	297.00	6.90	6.28	5.19			8.45	4.65	1.94	11.61	1.50	4.95	0.00	19.63	1.63
11/15/95	22:00	301.00	7.48	6.04	5.17											
11/16/95	2:00	305.00	8.82	5.48	5.02			10.44	5.38	2.02	13.59	1.71	4.41	0.00	17.58	1.50

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C YSI Gluc (g/L)	455C YSI EtOH (g/L)	455C pH Micro	455C Oven (%)	455C TDS (%)	455C Glucose	455C Xylose	455C Gal.	455C Arab.	455C Man.	455C Cello.	455C Succinic	455C Lactic	455C Glycerol
								HPLC (g/L)								
11/16/95	6:00	309.00	9.21	5.02	5.00											
11/16/95	10:00	313.00	9.80	4.90	5.11			11.48	5.84	2.10	15.07	0.00	4.58	0.00	15.77	1.53
11/16/95	14:00	317.00	8.95	5.64	5.09											
11/16/95	18:00	321.00	4.61	7.92	5.07			3.65	6.53	2.25	16.59	0.00	4.62	0.00	14.09	2.05
11/16/95	22:15	325.25	0.87	9.92	5.07											
11/17/95	2:10	329.17	0.41	9.86	5.07											
11/17/95	2:20	329.30														
11/17/95	6:00	334.00	0.30	9.52	5.06			1.26	7.01	2.31	17.27	0.00	4.56	0.00	13.04	2.23
11/17/95	10:00	337.00	0.74	9.68	5.10											
11/17/95	14:00	341.00	0.62	8.52	5.08			1.58	8.12	2.61	18.20	0.00	4.54	0.00	11.13	2.07
11/17/95	18:00	345.00	0.22	10.16	5.10											
11/17/95	22:00	349.00	0.78	11.60	5.24			1.77	9.13	2.76	19.58	0.00	4.61	0.00	9.72	2.83
11/18/95	2:00	353.00	0.83	12.58	5.17											
11/18/95	6:00	357.00	0.80	11.66	5.20			1.90	9.91	2.81	20.42	0.00	4.97	0.00	8.57	2.47
11/18/95	10:15	361.25	0.69	11.64	5.23											
11/18/95	14:00	365.00	0.76	12.52	5.34			2.46	10.34	2.85	22.45	0.00	4.38			
11/18/95	18:00	369.00	0.73	11.30	5.14											
11/18/95	22:00	373.00	1.18	10.00	5.17			2.74	10.66	2.80	22.52	0.00	4.20			
11/19/95	2:00	377.00	0.86	12.50	5.10											
11/19/95	6:00	381.00	1.42	15.48	5.10			3.27	10.61	2.76	22.57	0.00	4.09			
11/19/95	10:00	385.00	0.74	11.34	5.07											
11/19/95	14:00	389.00	0.68	13.12	5.15			2.42	11.55	2.74	23.49	0.00	4.41	0.00	6.68	1.58
11/19/95	18:00	393.00	1.26	13.76	5.14											
11/19/95	22:00	397.00	1.20	13.92	5.08			2.49	12.20	2.72	24.25	0.00	4.60	0.00	6.35	1.93
11/20/95	2:00	401.00	1.22	14.90	5.03											
11/20/95	6:00	405.00	1.18	14.60	4.96			4.59	13.96	2.93	23.72	0.00	3.94	0.00	5.60	1.64
11/20/95	10:00	409.00	0.67	14.50	5.05											
11/20/95	14:00	413.00	0.57	14.88	5.03			4.79	12.58	2.72	25.10	0.00	3.55	0.00	6.33	1.95
11/20/95	18:00	417.00	0.46	16.00	5.05											
11/20/95	22:00	421.00	0.42	17.50	5.02			4.97	13.09	2.69	22.26	0.00	3.32	0.00	8.39	2.15
11/21/95	2:00	425.00	0.51	17.22	5.01											
11/21/95	6:00	429.00	0.53	17.92	5.00			4.99	12.67	2.58	19.46	0.00	3.60	0.00	10.63	2.16
11/21/95	10:00	433.00	0.63	14.90	5.00											
11/21/95	14:00	437.00	0.71	15.14	4.98											
11/21/95	18:00	441.00	0.96	14.46	5.10											
11/21/95	22:00	445.00	1.06	14.06	4.95											
11/22/95	2:00	449.00	1.23	14.46	4.99											
11/22/95	3:45	450.75														
11/22/95	6:00	453.00	1.41	14.58	5.04											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C HPLC (g/L) Acetic	455C EtOH	455C HMF	455C furfural	455C GC Ethanol	455C Liquor Analysis (Total Dissolved Sugars) Glucose	455C Xylose	455C Galactose	455C Arabinose	455C Mannose	455C Lactic (YSI) (g/L)
11/3/95	8:15	-0.75											
11/3/95	10:00	1											
11/3/95	10:15	1.25											
11/3/95	13:00	4											
11/3/95	13:15	4.25											
11/3/95	15:10	6.17											
11/3/95	15:15	6.25											
11/3/95	18:10	9.17											
11/3/95	22:00	13.00											
11/4/95	2:00	17.00											
11/4/95	2:15	17.25											
11/4/95	3:00	18.00											
11/4/95	6:00	21.00											
11/4/95	10:00	25.00											
11/4/95	14:10	29.17											
11/4/95	18:10	33.17											
11/4/95	22:00	37.00											
11/5/95	2:00	41.00											
11/5/95	6:00	45.00											
11/5/95	10:15	49.25											
11/5/95	14:00	53.00											
11/5/95	18:05	57.08											
11/5/95	22:00	61.00											
11/6/95	2:00	65.00	4.52 N/A		0.00	0.00	11.93	43.17	49.61	7.33	24.89	0.00	
11/6/95	6:00	69.00											
11/6/95	10:00	73.00	4.49		0.00	0.00							
11/6/95	14:00	77.00											
11/6/95	18:00	81.00	5.70		0.19	0.00	12.39	42.64	35.96	6.20	22.44	0.00	
11/6/95	22:00	85.00											
11/7/95	2:00	89.00	6.18		0.14	0.00	12.85	42.52	35.96	6.24	22.43	0.00	
11/7/95	6:30	93.50											
11/7/95	10:00	97.00	4.29		0.12	0.00	9.13	46.20	32.98	6.44	22.38	0.00	
11/7/95	14:00	101.00											
11/7/95	18:00	105.00	6.18		0.22	0.03	10.81	38.89	31.37	6.32	20.87	0.00	
11/7/95	22:00	109.00											
11/8/95	2:00	113.00	5.70		0.06	0.00	12.56	44.40	29.76	6.38	21.46	0.00	
11/8/95	6:00	117.00											
11/8/95	10:00	121.00	13.08 N/A		0.00	0.00	10.45	23.56	22.14	4.96	12.69	0.00	
11/8/95	14:15	125.00											
11/8/95	18:15	129.25					9.78						
11/8/95	22:00	133.00											

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C HPLC (g/L) Acetic	455C EtOH	455C HMF	455C furfural	455C GC Ethanol	455C Liquor Analysis (Total Dissolved Sugars) Glucose	455C Xylose	455C Galactose	455C Arabinose	455C Mannose	455C Lactic (YSI) (g/L)
11/9/95	2:00	137.00					8.56		14.52	3.57	9.67	0.00	
11/9/95	6:00	141.00											
11/9/95	10:00	145.00	13.59		0.00	0.08	10.83	12.34	16.06	4.39	7.02	0.00	
11/9/95	14:10	149.00											
11/9/95	18:15	153.25											
11/9/95	22:00	157.00											
11/10/95	2:00	161.00					8.77	13.37	12.56	3.82	6.37	0.00	
11/10/95	2:15	161.25											
11/10/95	6:00	165.00											
11/10/95	10:00	169.00	11.11		0.00	0.00	7.82	13.37	12.07	3.37	8.26	0.00	14.50
11/10/95	14:00	173.00											13.50
11/10/95	18:00	177.00	10.96		0.00	0.00		14.45	12.45	3.40	9.09	0.00	
11/10/95	22:00	181.00											
11/11/95	2:00	185.00	10.36		0.00	0.00	7.82	13.03	13.72	3.52	9.64	0.00	
11/11/95	6:00	189.00											
11/11/95	10:00	193.00	9.98		0.00	0.00		14.45	15.17	4.13	10.44	0.00	13.30
11/11/95	14:00	197.00											13.10
11/11/95	18:00	201.00	9.29		0.00	0.00		15.02	16.73	4.38	11.83	0.00	11.00
11/11/95	22:00	205.00											11.60
11/12/95	2:00	209.00	8.72		0.02	0.00							10.70
11/12/95	6:00	213.00											10.10
11/12/95	10:00	217.00											8.82
11/12/95	14:00	221.00											8.84
11/12/95	18:00	225.00											8.44
11/12/95	22:05	229.00											8.46
11/13/95	2:30	233.50											4.39
11/13/95	6:15	237.00											9.56
11/13/95	10:00	241.00											9.76
11/13/95	14:00	245.00											10.19
11/13/95	18:00	249.00											12.00
11/13/95	22:00	253.00											13.90
11/14/95	2:00	257.00											
11/14/95	6:00	261.00											
11/14/95	10:30	265.50											15.60
11/14/95	14:00	269.00											15.44
11/14/95	18:00	273.00											15.74
11/14/95	22:00	277.00											17.10
11/15/95	10:15	289.25											15.60
11/15/95	14:00	293.00											
11/15/95	18:00	297.00	12.22		0.00	0.00	5.46	15.02	16.46	4.50	13.76	0.00	13.74
11/15/95	22:00	301.00											13.70
11/16/95	2:00	305.00	11.23		0.02	0.00	4.65	20.14	20.56	5.19	16.49	0.00	12.10

All 9000-L Fermenter Data

Date	Time	Run time (h)	455C HPLC (g/L) Acetic	455C EtOH	455C HMF	455C furfural	455C GC Ethanol	455C Liquor Analysis (Total Dissolved Sugars) Glucose	455C Xylose	455C Galactose	455C Arabinose	455C Mannose	455C Lactic (YSI) (g/L)
11/16/95	6:00	309.00											
11/16/95	10:00	313.00	10.41		0.08	0.00	4.68						
11/16/95	14:00	317.00											10.54
11/16/95	18:00	321.00	9.67		0.05	0.00	7.65						9.86
11/16/95	22:15	325.25											9.80
11/17/95	2:10	329.17											9.02
11/17/95	2:20	329.30	9.18		0.12	0.00	9.89						9.30
11/17/95	6:00	334.00											
11/17/95	10:00	337.00	8.26		0.08	0.00	10.37	20.45	30.40	6.65	22.38	0.00	8.24
11/17/95	14:00	341.00											8.10
11/17/95	18:00	345.00	7.31		1.95	0.00	10.85	22.43	33.65	7.08	24.40	0.00	5.38
11/17/95	22:00	349.00											
11/18/95	2:00	353.00	6.91		0.12	0.00	11.42	24.64	37.00	7.51	26.31	0.00	7.08
11/18/95	6:00	357.00											5.97
11/18/95	10:15	361.25					11.42						4.84
11/18/95	14:00	365.00											5.16
11/18/95	18:00	369.00					11.89						5.50
11/18/95	22:00	373.00											4.98
11/19/95	2:00	377.00					12.63						5.12
11/19/95	6:00	381.00											4.98
11/19/95	10:00	385.00	6.06		0.02	0.00	14.43	32.61	42.62	8.21	27.59	0.00	6.54
11/19/95	14:00	389.00											3.48
11/19/95	18:00	393.00	6.44		0.23	0.00	14.92	35.76	47.36	8.90	30.31	0.00	3.68
11/19/95	22:00	397.00											3.58
11/20/95	2:00	401.00	5.82		0.27	0.00	15.76	34.68	46.09	8.50	29.19	0.00	3.48
11/20/95	6:00	405.00											3.40
11/20/95	10:00	409.00	6.45		0.15	0.00	15.86	28.36	43.39	8.18	29.45	0.00	3.21
11/20/95	14:00	413.00											3.85
11/20/95	18:00	417.00	7.27		0.23	0.00	16.19	24.97	42.73	7.99	27.58	0.00	4.40
11/20/95	22:00	421.00											5.45
11/21/95	2:00	425.00	8.24		0.21	0.00	16.28	20.66	40.49	7.58	24.69	0.00	5.91
11/21/95	6:00	429.00											6.25
11/21/95	10:00	433.00											7.94
11/21/95	14:00	437.00											8.70
11/21/95	18:00	441.00											8.46
11/21/95	22:00	445.00											9.82
11/22/95	2:00	449.00											10.18
11/22/95	3:45	450.75											
11/22/95	6:00	453.00											10.32